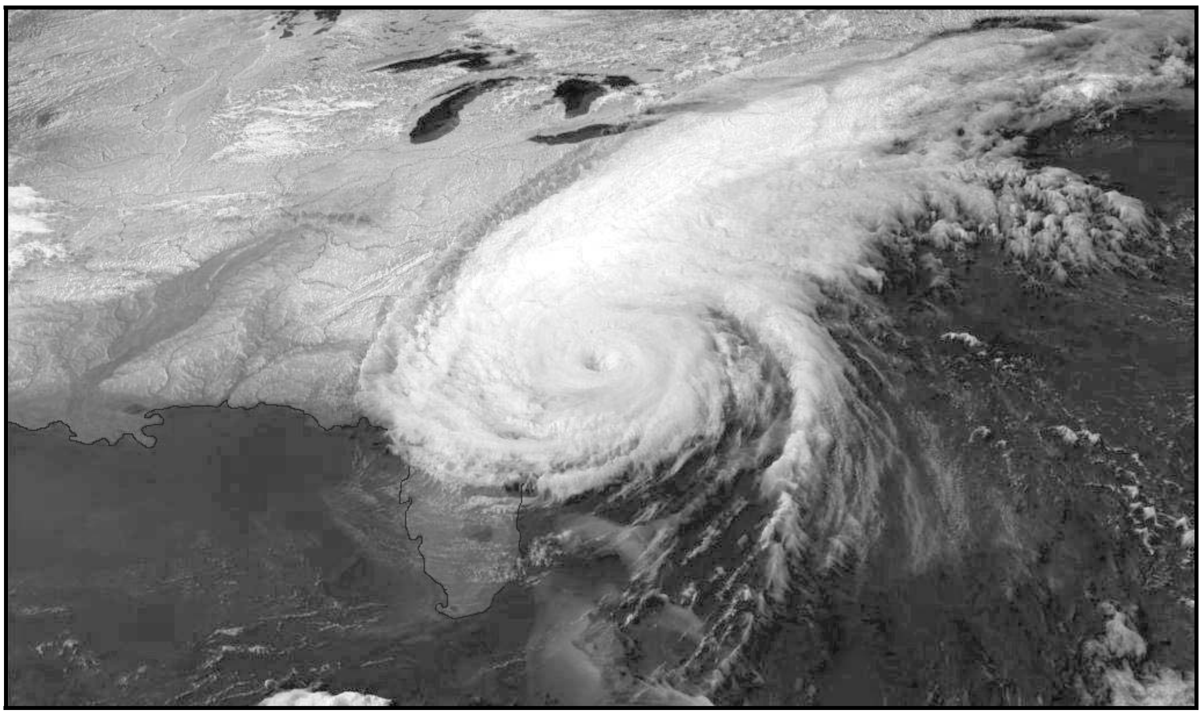
FINAL REPORT

A Study of the Impact of Nine Transportation Management Projects on Hurricane Evacuation Preparedness

November 2003

Contract Number: DTFH61-96-C-00098
Task Order 9817



Prepared for:
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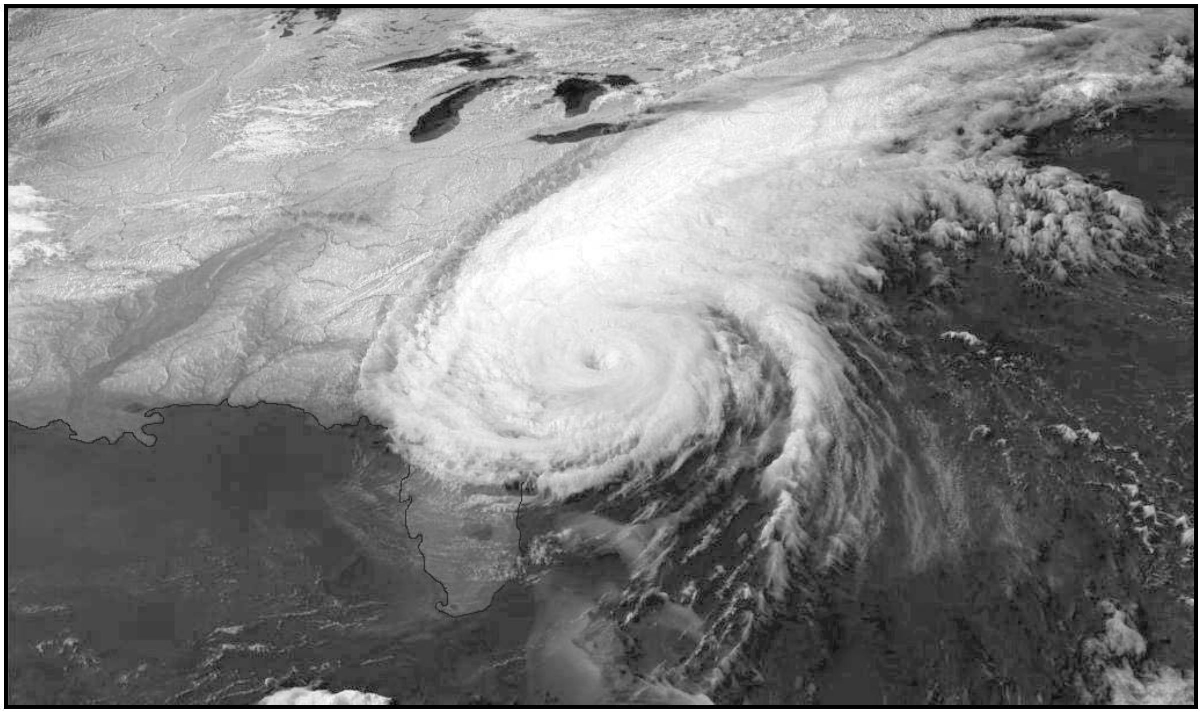

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Acronyms

ETDFS	Evacuation Travel Demand Forecasting System
ETIS	Emergency Transportation Information System
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
GIS	Geographic Information Systems
HAR	Highway Advisory Radio
HEADS UP	Hurricane Evacuation Analysis and Decision Support Utility Program
HERO	Highway Emergency Response Operator
LA DOTD	Louisiana Department of Transportation and Development
LOEP	Louisiana Office of Emergency Planning
NOAA	National Oceanic and Atmospheric Administration
NESDIS	National Environmental Satellite, Data, and Information System
NSIP	National Streamflow Information Program
TOC	Traffic Operations Center
TTMS	Telemetered Traffic Monitoring Site
USGS	U.S. Geological Survey

1.0 Introduction and Background

1.1 Hurricanes and Hurricane Evacuations in the United States

In the United States, hurricanes are an annual threat to the eastern and gulf coastal states. During the period from 1900 to 2002, more than 166 direct hits by hurricanes (including 65 major hurricanes) occurred on the mainland coastline, as recorded in Table 1–1. The table enumerates the total number of hurricane strikes experienced by the eastern and gulf coastal states.

Table 1–1. U.S. Mainland Hurricane Strikes by State (1900 – 2002)

Area	Major Hurricanes[a]	All Hurricanes
Texas	16	37
Louisiana	12	27
Mississippi	6	9
Alabama	5	10
Florida	24	60
Georgia	0	5
South Carolina	4	14
North Carolina	11	27
Virginia	1	5
Maryland	0	2
Delaware	0	0
New Jersey	0	1
New York	5	9
Connecticut	3	8
Rhode Island	3	5
Massachusetts	2	6
New Hampshire	0	2
Maine	0	5
Total[b]	65	166

Source: This data is compiled from the National Oceanic and Atmospheric Administration (NOAA) Website at http://www.nhc.noaa.gov/paststate.html.
[a] Hurricanes classified as category 3, 4, or 5 on the Saffir/Simpson scale.
[b] The columns do not sum to the value in the Total row because, in some cases, one hurricane affected several areas.

Of these, the 30 most costly and deadliest hurricanes are listed in Table 1–2, which identifies the year; hurricane by name, state, or location; category; costs incurred; and number of deaths. The Year 2000 Cost column lists the costs in inflation-adjusted Year 2000 dollars; the Normalized Cost column lists the expected cost if a similar hurricane hit the same location today.[1] The 30 costliest hurricanes are estimated to have caused a cumulative $132 billion of damage, and the

[1] Because there has been significant growth in population and wealth in the coastal regions, adjusting the historical cost of a hurricane for inflation does not fully account for the expected cost if a similar hurricane occurred today. The Normalized Cost column adjusts the historical costs for inflation, as well as changes in population, wealth, and other factors.

average expected cost if one of these hurricanes occurred today is about $14 billion. The cumulative number of deaths for the 30 deadliest hurricanes is almost 15,000.

Table 1–2. The Costliest and Deadliest U.S. Hurricanes (1900 – 2000)

Year	Hurricane	Category	Cost		Deaths[a]
			Year 2000[a]	Normalized[a]	
1900	(N TX)	4	928	32,090	8000
1906	(SE FL)	2			164
1906	(MS, AL, NW FL)	3			134
1909	(LA)	4			350
1909	(TX)	3			41
1910	(SW FL)	3			30
1915	(N TX)	4	1,544	27,190	275
1915	(LA)	4			275
1918	(SW LA)	3			34
1919	(S TX)	4		6,448	600
1926	(SE FL, AL)	4	1,738	87,167	243
1928	(SE FL)	4		16,631	1836
1932	(TX)	4			40
1933	(S TX)	3			40
1935	(FL Keys)	5			408
1938	(New England)	3	4,749	20,046	600
1940	(GA, SC, NC)	2			50
1944	(NE US)	3	1,221	7,790	390
1944	(SW FL)	3		20,331	
1945	(SE FL)	3		7,611	
1947	(SE FL, LA, AL)	4	930	10,015	51
1949	(SE FL)	3		7,038	
1954	Carol (NE US)	3	3,134	10,929	60
1954	Hazel (SC, NC)	4	1,911	8,486	95
1955	Diane (NE US)	1	5,541	12,335	184
1957	Audrey (SW LA, NW TX)	4			390
1960	Donna (FL, Eastern US)	4	2,408	16,631	50
1961	Carla (N TX, CE TX)	4	2,551	8,522	46
1964	Dora (NE FL)	2	1,541	3,747	
1964	Hilda (CE LA)	3			38
1964	Cleo (SE FL)	2		2,936	
1965	Betsy (SE FL, SE LA)	3	8,517	14,990	75
1967	Beulah (S TX)	3	1,113		
1969	Camille (MS, SE LA, VA)	5	6,992	13,219	256
1970	Celia (S TX)	3	2,016	4,024	
1972	Agnes (NW FL, NE US)	1	8,603	12,904	122
1975	Eloise (NW FL)	3	1,489		
1979	Frederic (AL, MS)	3	4,965	7,587	
1983	Alicia (N TX)	3	3,422	4,890	
1985	Juan (LA)	1	2,419	2,892	
1985	Elena (MS, AL, MW FL)	3	2,016		
1985	Gloria (Eastern US)	3	1,451		
1989	Hugo (SC)	4	9,740	11,307	
1991	Bob (NC, NE US)	2	2,005		
1992	Andrew (SE FL, SE LA)	4	34,955	39,896	
1994	Alberto (NW FL, GA, AL)	TS			30
1995	Opal (NW FL, AL)	3	3,521	3,617	
1996	Fran (NC)	3	3,670	3,735	
1998	Georges (FL Keys, MS, AL)	2	2,495		
1999	Floyd (NC)	2	4,667	4,680	56

Source: This data is compiled from NOAA Technical Memorandum NWS TPC-1 (updated October 2001) as posted on the NOAA Website at http://www.aoml.noaa.gov/hrd/Landsea/deadly/index.html.

[a] Data for only the 30 costliest/deadliest hurricanes in each category are listed. Missing values in these columns indicate only that the listed hurricane was not one of the 30 costliest/deadliest hurricanes for that column.

Clearly, the potential still exists for a hurricane to cause tremendous damage to coastal regions today.

One method used to reduce the number of deaths, and to a lesser degree, costs caused by hurricanes, is to evacuate those areas that might be impacted. The importance of this approach has grown with recent advances in the ability of forecasters to more accurately predict the track of a hurricane, thus reducing the number of unnecessary evacuations.[2] However, hurricane evacuations remain difficult transportation activities to manage.

Hurricane Floyd was a large hurricane that peaked in intensity as a Category 4 hurricane in the Bahamas. Although it dropped in intensity, weakening to Category 2 by the time it reached landfall in North Carolina, it's large size resulted in evacuations of roughly 3 million people from a 4-state area consisting of parts of Florida, Georgia, North Carolina, and South Carolina. This large-scale evacuation resulted in traffic jams across the affected regions as motorists flooded the highways. For example, travel time between Charleston and Columbia, South Carolina, normally only 2-1/2 hours, increased to as much as 18 hours during the period of peak congestion.

This breakdown in the effectiveness of the transportation system during the evacuation spurred a renewed interest in evacuation planning both within individual states and at the Federal level. For example, many states recognized the advantages of using lane reversals (or contraflow) to facilitate evacuations. State traffic and emergency management officials have since modified their evacuation plans and the highways as well to better support lane reversals in the future. State emergency management officials also took steps to improve coordination of evacuation and evacuation planning activities between states; monitor and control the transportation infrastructure during evacuations; and disseminate information to the public.

1.2 FHWA Grants To Improve Transportation Operations During Hurricane Evacuations

In May 2002, the Federal Highway Administration (FHWA) funded grants to nine southeastern states (Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, North Carolina, and Virginia) to improve transportation operations as part of their emergency management program for hurricanes evacuations. Following are brief descriptions of the activities each state proposed to fund with these grants.

- **Texas.** Before receiving this grant, Texas had recently completed hurricane evacuation plans that included contraflow on parts of I-37 from Corpus Christi to San Antonio to increase traffic flow. With this grant, nine additional methods of increasing evacuation traffic flow from Corpus Christi were evaluated.
- **Louisiana.** Louisiana was in the process of deploying traffic count stations to facilitate real-time monitoring of evacuation route traffic during hurricane evacuations. These stations, which include both traffic and hydrology instruments, were being deployed as a collaborative effort of Louisiana Department of Transportation and Development (LA DOTD) and U.S. Geological Survey (USGS) that use an existing USGS hardware platform

[2] In the 1970s, hurricane track forecasts 3 days in advance of landfall demonstrated errors as large as 450 nautical miles. This number gradually dropped to around 225 nautical miles, and some recent track predictions were within 120 nautical miles. (Source: http://www.noaanews.noaa.gov/stories/s853.htm.)

and satellite communication system to transmit data. Louisiana used its grant to extend this program to include additional detector stations.

- **Mississippi.** Mississippi recently confirmed plans to implement contraflow on I-59 to facilitate hurricane evacuations, particularly evacuation from New Orleans. With the grant, Mississippi produced and distributed a brochure in the fall of 2003 that explains hurricane evacuation procedures, and in particular, the use of contraflow on I-59 during hurricanes.
- **Alabama.** Alabama developed a reverse lane plan for portions of I-65 in 2000, and used the Federal grant to develop and implement a public information program concerning the lane-reversal plans during a hurricane evacuation.
- **Florida.** Florida used the Federal grant to help develop a geographic information system (GIS)-based hurricane evacuation software system known as HEADS UP (Hurricane Evacuation Analysis and Decision Support Utility Program). This program extends the capabilities of ETIS (Emergency Transportation Information System) by including additional data. In the future, ETIS will include a model that will compute dynamic clearance times.
- **Georgia.** Georgia first developed a contraflow plan in 1995, and has recently updated the plan. With the Federal grant it received, Georgia produced evacuation route maps and distributed those maps to Welcome Centers, Georgia Department of Transportation (GDOT) district offices, and Georgia State Patrol posts in the southern half of the state.
- **South Carolina.** South Carolina has recently revised its evacuation plans to consider broader effects of a hurricane evacuation and to extend the evacuation area further inland. With its Federal grant, South Carolina printed and distributed hurricane evacuation route maps and hurricane guides that included information on these updates.
- **North Carolina.** North Carolina identified a need for real-time traffic information to better monitor hurricane evacuation activities. North Carolina plans to use the Federal grant to deploy traffic-monitoring detectors at key locations along hurricane evacuation routes.
- **Virginia.** Virginia applied its Federal grant to develop an abbreviated clearance time model that would be easier for a non-traffic planner to run and applied this model to the Hampton Roads area.

1.3 This Evaluation Project

The purpose of this evaluation report is to draw some lessons learned from the activities pursued using the Federal grants that were received by the nine states. Two approaches were pursued for doing so. The first approach expands on the brief descriptions of the state activities listed in Section 1.2, and also notes other activities called out by those states in recent presentations at the Transportation Evacuation Planning and Operations Workshop held in New Orleans, Louisiana on April 14 – 15, 2003. The primary purpose of this review is to gain insight into the areas that the states deem important for supporting hurricane evacuations by documenting what their traffic and emergency management officials are pursuing. This information was synthesized to identify lessons learned that might have broad application among the states and is documented in Section 2.0.

The second approach focuses on the Louisiana partnership with the USGS to deploy Hydrowatch stations (identified by Louisiana as "Information Stations") that also monitor traffic. It is believed that this type of partnership might be a cost-effective approach for deploying traffic count stations at remote locations in many states. This portion of the evaluation is documented in Section 3.0 of this report, and provides a case study of the Information Station deployment and how similar deployments could occur in other states.

2.0 State Hurricane Evacuation Planning Activities

Although each of the nine states received equal funding, individual state activities were quite different. The activities depended on the perceived needs in those states, and how well the states could use the FHWA funding to complement existing hurricane preparedness activities. In general, the type of activities pursued can be divided into two groups:

- The states of Mississippi, Alabama, Georgia, and South Carolina used the funds to support public information activities. These activities concentrated on providing information to the public on evacuation routes and contraflow that might be used on some of those routes.
- The other five states, Texas, Louisiana, Florida, North Carolina, and Virginia, used the funds to support technical activities related to hurricane evacuations.

This section provides information on the activities pursued by each of these states, with the activities of the states pursuing public information activities described in section 2.1 and those pursuing technical activities described in section 2.2.

2.1 States Pursuing Public Information Activities

Each of the following four states used the FHWA funds to support public information activities.

2.1.1. Mississippi

Unlike many of the other states that received hurricane evacuation grant money, Mississippi has a relatively small, less populated coastal region, and evacuation routes from these regions are expected to be sufficient. However, there is significant potential for large cross-border evacuations from New Orleans, and to a lesser extent, from Alabama. In fact, the potential for large cross-border evacuations from New Orleans on I-59 creates the potential need for Mississippi to implement contraflow on I-59 to better support evacuation of Louisiana residents.

Lesson Learned 1 – Coordinate plans that cross state lines.

However, these plans were put on hold in October 2002 as Mississippi wrestled with the issue of how to ensure appropriate services to residents of Mississippi while supporting the evacuation of Louisiana residents into Mississippi. By June 2003, Mississippi and Louisiana had reached a revised agreement for Mississippi to use contraflow on I-59 in Mississippi to support Louisiana’s evacuation when contraflow was implemented on I-59 in Louisiana.

To educate the public on hurricane evacuation procedures, including contraflow on I-59, Mississippi released a new hurricane evacuation brochure in September of 2003. Mississippi elected to devote its grant money towards a publicity campaign to increase awareness of and confidence in these brochures. This publicity campaign consisted of billboard and radio advertisements, coverage by local media, and insertion of the brochures in local newspapers. The benefit of this grant usage was a high degree of public awareness that resulted in the distribution of the entire initial run of 100,000 brochures was. A reprint of 50,000 additional brochures is being produced to meet the excess demand.

Lesson Learned 2 – Share information.

In addition, Mississippi used a small amount of the FHWA grant to help sponsor a symposium that gathered participants from multiple states to discuss emergency management practices. The symposium participants all agreed that future conferences of the same nature would be extremely important.

2.1.2. Alabama

In 2000, Alabama developed a contraflow plan for I-65 from North of Mobile to just south of Montgomery. While implementation and operation exercises have helped confirm that the plan can quickly and safely set up this section for contraflow, Alabama felt that there was a need to educate the public on contraflow operations so that they could participate more easily – and quickly – with a contraflow-assisted evacuation. Alabama used the FHWA grant money to evaluate various methods of disseminating information about the I-65 contraflow plan. This evaluation led to the use of reversed direction signing, variable message signs, Alabama Emergency Radio, and annual implementation exercises as the primary means of educating the public at this time. After this evaluation, Alabama used the remaining FHWA funds (along with other funds) to purchase two Highway Advisory Radio (HAR) units with permanent quick disconnect antennas and advanced notification signage. The signs and HAR units will be used on both ends of the contraflow route on I-65 that runs from Mobile to Montgomery.

While these signs have not been used during a hurricane evacuation, Alabama believes that the use of HAR at the contraflow entry and exit points will significantly improve traffic flow at these evacuation decision points.

2.1.3. Georgia

Georgia, like the other coastal, hurricane-prone states, continues to improve its preparations for hurricane evacuations. Some of the key features of these preparations are:

- **Signage improvements.** Defining and improving hurricane evacuation routes with signage on those routes, including contraflow plans for I-16 with drop gate barriers on the east bound entrance ramps to prevent access in the east bound direction.
- **Improved traffic flow.** Planning activities to improve traffic flow on evacuation routes, including pre-evacuation clearing of Interstate highway shoulders, manned push button traffic control at important signal-controlled intersections along evacuation routes, and coordination with railroads to help ensure that trains do not block evacuation routes.
- **Improved evacuation routes.** Implementing improvements to evacuation routes to increase capacity (e.g., by adding lanes) and decrease the likelihood that the road is blocked (e.g., by raising the road elevation to avoid flooding).
- **Expanded traveler information.** Expanding traveler information during evacuations through portable HAR, variable message signs, and cooperative agreements with Georgia Public Radio stations.
- **Expanded traveler assistance.** Expanding traveler assistance by the Highway Emergency Response Operator (HERO) incident response vehicles.

Lesson Learned 3 – Educate the public about contraflow.

Despite all of these preparations, Georgia noted that the effectiveness of these preparations is limited if evacuees are not aware of the available resources. Consequentially, Georgia used the grant money to create information sheets and posters that contained information on evacuation routes (including maps), what to do, who to call, and other information and things to remember when evacuating. One example was a suggestion to pack supplies and to fill the car up with gas before evacuating. The information sheets where double-sided, letter-sized sheets that were distributed to Georgia State patrol, local GDOT offices, and local Georgia Emergency Management Agency personnel for redistribution to the public. The posters, which were larger versions of the information sheets, were positioned at state patrol offices and Georgia rest areas and welcome centers.

Since the state of Georgia did not sustain a hurricane this past season, it was difficult to identify specific benefits that were achieved. However, citizens did mention that they appreciated the fact that all the pertinent hurricane evacuation information was on a single sheet. Georgia believes that many citizens kept this sheet handy to guide them in the case that a hurricane occurred.

2.1.4. South Carolina

During Hurricane Floyd, South Carolina noted several problems with the hurricane evacuation routes, including the following:

- **Conflicting needs.** The evacuation routes were developed from individual scenarios for each population area, so there was potential for conflicting needs during more wide scale evacuations.
- **Traffic impediments.** Evacuation routes from different areas sometimes crossed, which impeded evacuating traffic at those points.
- **Insufficient evacuation length.** The evacuation routes only reached 50 miles inland.

Recently, the evacuation routes were revised to address these problems, which created a need to prepare better evacuation maps. South Carolina used the grant funds to print and distribute hurricane evacuation route maps and hurricane guides and to make similar maps and guides available from its Website.

2.2 States Pursuing Technical Activities

Each of the following five states used the funds to support technical activities related to hurricane evacuations.

2.2.1. Texas

Texas has a large coast with 22 coastal counties that are subject to a significant risk from hurricanes. For most of these counties, a combination of relatively low populations and a good road network make evacuations relatively quick – typically less than 10 hours. The exceptions, listed in Table 3, are several of the more densely populated counties and counties that include particularly remote locations. Table 3 identifies some of the Texas counties and areas affected by hurricane Categories 1 – 5, and the estimated evacuation time in hours residents would take to reach safer locations.

Table 2–1. Estimated Evacuation Times (in Hours) for Some Texas Coastal Counties

Area	Hurricane Category				
	1	2	3	4	5
Cameron County (Brownsville)	15	21	28	32	33
Nueces County (Corpus Christi)	11	20	28	31	32
San Patricio	8	11	15	17	18
Brazoria	7	9	13	15	17
Galveston County (Galveston)	14	20	28	32	33
Harris County (Houston)	14	20	28	32	33
Chambers	10	13	17	19	19
Orange County (Orange)	14	20	29	33	34

Source: http://hurricanes.tamu.edu/maps/maps.asp

Since exact hurricane landfall location is often determined less than 24 hours from landfall, it is important to take steps to decrease evacuation clearance times. Consequentially, a contraflow evacuation plan was developed in 2000 for parts of I-37 to support evacuation from Nueces County. The development of this plan brought to light several difficulties (e.g., reluctance of the Department of Public Safety to use contraflow, manpower demands of implementing contraflow, and dangers of unofficial entry to contraflow lanes from rural frontage roads). Chief among these difficulties was the fact that much of the contraflow capacity would remain unused during an evacuation due to bottlenecks in the system leading up to the contraflow area.

To address these difficulties, Texas chose to conduct a study of the following six alternatives for improving evacuations from Nueces County during a hurricane:

Lesson Learned 4 – Locate your bottlenecks.

- **Land addition.** Analyze adding a lane on the I-37 evacuation route from Corpus Christi. Analysis indicates that by reducing the inside shoulder to 4 feet and the lane widths to 11 feet, the current 3-lane northbound I-37 could be restriped to 4 lanes without significantly impacting vehicle speeds. The added lane would help remove the potential bottleneck, thereby increasing access to the contraflow portion of I-37.

- **Shoulder access.** Assess using the existing I-37 shoulder as a hurricane evacuation lane. The primary concerns for this approach includes the lack of a shoulder on which to move disabled vehicles; the potential for confusion at exit ramps; and impediments often found in the shoulder (e.g., rumble strips, raised pavement markings at exits).

- **Other potential entry points.** Identify other potential contraflow entry points. The current contraflow entry point is just north of the I-37 and Route 77 interchange. The Nueces River Bridge just south of this point is the only nearby crossing that could allow emergency vehicles to travel south to Corpus Christi. Extending the contraflow region south across that bridge was not deemed feasible.

- **Signage needs.** Identify signage needs and other impediments to smooth traffic flow on other evacuation routes from Corpus Christi. An alternate route on Route 43 was identified as a feasible evacuation route and a signage plan for this route was developed.
- **Additional technologies.** Consider technologies to provide real-time traffic data on I-37 during an evacuation.
- **Improve hurricane evacuation map.** Improve the hurricane evacuation map for the Corpus Christi area.

2.2.2. Louisiana

Lesson Learned 5 – Leverage the USGS streamgaging programming.

In Louisiana, the need existed for better traffic monitoring during evacuations. Because of the high potential for flooding to block routes, there needed to be better monitoring of water levels near roads. Since USGS also has an interest in monitoring water levels and the Louisiana Office of Emergency Planning (LOEP, now called the Louisiana Office of Homeland Security Preparedness), has an interest in flood detection, the Louisiana Department of Transportation and Development (LA DOTD) developed a collaboration with these agencies to deploy combined traffic and hydrology monitoring stations, which they called Information Stations. This approach pooled funding from three agencies to provide a cost effective approach for LA DOTD to obtain real-time traffic and road flooding information.

The primary benefits of the project are that LA DOTD now has access to near real time traffic information from seven Information Stations located along key evacuation routes near Lake Pontchartrain. Because of the success of this initial deployment, LA DOTD now plans to deploy an additional fifteen stations in the same area. The collaboration with USGS has also resulted in plans for USGS to provide LA DOTD with flood alarms for flood-prone roads on which hydrowatch stations are located.

For more information on the Louisiana Information Station project, see section 3.0.

2.2.3. Florida

Florida has in place a number of measures to help support hurricane evacuations. Five contraflow plans have been developed and information has been publicized about these routes, including a significant amount of information available online from the Florida Division of Emergency Management. Evacuation routes in Florida are signed with flip up signs used for hurricane-specific traveler information (e.g., shelter locations). A series of radio stations provide coverage for disseminating traveler information during hurricanes. Florida has also equipped these contraflow routes with traffic counters and will be upgrading many of these traffic count stations to include traffic video cameras.

With all of these elements in place already, Florida chose to apply the grant funding, combined with other funding, to help integrate some of these resources by developing a hurricane evacuation decision support software tool called HEADS UP. Planned features for HEADS UP include:

- **Data links.** Currently, HEADS UP links to the following elements: shelter status (e.g., location, capacity, current population); road closure status; traffic counts (through a link to a Florida DOT site); road construction and real-time traffic (via http://www.myflorida.com/); traffic incidents (via http://www.fhp.state.fl.us/); and weather information (via http://fawn.ifas.ufl.edu/). For data that is needed for HEADS UP calculations, there is an active effort to consolidate that data into the HEADS UP database rather than just link to it. For example, one of the Phase 2 objectives is to eliminate the need to enter data in both HEADS UP and ETIS by creating software tools that will keep the two systems synchronized.

- **Time stepped calculations.** The HEADS UP traffic model is a time-stepped model that uses a mixture of measured and estimated parameters to predict current and future traffic conditions.
- **Calculate shut down times for areas.** If traffic counters indicate traffic is backed up on a link and a queue has formed, HEADS UP will estimate the amount of time it will take to clear that link. This action will help to devise alternate route plans.
- **Sheltering calculations.** HEADS UP will calculate information necessary to help estimate sheltering requirements, such as the number of evacuees expected to select a site as a final destination and the number of pass-through evacuees.
- **Compare to actuals.** HEADS UP will compare predicted/estimated values (e.g., traffic counts) to measured values so that estimates can be improved. For example, if HEADS UP anticipated an evacuation rate of 20,000 vehicles per hour from a county, but traffic counts indicate that a much lower rate of evacuations is occurring, then this information will feed back into the model.
- **Integrate mesoscale weather (proposed).** HEADS UP might integrate mesoscale weather predictions into the model. For example, if weather predictions indicate rainfall of 1.5 inches/hour on an important evacuation route, then HEADS UP might decrease the capacity on that route because of the poor weather conditions.

In particular, Florida used the FHWA grant to support HEADS UP, Phase 1, which included only some of these features. The success of the Phase 1 implementation of HEADS UP led to the Phase 2 version of that software, which includes most of the features listed above. For example, HEADS UP now includes an Abbreviated Transportation Model (see section 2.2.5) that helps calculate dynamic clearance times based on specific storm information.

Florida views this program as the next generation of the ETIS software, and is interested in working with other states that might be interested in using the software.

2.2.4. North Carolina

In reviewing needs that could be addressed by the FHWA grant, North Carolina identified the need for real-time traffic information that could be monitored during hurricane evacuations. Real-time traffic information on evacuation routes, especially along the contraflow portion of I-40, was of particular interest. North Carolina advertised its interest in receiving bids for a best-value deployment of monitoring stations that would deliver speed, volume, occupancy, and video data to the state Traffic Operations Center (TOC) and the Website www.ncsmartklink.org. However, there were no responses. Apparently, the cost of providing the field hardware to take and transmit traffic measurements and the software costs to fuse that data with existing systems and provide a user interface to access the data made the low price unappealing to vendors.

Lesson Learned 7 – Develop simple-to-use decision-support tools.

North Carolina then began looking for other funding sources that could be combined with the FHWA grant to deploy a larger traffic monitoring project that would attract vendor participation. This search identified a Federal ITS earmark that had been granted to support traveler information for Johnston County, The location of the planned exit point of the I-40 contraflow. This earmark would be spent on deploying four cameras, four detectors, a communication network to transmit the data to the TOC, and a GUI interface to manage it all. The hurricane evacuation grant was added to these earmark dollars to deploy an additional four detectors that are at locations important for monitoring I-40 contraflow. The project is currently in the design phase, should be advertised in the spring of 2004, and installed by next hurricane season. Eventually, the additional evacuation data will feed into the traveler information system.

Because the project is still in the planning stages, no direct benefits of the project have been observed. However, North Carolina expects that the availability of real-time traffic data near the exit point of the contraflow portion of I-40 will help them better manage evacuations in the future.

2.2.5. Virginia

Lesson Learned 7 – Develop simple-to-use decision-support tools.

Virginia used the FHWA grant to update estimated hurricane evacuation clearance times for the at-risk population in the Hampton Roads area by developing an interim abbreviated transportation model (ATM). In the past, the application of clearance time models has been limited in two ways. First, since the models were difficult to update as population and behavioral parameters change, such updates were infrequent. For example, the clearance times for the Hampton Roads area had not been updated since the early 1990's, despite significant changes in the population and population distribution in that area. Second, the models were difficult for non-transportation planners to understand and use. This has meant that the models were seldom used to estimate the impact of new developments on clearance times.

In response to these limitations, the Hurricane Evacuation Study process has recently been modified to produce an ATM. The ATM is designed to be relatively easy to update to estimate the impact of expected or actual population changes on evacuation clearance times. Virginia is already in the process of updating the HES for the Hampton Roads area, and this update will produce an ATM. However, Virginia was anxious to have improved evacuation clearance time estimates before the completion of the HES. To this end, Virginia used the FHWA grant to develop an interim ATM that is based on current census data and evacuation phasing strategies developed in the 1980's and updated in 2001.

The first benefit of developing the interim ATM was that it indicated that, despite the population increases, the updated evacuation strategies resulted in clearance times that had not increased significantly since the completion of the last HES. This allowed evacuation planners to focus their attention on other issues will waiting the completion of the HES. For example, the interim ATM was used to evaluate what-if scenarios of what would happen if a major evacuation route were blocked in order to better plan mitigation activities.

The second benefit occurred because, once completed, the interim ATM was distributed to each hurricane risk jurisdiction in the Hampton Road area, and planners have been using the interim

ATM to assess the impact of new developments on hurricane evacuations. For example, when a developer comes in and looks at siting a major housing development, the planners have used the interim ATM to estimate the impact of changing demographic and population figures on the evacuation clearance times given the existing roadways.

A third benefit is that working on the interim ATM opened communication pathways between hurricane response organizations in Virginia and North Carolina. While these communications were originally necessary to develop the interim ATM, they have continued (e.g., via bi-state meetings) because they have helped everyone improve their hurricane evacuation planning and response activities.

3.0 The Louisiana Information Station Deployment

This section describes the Louisiana Information Station Deployment for monitoring traffic and water level conditions and transmitting the data in near real time to appropriate traffic and emergency operations.

3.1 Overview

Like many U.S. coastal states, Louisiana is at risk for hurricane damage. There are several elements related to the geography of Louisiana that put this state at particular risk. First, there is a large coastal area southeast of New Orleans (the parishes of Jefferson, Plaquemines, and St. Bernard) with long evacuation routes that pass through New Orleans. Since New Orleans, too, will be evacuated if a significant hurricane is expected to strike the southeast coast of Louisiana, the evacuation times for these counties is lengthened by the already long evacuation times expected for New Orleans.

Since most of New Orleans is below sea level and a large hurricane has the potential to put most of the city under water, evacuees must escape the New Orleans basin before they can expect to be safe. Another result of the low elevations of much of Southeast Louisiana is that important hurricane evacuation routes are subject to flood. One of the greatest challenges facing Louisiana is that it must manage long evacuations across terrain that is subject to significant flooding.

One of the priorities that Louisiana needed to address in order to better manage such evacuations was that of gathering real-time data on traffic and water level conditions for evacuation routes. This led Louisiana to work with the United States Geological Survey (USGS) to design and deploy Information Stations that simultaneously monitor traffic and water level conditions and transmit that data in near real time. Deploying the Information Stations led to several benefits that could benefit other states that might use a similar approach to gathering real-time traffic and hydrographic data:

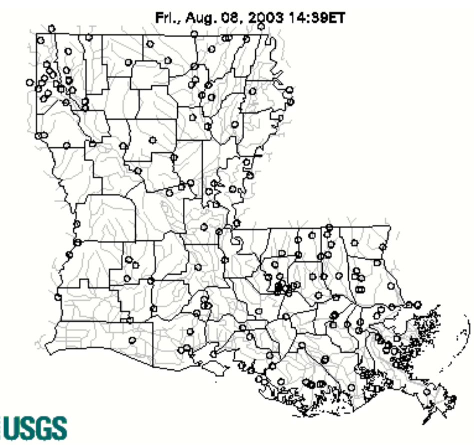
- **Cost sharing.** Because the Information Stations provide data of value to both the LA DOTD and USGS, the costs of installing, operating, and maintaining those stations are shared between those organizations and other cost-sharing partners. This reduces the effective cost for each organization.
- **Reduced infrastructure requirements.** Because the Information Stations rely on satellite communications and solar power, they can be installed where access to communication and power utilities would be expensive. Also, the NOAA communications and data processing infrastructure that already supports data collection from USGS hydrographic stations can be used to facilitate DOT access to the traffic data collected from Information Stations.
- **Ease of deployment in remote locations.** Because the Information Stations do not rely on access to power and communication utilities, they can be easily installed at remote locations that are not part of the power and communication grids used to support other transportation monitoring field devices.

This combination of benefits may make this collaborative approach to deploying traffic monitoring devices attractive to states other than Louisiana.

3.2 The History of the Information Station

Because of its low-lying landscape, Southeastern Louisiana and its roadways have long been subject to flooding. While a flooded roadway can be dangerous in any circumstance, it can be disastrous if it occurs during a hurricane evacuation. The most recent such occurrence in Louisiana was when a low-lying section of I-10 that passes beneath the Southern Railroad underpass flooded 12 hours before Tropical Storm Isidore hit land in 2002. Since this section of I-10 is part of an important evacuation route from New Orleans, losing this section of road during a hurricane could strand many evacuees.[3] A recent notice from the NOAA[4] reinforced the significance of this problem by pointing out that many roads in South Louisiana are sinking, which increases their risk of being flooded.

In response to this problem, Louisiana began working with USGS to develop a Flooded Road Alert System. The basis of this system is 165 USGS Hydrowatch stations (see Figure 3–1) that monitor in near real-time stream stage, streamflow, and other hydrographic information in Louisiana. (Other Hydrowatch stations exist in Louisiana that do not monitor stream stage; these are not used by the Flooded Road Alert System.) Because 95 percent of these stations are located on LA DOTD bridges, they are an ideal source of information on the water level beneath the bridges. By combining this stream stage information with data on the height of the roadbed above the stream, alerts can be generated when the measured stream stage approaches the height of the roadbed.



USGS

Source: http://water.usgs.gov

Figure 3–1. USGS Hydrowatch Stations

In working with USGS on the Flooded Road Alert System, LA DOTD became aware of the potential for a collaborative effort between LA DOTD and USGS to deploy additional stations that combine the hydrographic measurement instrumentation common on Hydrowatch stations with traffic count instrumentation desired by LA DOTD. The combined station, dubbed an Information Station, could leverage the data collection and communication infrastructure already supported by USGS for its network of Hydrowatch stations. This combined system could provide traffic count information at a cost below that for using separate instrumentation for each. LA DOTD approached USGS with the Information Station concept, and USGS agreed to deploy prototype Information Stations if LA DOTD could provide traffic count instrumentation that was plug-compatible[5] with the existing Hydrowatch station configuration.

At the same time, the Louisiana Office of Emergency Planning (LOEP), now called the Louisiana Office of Homeland Security Preparedness, was encouraging LA DOTD to build on a

[3] Louisiana is addressing this specific flooding problem by installing a large pumping station to prevent water from accumulating at that underpass.

[4] See the NOAA release NOAA 2002-R440 at http://www.publicaffairs.noaa.gov/releases2002/dec02/noaa02r450.html.

[5] In this context, plug-compatible means that the output plugs for the traffic count instrument must plug directly into the existing plugs for the Hydrowatch station and function properly. This requires that the physical connections, the electrical properties, data transmission standards, and the traffic count instrument software for the traffic count instrument all be compatible with the those of the Hydrowatch station data logger.

failed 1997 effort to deploy real-time traffic count stations to support hurricane evacuations. LA DOTD and LOEP agreed to support development, testing, and prototype deployment of the Information Stations. LA DOTD then began working with a vendor, PEEK, to develop such a plug-compatible loop detector instrument. Development and testing of the loop detector instrument for the Information Station required about 1.5 years.

During that period, LA DOTD also worked with LOEP to identify 22 flood-prone locations around Lake Pontchartrain for which real-time traffic and flooding information would be critical for supporting hurricane evacuations. Funding for seven of these sites was committed by three agencies: LA DOTD; LOEP; and USGS. Deployment of prototype stations began in the Spring of 2003. At the time of this report, seven Information Stations are deployed and operating. Early indications showed that these stations operated well, reliably providing LA DOTD with near real-time traffic information and water level in all weather conditions. Additional deployments are planned, but LA DOTD has delayed those deployments while they determine the type of traffic detector to use in future stations.

3.3 What is an Information Station?

An Information Station (see Figure 3–2) is a USGS Hydrowatch station that is fitted with a plug-compatible traffic detector. A typical Hydrowatch station is a set of measurement devices – typically, water level, wind speed, wind direction, and rainfall – powered by a battery with a solar array for recharging and equipped with a satellite-based communication system. Typically, the data logger has unused ports that are free to be used to register other information, such as traffic information.

Figure 3–2. A USGS Hydrowatch Information Station

Without the solar array or satellite communication, the station is designed to run unattended for several weeks. Periodically, such a station must be visited to replace or recharge the battery and retrieve the logged data. With the solar array and satellite communication, less frequent and less costly equipment maintenance visits are required. USGS personnel still visit each site, on average, once every 6weeks in order to check on the integrity of the site and to take streamflow measurements to confirm the calibration between stream gage and streamflow.

Each measurement device is connected to a data logger, which records the measured results from the devices. For new Hydrowatch stations, the data from the station is transmitted once per hour via the National Environmental Satellite, Data, and Information System (NESDIS). Each station is allocated a 10-second time slot once per hour to transmit data over a 300-baud channel. (Older stations only transmit data once every 4 hours using a 1-minute slot on a 100-baud channel.)

When needed (e.g., during emergency operations), stations can also access additional communication channels to transmit data once every 15 minutes. For example, a Hydrowatch station can be programmed to use these extra channels to transmit an alert notice when the measured water level approaches a pre-selected flood level. LA DOTD is currently working with USGS to provide three different alerts as the water level approaches flood stage at a Hydrowatch station: a first alert when the water level is within 2 feet of the road level, a second alert at 1 foot, and a final alert when the water level equals the road level. Many stations are also equipped with a phone line or cell phone connection, in which case the station can be polled as needed.[6]

The transmitted data passes via satellite to a receiving station in Virginia. It is then transmitted to the regional USGS office, archived in a database, and forwarded to an Internet server. The data can be accessed via the regional Hydrowatch home page and can be pushed to another server using an Internet-based connection. The typical latency is between 2 and 3 minutes from the time the data is transmitted from the field device and when it is available at the regional Web page.

An Information Station is a Hydrowatch station in which some of the unused ports are connected to traffic detectors. Loop detectors were used in the initial deployments, but LA DOTD is considering the use of other types of traffic detector. The data logger merges the traffic count and hydrographic data, and transmits the combined data as part of the hourly satellite transmission. The transmitted data can then be retrieved from the regional Hydrowatch home page via the Internet-based connection mentioned previously. The traffic data from an Information Station is not available on the regional Hydrowatch home page. Thus, an Information Station allows LA DOTD to collect traffic count data in near real time in a way that leverages existing USGS capabilities, eliminating the need to connect the station to either a power grid or a LA DOTD communication network.

3.4 Deployment and Operational Costs for the Louisiana Information Stations

At the time of this report, Louisiana had deployed seven information stations and had plans for deploying 15 others. The expected cost breakdown for one of these stations is given in Table 3–1. The table also specifies the type of equipment, purchase or installation cost, and the anticipated maintenance costs associated with the various types of equipment for an average total deployment and maintenance cost of nearly $49,000 per unit.

Table 3–1. Expected Costs an Information Station at Highway 90 Near Pearlington, MS

Type of Equipment	Purchase / Install Cost	Maintenance Cost
Hydrowatch Equipment		
Data Collection Platform	$12,400	$ 4,500
Rain Gage	$ 1,000	$ 1,000
Wind Speed and Direction	$ 3,000	$ 1,000
O&M	---	$ 6,000
Traffic Equipment		
Traffic Counter*	$ 7,930	---**
Permanent Loop (6 x 6)	$ 1,500	---**
TOTALS	$25,830	$12,500

* Includes counter, surge protector, solar panel, mounting kit, gel cell, and cable.
** Costs to be determined.

[6] USGS prefers cell phone rather than phone line connections. Stations with phone line connections have had problems with lightening strikes causing power surges over the phone lines and damaging the equipment.

While the costs in the Table 3–1 are typical, considerable variation can exist in the costs of the Hydrowatch equipment. At LA DOTD, the Information Station project began with $60,000 in funding from FHWA and $140,000 in funding from LOEP. This funding, along with some Hydrowatch deployment and maintenance funds available to USGS, was sufficient to test, deploy, and maintain seven Information Stations. Plans approximate the costs at about $426,000 to deploy and maintain an additional 15 stations.

The Mississippi USGS also provided information on the costs of deploying and operating streamgages.[7] The typical deployment cost for streamgages in Mississippi is about $12K, with operational costs varying depending on the type of station. The operating costs for a station that continuously monitors streamflow is about $12K per year, with costs of about $8K per year if a station monitors streamflow only during floods and costs of about $6K per year if a station is only used to monitor streamstage. These costs are comparable to the costs listed in Table 3–1 after removing the costs of the meteorological and traffic instruments.

For comparison, the Transportation Statistics Office of the Florida DOT provided cost estimates for deploying and maintaining their collection of telemetered traffic monitoring sites (TTMSs).[8] Florida's TTMS program includes over 300 data collection stations, most of which collect traffic count, speed, and vehicle classification information. The stations use batteries for power with solar panels for recharging the batteries and use modems for transmitting data back to the Transportation Statistics Office. Most stations collect data continuously and transmit the data each night.[9] The typical cost for deploying a TTMS station for collecting traffic counts only (i.e., not speed or vehicle classification) ranges from $10K to $15K per station. Operating costs for the stations range between $20 and $30 per month for phone charges, and maintenance costs average about $100K per month for the all of the stations, or about $4K per station per year. In addition, the Transportation Statistics Office maintains a bank of about eight receiving modems that are used to poll the TTMS stations each night. (For real-time access via modems, a larger bank of modems would be required.) The costs of deploying and operating the modem bank for receiving this data is not included in the preceding listed operating and maintenance costs.

3.5 The USGS Streamgaging Program

Because an Information Station is based on a Hydrowatch station, it is important to understand the USGS program that is responsible for deploying Hydrowatch stations – the USGS Streamgaging Program. The USGS Streamgaging program collects streamflow information from a network of about 7,000 streamgages nationwide, with about 5,000 of these gages equipped with satellite communication equipment so that collected data can be relayed to USGS in near real-time. The collected data is available at http://waterdata.usgs.gov/.

Funding for these gages comes from a variety of sources – more than 700 Federal, State, and local agencies cooperate with USGS to fund, in whole or in part, about 93 percent of USGS-operated stations. The majority of these stations (about 4,000) are funded under the Federal-State Cooperative Program, under which USGS provides up to 50 percent of the funds required to

[7] This information was provided by Mickey Plunkett of the USGS MS Regional Office.
[8] This cost information was provided by Harshad Desai of the Florida DOT Transportation Statistics Office.
[9] Florida has plans to upgrade 54 of these stations to provide real-time data during emergencies. Of these, 26 will use the FDOT 5.9-GHz communication backbone, and 11 will use ITS fiber optic communication for full-time, real-time data transmissions. The remaining 17 stations will use modems and will transmit real-time data only during emergencies.

operate the station. A large number of stations (about 2,000) are funded by other Federal agencies, with about 500 stations funded directly from USGS Congressional appropriations.

While this diversity of funding sources has enabled USGS to develop a streamgage network that is substantially larger than one that could be created using USGS resources alone, this network recently was reduced in size because funding partners discontinued support for some streamgages. This change induced USGS to begin developing the USGS National Streamflow Information Program (NSIP).[10] Under this program, USGS intends to directly support streamflow measurement activities for a core set of critical streamgages and the network used to collect, validate, and disseminate the collected data. USGS would continue to support non-critial streamflow gages through the Cooperative Program. Because the network expenses for each gage would be covered by NSIP rather than by the partners funding each gage, it is expected that costs for streamgages under the Cooperative Program would decrease.

Because NSIP is not fully funded at this time and the Cooperative Program funding in most states is fully utilized, USGS funding for new sites may be unavailable in some states. For transportation agencies, this will decrease the cost-effectiveness of Information Stations in states where USGS Cooperative Program matching funds are not available. More details on the factors that should be considered before deciding to deploy Information Stations are listed in section 3.6, and section 3.7 lists some hypothetical examples that demonstrate some of the factors that impact the cost-effectiveness of Information Stations.

3.6 Key Elements for Deploying Information Stations

Deploying an Information Station for measuring near real-time traffic counts rather than a traditional real-time traffic count station seems like a win-win proposition for both a DOT and USGS. However, several elements must be considered before the benefits of this approach can be achieved, which are described as follows:

- **Operating costs of streamgages can be higher than traffic count stations.** USGS uses water-level data to estimate streamflow by applying a site-specific rating curve that relates water-level to streamflow. Because the streambed can change significantly over time, USGS technicians visit streamgages that measure streamflow about once every 6 weeks[11] to measure the flow directly. This results in significantly higher operating costs than might be expected by state DOTs considering the operating costs of remote traffic count stations, which require less frequent service. Because USGS will typically want to share the operating costs for new streamgage installations, the high operating costs of streamgages could make an Information Station uneconomical for most state DOTs. Note that some USGS streamgages only measure water level, not streamflow, in which case lower operating costs may be possible. Other strategies for making these costs more economical are considered in some of the paragraphs below.

- **It is possible to retrofit existing streamgages with traffic count instrumentation.** Because an Information Station employs unused data ports on the data logger to connect to the USGS streamgage equipment, it may be possible to retrofit existing streamgages with

[10] NSIP is a conceptual plan developed by USGS for improving national streamgaging. The program has been authorized, but at no specific spending level.

[11] This information was taken from an April 2001 USGS fact sheet available at http://water.usgs.gov/nsip/pubs/nsip-2page.pdf.

traffic count instrumentation. One approach for ensuring that an Information Station program benefits both USGS and a state DOT could be to use a mix of new streamgaging stations partially supported by the DOT – the costs to the DOT for these new stations may be higher than other approaches for gathering traffic count information, and retrofits of existing stations that are supported from other sources – the costs to the DOT for these new stations will be below that of other approaches. By using both low-cost add-ons to existing stations and higher cost deployment of new stations, the overall cost to the DOT may be below that of other alternatives. See section 3.7 for some hypothetical examples that demonstrate the impact of this factor on the cost of Information Stations.

- **Identify funding sources other than the DOT and USGS.** USGS actively collaborates with numerous partners in funding the streamgage network. In Louisiana, LOEP is already participating in a program to fund new streamgage stations in areas likely to flood. LOEP also has a natural interest in helping with hurricane evacuation routes, so the combined benefits of an Information Station that could monitor for flooding during normal operations and measure evacuation traffic and monitor for flooding during hurricanes was very appealing to LOEP. Emergency planning organizations in other states may find that combination of benefits appealing, as well. Local municipalities may have an interest in improving stream monitoring in flood-prone regions. By working with USGS to identify other potential funding partners, a DOT can reduce its portion of the costs for Information Stations.

- **Consider the full range of benefits of deploying Information Stations.** An Information Station does not just provide traffic count data to a state DOT, but can also provide warnings if the stream height approaches flood levels. A secondary benefit is that accurate streamflow data can help improve downstream flood stage predictions so that appropriate precautions can be taken to safeguard both the affected roads and the community. An information station that includes wind speed measurements can be used to identify when dangerous driving conditions exist due to excessive winds, and could also be used to identify when to close bridges during storms. Also, the USGS streamgaging network has proven itself to provide reliable data during all sorts of adverse conditions when other systems may fail. For example, damage to phone lines during a hurricane or spikes in cell phone communications can eliminate phone or cell phone communications from remote detectors. This type of failure does not affect the satellite communication network used by USGS for collecting streamgage data.

- **The reliability of the USGS streamgaging network.** USGS has placed considerable emphasis on the reliability of the streamgaging network. The stations are capable of withstanding strong weather events. The battery/solar power supply and satellite communications used are less vulnerable to disruptions in utility services than many other approaches (e.g., storms downing phone and power lines, cell phone users overloading cells during emergency situations). A redundant receiver station for the satellite downloads is being considered. Many state USGS offices have arranged partnerships with other state USGS offices to provide redundancy for the Websites that make the collected data available. These actions lead to a high level of reliability that may be difficult for individual state DOTs to match at a comparable cost.

- **Consider the full range of cost savings of deploying Information Stations.** Deploying a typical permanent traffic count station requires trenching to connect to a local power and phone service. In many locations, these trenching costs can be a significant fraction of the overall deployment costs. Also, a data collection system (e.g., modem bank with software for polling stations and storing retrieved data) must be developed and maintained, and monthly power and communication charges will be assessed. The Information Station does not require any power or phone connections (though phone or cell phone connections are often built-in for backup communication), and the USGS data collection system is already in place. These factors can significantly reduce the overall operating cost of an Information Station as compared to a typical station.

- **The Information Station approach can complement other DOT data collection activities.** The Information Station approach to gathering near real-time traffic data is at its best in remote locations where access to power and a statewide communications network is more costly or does not exist. Even if a DOT can use an existing statewide communication network for many locations, the Information Station approach may still make sense for more remote locations.

- **Compromises in the location of the Information Stations may be required.** Information Stations must be deployed at locations where streamgage measurements are desirable for USGS. In some circumstances, this may mean that an Information Station cannot be used at a location where traffic measurements are desired because there is no nearby stream where streamgaging is desired.

- **Use available USGS resources to identify existing streamgages in locations of interest.** USGS online resources at http://water.usgs.gov/waterwatch/ include both maps and text descriptions of streamgage locations that can be used to identify whether streamgages already exist at locations of interest for measuring traffic counts during hurricane evacuations. For example, Tables 3–2 and 3–3 list streamgage locations in South Carolina that were identified as being on hurricane evacuation routes or on other routes depicted on the 2002 South Carolina Evacuation Map. Table 3–2 lists the streamgages that are in the counties lying along the evacuation routes from the Hilton Head Island and Beaufort regions of the state. Table 3–3 lists the streamgages located in the counties lying along the I-26 evacuation route.

Table 3–2. USGS Streamgage Stations in Counties Along Hilton Head Evacuation Routes

Location Type	Gage # and Location
Beaufort County	
On evacuation route.	USGS 02176603 (on route 21 bridge near Beaufort) USGS 02176575 (on Route 278 east of Route 179)
On alternate route.	USGS 02176635 (on Route 802 bridge near Port Royal) USGS 02176611 (on Route 802 bridge east of Port Royal)
Not on state route.	USGS 02176589, USGS 02176640, USGS 02176585, USGS 02176576, USGS 02176735, USGS 02176735, USGS 02176720, USGS 02176735, USGS 02176711
Jasper County	
Not on state route.	USGS 02157470, USGS 02198760
Hampton County	
On alternate route.	USGS 02176500 (on Route 601 South of Hampton) USGS 02175500 (on Route 601 North of Hampton)
Allendale County – None	
Barnwell County	
Not on State route.	USGS 02197326, USGS 02197323
Aiken County	
On alternate route.	USGS 02172300 (on Rd 209 near Monetta.)

Table 3–3. USGS Streamgage Stations in Counties Along I-26 Evacuation Route

Location Type	Gage # and Location
Charleston County	
On evacuation route.	USGS 021720677 (on I-526 bridge) USGS 021720709 (on Route 17 bridge) USGS 021720713 (on Route 17 bridge East of I-526)
On alternate route.	USGS 02171850 (On Route 17 bridge North of McClellanville)
Not on state route.	USGS 021720875, USGS 02172110, USGS 02171905
Dorchester County	
On evacuation route.	USGS 02175000 (on Route 61 bridge North of Route 27) USGS 02172076 (on Route 78 bridge South of Ridgeville)
On alternate route.	USGS 02172080 (on Alt Route 17 bridge East of Summerville) USGS 02172081 (on Route 165 bridge South of Summerville) USGS 021720816 (on Route 642 bridge South of Summerville) USGS 021720817 (on Route 642 bridge South of Summerville)
Not on state route.	USGS 02172084, USGS 021720812
Orangeburg County	
On alternate route.	USGS 02173500 (on Route 601 in Orangeburg)
Not on State Route.	USGS 02174250
Calhoun County – None	
Richland County	
Not on State route.	USGS 02169672, USGS 02169300, USGS 02169625, USGS 02169570, USGS 02169000, USGS 02148315

- **Funding partners could change their funding levels in the future.** If a DOT partners with another agency to fund an Information Station location or makes use of the USGS Cooperative Program for matching funds, then the amount of support received by this station from these other sources may change in the future. In fact, one of the reasons USGS is anxious to identify new streamgaging partners is that some of their traditional partners have reduced their support for existing streamgages.

- **The frequency and amount of data collected through the USGS network is limited.** Newer USGS telemetered streamgaging stations transmit data at 1-hour intervals during a 10-second time slot over a 300-baud communication channel. These criteria limit both the frequency with which data from these stations can be collected and the amount of data that can be collected. For example, these stations would not be appropriate for collecting data to support real-time decision support concerning fast changing events (e.g., incident detection) during day-to-day operations because the data collection frequency is too low. The stations would also not be appropriate for high bandwidth applications like video. Because the stations can transmit data more frequently during emergency operations, the stations could be used for real-time decision support during emergencies, such as hurricane evacuations. The stations also have the capability to transmit alert notices (e.g., when stream levels reach flood levels) when the alerted event occurs, which provides another level of real-time support.

In the end analysis, the key step is simply to start a dialog between the DOT and USGS regarding how the DOT can leverage the capabilities of the USGS streamgaging network. One approach for doing so is the joint deployment of Information Stations for gathering near real-time hydrographic and traffic data, as done in Louisiana. However, the genesis of the Information Station project in Louisiana was an effort by LA DOTD to use the streamgage data to generate alerts before roads flooded, and this application could benefit even those states without the expense of deploying new streamgage stations.

3.7 Information Station Costs – Example Scenarios

The cost-effectiveness of leveraging the USGS streamgaging network to support traffic counts depends on the key factors that were described in the previous section. This section of the document provides several hypothetical examples of expected deployment and operational costs for Information Stations. These costs are based on the following approximate costs.

- Installation costs for a hydrographic station costs are about $12,000. LA DOTD reported installation costs for twenty-two planned Information Stations, including six that have been deployed. The installation costs for the hydrographic station portion of these stations ranged from $2,500 to $24,800, with an average of $13,325. MS USGS reported typical streamgage deployment costs of about $12,000.

- Operating and maintenance costs for a hydrographic station are about $12,000 per year for a station that continuously monitors streamflow, $8,000 per year for a station that monitors streamflow only during floods, and $6,000 per year for a station that only monitors stream stage. LA DOTD reported operating and maintenance costs for twenty-two planned Information Stations, including six that have been deployed. The operating and maintenance costs for the hydrographic station portion of these stations ranged from $2,000 to $13,000, with an average of about $7,000. MS USGS reported typical streamgage operating and maintenance costs of about $12,000 per year for a station that continuously monitors streamflow, $8,000 per year for a station that monitors streamflow only during floods, and $6,000 per year for a station that only monitors stream stage.

- Installation costs for a traffic counter connected to an Information Station are about $9,400. This is the cost reported by LA DOTD for the twenty-two planned Information Stations.
- Operation and maintenance costs for a traffic counter connected to an Information Station are about $2,500 per year. No cost data was available, so these costs were estimated to be about half the cost of maintaining a stand-alone traffic counter, as estimated below.
- Installation costs for a stand-alone traffic counter are about $12,000. FL DOT reported deployment costs of between $10,000 and $15,000 for their Telemetered Traffic Monitoring Sites (TTMSs). These stations use battery with solar cell recharging for power and land-line modems for communications. These costs do not include the costs of a central modem bank for polling the traffic counters. North Carolina reported costs of $15,000 per station for four Remote Traffic Microwave Sensor (RTMS) stations that use wireless hubs to collect data from the stations.
- Operating and maintenance costs for a stand-alone traffic counter are about $4,500 per year. FL DOT reported maintenance costs of about $4,000 per station for TTMS with phone costs of about $300 to $400 per year. Costs for maintaining the central modem bank were not provided, but were estimated at $100 to $200 per year for this analysis.

Using these estimates of installation and operating and maintenance costs, the DOT costs for a number of different operating scenarios can be estimated.

Example: Stand-alone Traffic Count Station. Costs for a stand-alone traffic count station are about $12,000 for installation and $4,500 for operation and maintenance.

Example: Louisiana Information Stations. In general, LA DOTD is responsible for installing and maintaining the traffic count portion of the Information Stations and USGS is responsible for the hydrowatch equipment. (USGS had an existing agreement with LOEP for sharing the installation costs of hydrowatch stations in flood-prone areas. By choosing sites that were susceptible to flooding and were appropriate for traffic monitoring, LA DOTD leveraged this USGS-LOEP agreement. Local funds were found to cover the operating and maintenance costs of the hydrowatch stations.) LA DOTD costs for the Information Stations were about $9,400 for installation and $2,500 for operation and maintenance. These costs are below the costs for stand-alone stations, will also provide flood stage data to LA DOTD, and should provide more reliable performance because of the robust USGS communication network.

Example: A Stage-Only Information Station with Cooperative Funds. The costs for a stage-only Information Station are about $21,400 for installation and $8,500 per year for operation and maintenance. If Cooperative Program funds are available for a 50-50 split of the installation and operation and maintenance costs, then the DOT costs are about $10,700 for installation and $4,300 for operation and maintenance. This compares favorably to the cost of a stand-alone traffic count station and provides flood stage data, as well.

Example: An Information Station with Cooperative Funds. The costs for a stage-only Information Station are about $21,400 for installation and $14,500 per year for operation and maintenance. If Cooperative Program funds are available for a 50-50 split of the installation and operation and maintenance costs, then the DOT costs are about $10,700 for installation and $7,250 for operation and maintenance. The installation costs are a bit less expensive than for a stand-alone traffic count station, but the operation and maintenance costs are significantly more expensive. This option would not be cost effective for a state DOT unless either (a) the flood stage data was important to the DOT or (b) a local partner was found to support some of the operation and maintenance costs.

Example: Retrofitting an Existing Information Station. When retrofitting an existing Information Station to collect traffic count data, the installation and deployment costs for the hydrographic station are already covered by other organizations. The DOT costs are about $9,400 for installation and $2,500 for operation and maintenance, which compares very favorably with a stand-alone traffic count station. Note that this arrangement provides no value added to USGS, so this example might need to be part of an arrangement to install new and retrofit existing hydrographic stations, as described in the following example.

Example: A Mixed Deployment of New and Existing Information Stations. Suppose a deployment consists of two new Information Stations with Cooperative Fund support and two retrofits of existing hydrographic stations. Then the DOT costs would be $40,200 (about $10,000 per station) for installation and $19,500 per year (about $5,000 per station) for operation and maintenance. These costs are comparable to those for four stand-alone traffic count stations.

Example: An Information Station. The costs for an Information Station are about $21,400 for installation and $14,500 per year for operation and maintenance. If Cooperative Funds are not available and no local partners are found to help support the station, then the DOT must bear the full cost and the station is significantly more expensive than for a stand-alone traffic count station.

These hypothetical examples point out the reality of funding Information Stations – operating and maintaining a full hydrographic station is significantly more expensive than a traffic count station. Without other funding partners, either explicitly through the USGS Cooperative Program or with local partners or implicitly by retrofitting existing hydrographic stations, stand-alone traffic count stations are more cost effective. In cases where funding partners are available or in flood-prone areas in which the DOT is interested in obtaining flood-stage information, an Information Station can be a cost-effective approach to providing real-time traffic information.

3.8 Summary

LA DOTD formed a successful collaboration with LOEP and USGS to deploy field devices that included hydrographic and traffic data collection instruments and communicated this data in near real-time through the existing satellite communication and data collection network used by USGS. This traffic count data was then available to LA DOTD over the Internet. This arrangement brought strong benefits to each of the participants:

- USGS benefited because it found a new partner to help support its national streamgaging effort.
- LOEP benefited because it was interested in obtaining stream level measurements in flood-prone regions in order to help with emergency response to flooding. A secondary benefit to LOEP was that the deployed devices also provided traffic count data on hurricane evacuation routes.
- LA DOTD benefited because they obtained near real-time traffic count measurements without the expense of establishing and maintaining a data collection network. At the same

time, LA DOTD got access to information that would aid in better response to roads that flood.

This collaborative effort has proven the feasibility of the Information Station concept and helped demonstrate the advantages and disadvantages of this approach to gathering traffic count data. One of the important factors that should be considered is the cost of using an Information Station versus the cost of deploying and operating a stand-alone traffic count station. Typical costs for deploying and operating an Information Station and a traffic count station are listed in Table 3–4.

Table 3–4. Cost Estimates for an Information Station and a Traffic Count Station

Type of Cost	Information Station*	Traffic Count Station**
Deployment Cost	$26K	$13K
Operation Cost	$14K	$4K

* Information Station costs are derived from Table 3–1 with an assumed cost of $1.5K per year for maintaining the traffic counter and loops.
** Traffic Count Station costs are typical costs for a Florida TTMS traffic count station, but do not include the costs of establishing and operating a receiving center to collect data from the TTMS stations.

If an Information Station qualifies for 50 – 50 cost sharing as part of the USGS Cooperative Program, then the DOT portion of the deployment costs for an Information Station are the same as for a stand-alone traffic count station, but the operating costs are higher ($7K versus $4K). If Information Stations are deployed, in part, by retrofitting existing Information Stations or by sharing costs with other partners, then the costs of deploying and operating an Information Station can be less than that for a traffic count station providing real-time data. If one considers the additional benefits of using an Information Station – for example, the high reliability of the transmission technology and the additional data that is available – then the use of an Information Station may be a good alternative, even if cost sharing is not available. More information on state streamgaging programs and interest in collaborating with a DOT is listed in Table 3–5.

Table 3–5. Information on State USGS Streamgaging Operations

State	Level of Interest	Streamgages***	Contact
Texas	**	433 Active streamgages 1 Streamgage marked as inventory only 177 Other active gages	**
Louisiana	Already Participating	179 Active streamgages, 95% located on bridges 48 Other active gages	George Arcement garcemen@usgs.gov 225-298-5481
Mississippi	Very High Limited Funds Available	118 Active streamgages, all located on bridges 18 Other active gages One partner recently cancelled funding for 20 gages	Mickey Plunkett plunkett@usgs.gov 601-965-4600
Alabama	Very High Limited Funds Available	155 Active streamgages, 90+% located on bridges 11 Other active gages	Vick Stricklin vstrick@usgs.gov 202-752-8104 x223
Florida	**	245 Active streamgages 144 Other active gages	**
Georgia	Very High Limited Funds Available	155 Active streamgages, 90+% on bridges 12 Other active gages	Ed Martin ehmartin@usgs.gov 770-903-9100
South Carolina	Interested – initiated talks with DOT Some Funds Available	128 Active streamgages, most located on bridges 11 Streamgages marked as inventory only 33 Other active gages	Ted Cooney twcooney@usgs.gov 803-750-6112
North Carolina	Interested* No Matching Funds Available	235 Active streamgages, many located on bridges 1 Streamgage marked as inventory only 124 Other active gages	Jeanne Robbins jrobbins@usgs.gov 919-571-4017
Virginia	Very High Limited Funds Available	32 Active streamgages, with about 70% on bridges 89 Streamgages marked as inventory only 1 Other active gage	Roger White rkwhite@usgs.gov 804-2561-2605

* The USGS office in North Carolina has spoken with NC DOT in the past, but interest in collaborating with USGS has waned on the DOT side.
** No information was provided by the state USGS office.
*** This information was extracted from the USGS Website at http://waterdata.usgs.gov/nwis/rt.

4.0 Lessons Learned

Lesson Learned 1 – Coordinate plans that cross state lines.

In Louisiana, plans for an evacuation of New Orleans call for contraflow on I-59 leading north into Mississippi. In order to prevent a bottleneck from occurring at the Mississippi line, this requires that the contraflow operation continue into Mississippi. These plans created considerable controversy in Mississippi because the manpower requirements of establishing contraflow on I-59 in Mississippi, estimated at 250 people, will diminish the manpower pool available to provide services to Mississippi residents. (To put this manpower demand in perspective, the Mississippi Highway Patrol has only about 350 officers.)

A second concern was related to the costs of implementing contraflow in Mississippi. If Mississippi implements contraflow on I-59 as a result of a Louisiana contraflow evacuation decision, but the hurricane changes course or weakens, Federal funds may not be available to reimburse Mississippi for the costs of supporting the Louisiana evacuation. In this case, the State of Mississippi may be left paying part of the cost of a Louisiana evacuation.

In October 2002, these pressures resulted in Mississippi rescinding its contraflow plans for I-59. Continued talks between Mississippi and Louisiana officials eventually resulted in a revised agreement for contraflow on I-59 in Mississippi to occur if Louisiana implements contraflow plan on I-59 in Louisiana.

Lesson Learned 2 – Share information.

Mississippi supported a conference on emergency management practices called the EmTech.Com Symposium, and representatives from multiple state and Federal agencies attended. During this symposium, participants discussed their emergency management practices and how to improve them and set targets for improving coordination and cooperation in the future. At the end of the symposium, participant questionnaires indicated that:

- Up to 75 percent of participants indicated that coordination meetings of this type were extremely important to their organization, with the remaining 25% indicating these meetings were very important.
- 100 percent of participants felt that having similar conferences in the future was extremely important.

The consensus among participants, then, was that meetings helping to coordinate across state and agency boundaries were very important.

Lesson Learned 3 – Educate the public about contraflow.

The public can slow traffic flow during contraflow situations in many ways, many of which are related to the public's uncertainty in what they are expected to do during contraflow. For example, it was reported that one location planned on using uniformed officers at key contraflow entry points to help maintain traffic flow. However, experience indicated that a significant number of drivers might take advantage of the fact that an officer was present to stop and ask questions before entering the contraflow highway. Thus, the presence of the officers at the contraflow entry point might hinder rather than improve traffic flow.

Lesson Learned 4 – Locate your bottlenecks.

Contraflow operation increases the capacity of the evacuation route for which it is used, but does not increase the capacity of the feeder roads for the evacuation route. In Texas, it was discovered that the feeder roads from Corpus Christi leading to the contraflowed portion of I-37 were a bottleneck that would prevent contraflow I-37 from operating at full capacity. This finding was compounded by the fact that the Nueces River Bridge north of Corpus Christi could not be contraflowed because it was the only viable southbound route for emergency vehicles entering the city. This meant that the primary feeder for the contraflow portion of I-37 was the non-contraflow portion of I-37 crossing the Nueces River Bridge.

The road network around Corpus Christi was analyzed to identify several alternatives for improving the feeder system to the contraflow portion of I-37. The one identified as the most promising was adding a lane to northbound I-37 south of the contraflow entry point by decreasing shoulder and lane widths to accommodate another lane. Traffic simulations indicated that the impact of the reduced shoulder and lane widths on vehicle speed was minimal, and that the increased capacity of this section of I-37 would help decrease the potential bottleneck in the feeder system to contraflow I-37. Before implementing a contraflow plan, it is important to conduct a network analysis to ensure that the contraflow does relieve the traffic bottlenecks that might occur.

Lesson Learned 5 – Leverage the USGS streamgaging programming.

Louisiana began working with USGS to obtain real-time warnings when stream height measurements approached levels that would flood State routes. During this process, Louisiana discovered that the streamgaging field devices used by USGS had extra ports available for collecting additional data and that LA DOTD might be able to connect traffic count instrumentation to these ports. This would allow LA DOTD to collect near real-time traffic data from locations across the state without the need to deploy a communications network for transmitting this data. Instead, the traffic data would be communicated via satellite to the USGS data processing centers, and LA DOTD could pull the data from that center over the Internet.

As it turned out, LOEP was interested in deploying new streamgages for detecting floods. A 3-way collaboration between LA DOTD, LOEP, and USGS was formed to develop and deploy Information Stations that would provide near real-time access to both hydrographic and traffic data. LA DOTD developed traffic count instruments that were compatible with the USGS streamgaging equipment, and stations were successfully deployed at seven test sites.

Lesson Learned 6 – Integration with other programs.

North Carolina attempted to fund a project to provide real-time traffic information along the contraflow portion of I-40. However, the amount of funds available from the FHWA grant were not sufficient to attract a contractor to deploy field traffic monitoring stations, install the infrastructure needed to communicate the traffic measurements from the field devices to a traffic operations center, and provide the software tools needed to access that data. This first attempt at a deployment did not succeed.

In the end, North Carolina used the FHWA grant to supplement an ITS earmark that was for I-95 and I-40 traveler information improvements in Johnston County, where end of the I-40 contraflow is planned. Because the traveler information project was already installing much of the infrastructure and software needed to communicate and display traffic information, the grant funding could be focused on purchasing additional traffic monitoring stations for deployment at locations key for monitoring evacuations. This project is now in the design phase, should be advertised in the spring of 2004, and installed by next hurricane season. By integrating the evacuation support activities with another ITS program, North Carolina could leverage the communications and software interface elements of the other program to help provide real-time traffic information during hurricane evacuations.

Lesson Learned 7 – Develop simple-to-use decision-support tools.

Virginia chose to use its FHWA hurricane evacuation grant funding to develop an Abbreviated Transportation Model, noting that the current model, which is a complicated spreadsheet model that requires a large number of fairly technical parameters, is difficult for most local and state officials to use. This difficulty-of-use has several negative effects on how the model is used. For example, the model is not typically updated to reflect recent changes in the population or in the road network, so that evacuation planning relies, in part, on old model estimates. The model could be used to evaluate “what-if” scenarios that could help with planning decision, but those interested in these scenarios are not well-versed in the model. By developing an abbreviated transportation model for the Hampton Roads region, it is hoped that the evacuation transportation model will find wider use. In fact, there are many hurricane evacuation decisions that could benefit from an easy-to-use tool that could estimate the impact of different scenarios on hurricane evacuations.