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Environmental Monitoring System — A Tool for Traffic Operations During Severe Weather Events

PROJECT SUMMARY REPORT

Unpredictable and severe weather events often impact the regional transportation system of the Houston area. Heavy rains sometimes can cause many freeways, frontage roads, and major arterials to quickly become impassable, devastating mobility in the region (see Figure 1).

Flooding can be extremely dangerous and costly, with respect to both loss of life and property. During Tropical Storm Allison in June of 2001, 22 people died, and an estimated 4.88 billion dollars worth of damage occurred. The economic impact of lost time and opportunities for business as well as the disruption of normal day-to-day life make these values even higher and the benefit of an environmental monitoring system even greater.

In the fall of 2000, using available technology, TxDOT deployed a real-time monitoring system to provide area-wide environmental conditions to Houston TranStar, the local traffic and emergency management center. Combined with real-time National Weather Service radar and advisories, this system provides advanced warning of severe weather conditions that can impact the traveling public.

This warning system could be a strategically important component of the regional Advanced Traveler Information System (ATIS), especially considering its advantages during hurricane evacuation.

The Harris County Flood Control District and the Harris County Office of Emergency Management (OEM) implemented an Automated Local Evaluation in Real Time (ALERT) flood warning system in 1984 with 12 stream gauges. The Harris County OEM's system has grown over the years, increasing not only the number of sensors, but also the size of the infrastructure, which now includes radio receivers, transmitters, database, software

development, and notification system. TxDOT piggybacked its network of environmental sensors on the existing county's infrastructure thus leveraging resources, using the county's receivers and database, and providing the county with additional sensors and a more dense network of devices. The TxDOT environmental monitoring system contains a variety of field sensors that relay information back to a central monitoring location. Each of the locations contains one or more of the following types of sensors: roadway water depth, rainfall gauge, humidity gauge, wind speed, wind direction, air temperature, pavement temperature, pavement moisture, and stream velocity.

Figure 1 Tropical Storm Allison Flooding

The environmental monitoring system has many components that work together. Figure 2 shows how all these components interrelate. First, the environmental sensors at each site gather the data and relay that information to the base station or receivers via low-frequency radio. This information is stored in the Harris County OEM ALERT database where quality control checks are conducted and alarm thresholds are checked. If a threshold is met, an alarm is sent out via numeric pager and e-mail. This information is also summarized and displayed on the county's website. Both systems (118 Harris County OEM stations and 27 TxDOT stations) shown in Figure 3 operate on the same infrastructure and database. However, the purpose is different for each of the two systems. Harris County's primary concern is stream and bayou flooding. TxDOT is concerned with the effects of severe weather on the transportation system and the mobility of the region.

What We Did...

The research evaluated the maintenance and operational experience of the TxDOT environmental monitoring system as well as the public's understanding of the advanced warning signs. Two years of field maintenance reports were collected from Harris County OEM, entered into a database, and tabulated. A total of 1,421 reports were evaluated that represent 115 sites throughout Harris County. The data were reviewed and the sensors were divided by type and analyzed to determine which components fail and the relative frequency of failure.

Researchers reviewed existing flood, hurricane evacuation, and emergency plans and developed a draft environmental monitoring system operations plan. They also conducted after-event interviews with system users to develop and assess the operations of the

COLLECT

Remote Telemetry
Collect real-time environmental data, relay data to base station via radio transmitter

ANALYZE AND RECORD

ALERT Base Station
Receive radio signals, decode real-time data, analyze data, store data in ALERT database and export to TransStar database

EXPORT AND DISSEMINATE

TranStar
Receives sensor data from database, Traffic Management System displays environmental data and alarms on map

INFORM THE PUBLIC AND SAVE LIVES

Alarms sent to:
E-mail, internet, and text pagers

02: 3203 SENSOR upper limit met @ IH-10@ Beltway 2.43 feet 05/10/00 13:38:54

Benz, Robert

From: RainfallAlerts@hcoem.org [mailto:RainfallAlerts@hcoem.org]
Sent: Monday, October 28, 2002 7:41 PM
To: r-benz@tamu.edu
Subject: Excessive Rainfall - Station 3690

Road Gauges Watershed Station 3690 at IH 10 @ SH 6 has received 1.14 inches of rain in the last 30 minutes. For more information and to add additional email addresses contact Frank Gutierrez at 713-881-3100.

Welcome to the Harris County/TxDOT Roadway Weather Station Network

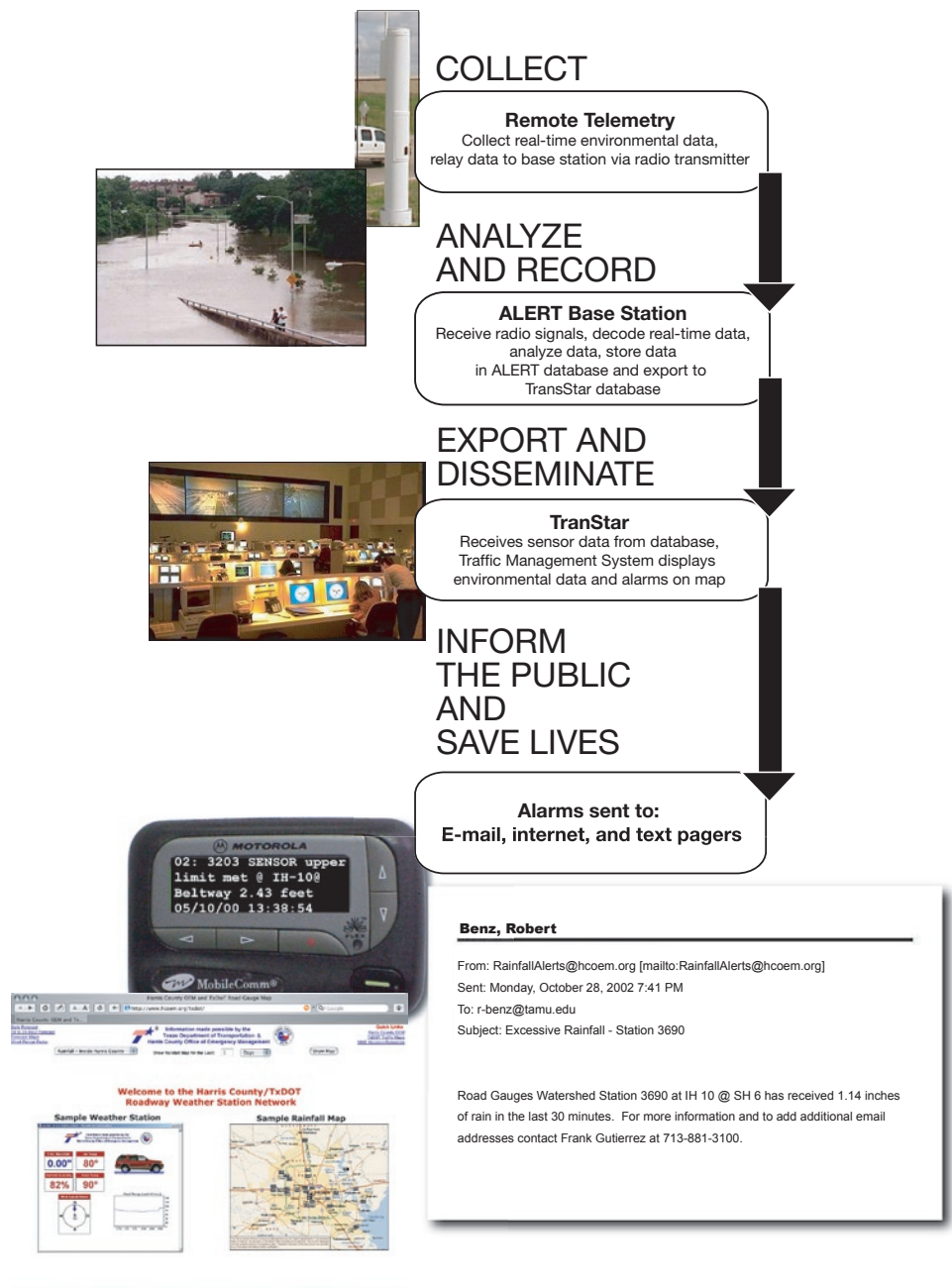Sample Weather Station   Sample Rainfall Map

Figure 2 Environmental Monitoring System and the Interrelated Components

system. Anecdotal benefits of the system were documented as part of these interviews. Managers and operations staff of several agencies were interviewed after one near-ice incident, six localized flood events, and four area-wide flood events.

Synchro 5 was used to set up a network around two flood sensor locations and SimTraffic 5 was used to evaluate motorist delays during off-peak and PM-peak time periods. Partial flooding, full detour with traffic

control, and full detour without traffic control were all compared to the base case or normal operations.

A survey was conducted as part of this study through the environmental sensor website to obtain information on the benefits of an Intelligent Transportation System environmental monitoring system. The survey contained 17 questions about how motorists obtain their environmental information and their experiences

with the environmental monitoring system. It also contained seven additional questions, which were used to distinguish demographic and other background information.

What We Found ...

Results from the two years of maintenance records revealed that the system performs well with regularly scheduled maintenance. However, routine monitoring of the devices and repair visits were required. The devices that failed and/or required the most frequent service were:

- Transmitters,
- Batteries,
- Solar panels, and
- Plugged rain gauge funnels and pipes.

General cleaning and calibration of the equipment reduced the need for unscheduled maintenance.

Existing operations plans provided general information and procedures but lacked the detail required to efficiently use the available tools and resources. After-event interviews provided the needed and evolving experience required to fully develop a draft operations plan. Although there exists a vast amount of experience by agency staff in executing the current operation plans, a fully coordinated approach would improve the efficiency of the system. A multilevel alarm system alerts operators to problem areas, allowing them to monitor and notify the responsible staff and agencies in the event that the roadway needs to be closed. Institutional issues and interagency agreements will need to be worked out to maximize efficiency. During the after-event interviews, many anecdotal benefits were mentioned. Some of these were:

- Emergency and transit vehicle detours,
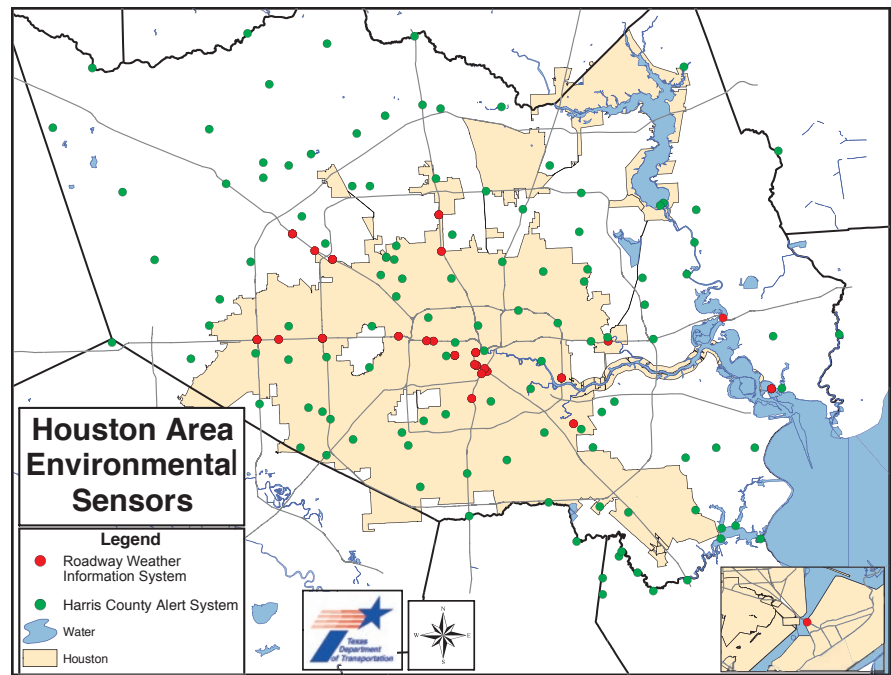- Reduced motorist delay or avoidance of the area,

Figure 3 TxDOT and Harris County OEM Combined Environmental Sensor Network

- Proactive prevention of loss of life and property, and
- Evacuation route monitoring.

Many other benefits will be realized as the system evolves.

The simulation model analysis of the two sites revealed the expected results: any event that slows or diverts vehicles will cause excess delay. However, the efficient use of the environmental monitoring system should minimize delay by alerting authorities to implement efficient detour routes, thus preventing the loss of life and/or property. These benefits vary depending on the magnitude and severity of the storm, geometrics of the base route, and the availability and length of the detour.

The web survey afforded an opportunity to gather information on how people obtain, understand, and use environmental information. From the Internet survey it was found that 75 percent had seen the advanced warning sign advising of flooded roadway, with 25 percent of those having seen the sign when the beacons were flashing. Another interesting result was that when asked to rank how they get information on threatening weather, 40 percent ranked television as the number one source, 43 percent ranked the Internet as second, and 36 percent ranked radio as third. These results confirm that motorists know what the warning signs mean and how to respond. All of the results will be helpful in improving the distribution of environmental data.

The Researchers Recommend...

The environmental monitoring system is considered to be a useful tool that is ready for implementation and will continue to evolve into a traffic operations tool. An effective operations plan and preventive maintenance program is necessary for the consistent use and reliability of the system. Resolving institutional issues, enhancing automation techniques, and establishing interagency agreements will greatly enhance the system's effectiveness. Future integration and display methods will make the system more user friendly.

For More Details . . .

The research is documented in the following report: 3986-1: *ITS Environmental Sensors: The Houston Experience*

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TxDOT Implementation Status
March 2003

Research Project 7-3986 examined the capabilities of the environmental monitoring system during severe weather events in Harris County. The environmental monitoring system has been successfully integrated into the Harris County Office of Emergency Management (OEM). This system provides continuous weather information to the OEM that is disseminated to the public during severe weather events. The continued success of the environmental monitoring system depends on the degree of preventive maintenance to ensure reliability.

For more information, please contact: Wade Odell, P.E., Research Engineer, Research and Technology Implementation Office, (512) 465-7403.

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