STATE OF THE PRACTICE AND REVIEW OF THE LITERATURE

Survey of Fog Countermeasures Planned or In Use by Other States

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In order to facilitate an exhaustive list of fog countermeasures to be placed under consideration, the Departments of Transportation from 49 states (all but Virginia) were contacted in an effort to document the fog countermeasures that are currently in use or being planned by the other states. The results are presented below, along with the contact name and phone number or email address for each state.

Alabama

Alabama has a 6.2-mile bay way stretch of I-10 near Mobile that is prone to heavy fog. Installation is almost complete on a $6.2 million system in this area. It consists of 6 forward scatter Scientific Technology brand fog detectors, 11 pan/tilt/zoom closed circuit cameras, 14 fixed closed circuit cameras, 3 Mark 4 dot matrix VMS's with strobes that accentuate the message, 1 portable VMS, streetlights, and fiber optic connections. The fog-mitigation system along I-10 was developed because of a severe 193-car accident in May of 1995. Traffic engineers from Alabama DOT then visited the fog system site in Calhoun, Tennessee.

The Alabama system stretches over the Cochrane Bridge and is located near a tunneled portion of the interstate. The control room for the tunnel has been modified to handle control of the fog system. A variable speed limit system responds to changes in visibility. As the visibility decreases, the speed limit is decreased to a safer level. The original system was installed in the spring of 1999 and used (unsuccessfully) for seven months. It is almost entirely automated; ADOT wanted to eliminate human error in the decision making process. Humans do monitor the system and have a supervisory role. They make the final decision as to accept the systems proposed action or reject it.

The fog detectors are spaced roughly 3/4 of a mile to a mile apart. The cameras are about 3/4 of a mile apart. The fog system uses fiber optic cables to route all information to a computer in the tunnel control room. When visibility drops below 900 feet, the fog countermeasures are tripped and that is the initial alert level. VMS's begin warning of fog, but the speed limit stays at 65 mph. When visibility drops to 660 feet, VMS's display "fog, slow, use low beams, trucks keep right." The speed limit is reduced to 55 mph. When fog visibility drops below 450 feet, the speed limit is reduced to 45 and the same VMS display is used. When visibility drops below 280 feet, the speed limit is reduced to 35 mph and the VMS's display "dense fog, slow, use low beams, trucks keep right." When visibility drops below 175 feet, the road is closed and the VMS's divert traffic off the highway.

The threshold for deactivation of each level of alert is 50 feet of visibility above the activation visibility level. This ensures that the system will not alternate between fog levels when visibility hovers around a threshold. Also if the average speed drops below 45 mph, the pan/tilt/zoom cameras activate and can be used to identify problems. The cameras are used primarily to verify accidents on the roadway. A computer screen shows the measurements at all fog detectors and displays a breakdown of the system by zone.

The main problem with Alabama's system is that the fog sensors are made for airports and only require a determination of visibility of 2,400 feet. They are not meant to distinguish between finer gradations of fog, so the margin of error is quite large. In 1999, Alabama incorporated backscatter fog detectors in the system, but encountered too many problems. The manufacturer of these fog sensors recommended not using backscatter detectors over water because the reflection from the water's surface can distort readings. ADOT had to use the sensors on the bridge, due to the fog's prevalence there. The manufacturer also recommended that all the detectors face north due to strong sun in southern Alabama, but fog rolls in from all directions so this decreases accuracy in detection. These back scatter detectors were so unsuccessful, ADOT called the manufacturer to see if there were any detectors that were even operational. They only found one operational in the whole US. They are currently installing more forward scatter fog detectors. ADOT is also experimenting with moving the thresholds up, with the initial threshold beginning at 1500 feet rather than 900, since this interstate handles such large traffic volumes (about 60,000 cars a day). Concerns about fog detectors still remain, as the detectors have a 25% margin of error when it comes to determining visibility distance. This margin of error is too great for ADOT's standards, especially when it comes to lower visibilities.

The funding for the system was 80/20 split between FHWA and ADOT. ADOT is in charge of the tunnel, so there was not much cooperation with other agencies for the system. The forward scatter system will be completed by the end of August in 2000. The system is expected to be fully automated by September/October 2000. They will need about two fog seasons to perform tests and gather data before a report comparing the before and after data can be released.

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Alaska

While reduced visibility is a problem in Alaska, the only countermeasure in place is increased delineators on the side of the road. Once they experimented with them in the middle of the road, but snowplows ripped them up. The lack of other countermeasures is blamed on the fact that in the fog-prone areas, there are no power lines to run any other type of system. For wintertime visibility problems, magnets have been installed 1.2 meters apart next to a guardrail and they will be under the road when it is resurfaced. Snowplows will have some instrument attached to them to follow the magnets, but officials have not decided which system to use. Costs for the system have not yet been estimated. Mike Jangensen at CalTrans is helping design this system.

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Arizona

Fog is not a major problem in Arizona, but dust storms are. The difficulty they have with dust storms is that the storms are very localized, but the areas susceptible to dust storms are wide (a 1/2 mile wide dust storm occurring anywhere within a 30 mile stretch of roadway). They would like to have some kind of automated system to warn drivers and set variable speed limits, but they do not have one at this time. They need visibility sensor technology that can accurately scan 1-2 miles in the distance for a system to be feasible.

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Arkansas

No countermeasures.

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California

Along Route 99 in the San Joaquin Valley, a multi-faceted system was implemented in the early 1990's. The five county area in the valley is prone to fog, and it stretches for about 300 miles. The cost of the system is about $3.6 million ($1.32 million for the CA Department of Transportation (CalTrans) and $2.35 million for the California Highway Patrol). The system has been expanded to include parts of I-5, and consists of 80 CalTrans VMS's, 15 SSI weather stations, visibility test signs, and Belfort fog detectors. The VMS's are located strategically important areas (usually about 1.5 miles ahead of major interchanges) to inform drivers of conditions ahead and to give motorists the option to pull off and wait for conditions to improve. There are nine separate monitoring stations, each with pavement sensors, wind speed and direction detectors, barometric pressure recorders, rain gauges, and a CPU.

One of the major fog strategies used in California is creating vehicle convoys. The PACE program (highway patrol pacing traffic through the fog section) and the TARIF (Trucks At Rest In Fog) programs have been implemented as fog countermeasures. In addition, truck staging areas were constructed to hold trucks in times of dense fog, truck lane restrictions were put in place, and a truck convoy strategy was established. Pamphlets containing information about the system as well as tips for how to drive in fog were also distributed. The California Highway Patrol (ChiP) cooperates with Cal Trans to monitor the roadway constantly for fog.

There are three activation levels. The first level is visibility distances above 500 feet. If visibility is still above 500 feet, then the roadways are just carefully monitored for degradation in visibility. The second response level is for visibility between 500 and 200 feet. At this point the system is activated (VMS's display "Fog Ahead"). The third level of response is for visibility less than 200 feet. At this point, the ChiP usually begin their PACEing program, creating speed-controlled convoys through fog prone areas. So far the roads have never been closed for fog visibility problems.

A 1992 report on the effectiveness of this system reported that, for the 1991-1992 fog season, while the number of days with fog increased (41 days compared to an average of 26 days), the number of accidents significantly decreased (9 accidents compared to an average of 34). Since then, permanent VMS's have also been added.

A fully automated fog system exists in the Stockton, California area. It runs on I-5 and Rt. 205 and was installed in 1996. It provides alerts for reductions in traffic speed during fog and high wind. The system consists of 9 RWIS weather stations positioned every 2 miles that provide wind speed, visibility, and precipitation data every 30 seconds, which is transmitted to the Traffic Management Center (TMC) for the Stockton area. There are 9 VMS's, spaced about every 2 miles. There are 36 inductive loop detectors spaced about every mile or half mile.

The system alerts drivers in the following ways:

- If visibility drops below 500 feet, then the message "FOGGY CONDITIONS AHEAD" is displayed on VMS's upstream of the reduced visibility area.
- If visibility drops below 200 feet, then the message "DENSE FOG AHEAD" is displayed on the VMS's.
- If average vehicle speed is 35 mph or less, then "HIGHWAY ADVISORY AHEAD" and "CAUTION SLOW TRAFFIC AHEAD" are displayed on the upstream VMS's.
- If average vehicle speed drops to 11 mph or below, then "CAUTION STOPPED TRAFFIC AHEAD" is displayed on upstream VMS's.
- If wind speed is detected above 25 mph, then "HIGH WIND WARNING" is displayed on upstream VMS's.

Due to budgetary problems, this system is installed on only the southbound lanes of I-5 and the westbound lanes of route 205 which are the roads most heavily used in the morning commute. Fog typically occurs in the morning, so Caltrans thought they could protect the greatest number of motorists during the morning commute if they installed the system on the most heavily traveled roads in the morning.

There have been no major problems with the system, but occasionally they have had problems with the system's communications. The dial-up lines that notify the TMC of a the detection of an incident are maintained by the local phone company, and a couple times the phone company has had problems with the lines. Unfortunately, the system was not set up to be expanded to include components on the other, unprotected side of the road. One set of loop detectors and a RWIS system has been installed on the unprotected side to gather data on how motorists fared when not warned about conditions ahead. One study using these data concluded that the system should be expanded to the northbound lanes of I-5 and the eastbound lanes of route 205. In addition, in the years before the system was installed there had been numerous multiple car accidents, and since the system has been installed, there has only been one multiple car accident.

About 2.5 million dollars were put forward for this system.

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Colorado

I-25 in Colorado runs through low-lying area bordered by water and wetlands, where fog-related crashes were prevalent in the past, including a 32 car incident. On this portion of I-25, CDOT has installed overhead and ground mounted VMS's. The VMS's are LED and Flip Fiber signs manufactured by Skyline. They followed FHWA specifications for Interstate roadways and mounted them between 17'-6" (min) and 18'-6" (max). They have a total of 12 roadside VMS signs available to use directly on I-25 and arterials but they usually use 4 to 6 for the fog problems.

This system can be used for fog, but is multifunctional, being available for driver notification of ice, snow, rain, construction, maintenance, accidents, and incidents. The system is not fully automated and does require human interaction and decision-making. When fog is visually detected by maintenance patrol personnel, the Traffic Operation Center (TOC) in Denver is contacted. They activate the system using a dial-up phone connection and have the signs display appropriate warnings. TOC personnel also have the authority to put messages on signs such as "FOG CONDITIONS MAY EXIST" when conditions are favorable for fog even if fog has not been reported. TOC personnel monitor NWS and local weather broadcasts. The Colorado State Patrol also has the authority to call and request messages.

Currently, there are no plans for automated fog detection, since CDOT has not seen any quality fog sensing systems that could be used in Colorado. The costs of the overhead variable message signs are approximately $275,000 installed. Dial up costs are nominal depending on usage; CDOT has a state rate of .06 cents a minutes for long distance. CDOT maintenance takes care of the signs.

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Connecticut

Connecticut does have some areas that are prone to fog; however, they just have static signs for those areas. There are a few VMS's located on the approach to certain fog-prone bridges, but Connecticut has never used the VMS's for fog. Their opinion is that the VMS's would be too difficult to see in fog. Activation would also require some sort of fog surveillance, and Connecticut has made no provisions for such actions.

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Delaware

No countermeasures.

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Florida

Tampa Bay has a history of fog related problems, and has an average of 22 "heavy fog" days per annum. Unfortunately, fog events in this area are not site specific, and there are no established trends by location, so no automated fog detection systems have been installed. From 1987 until 1998, the surveillance system on the Sunshine-Skyway Bridge (I-275) over Tampa Bay doubled as a fog detection system. This is a toll bridge, and has a control center where the toll plaza and the bridge are monitored. The closed circuit cameras along the bridge were used to judge visibility, and if it was poor enough, then the toll plazas would be shut down and the traffic would be diverted. Portable VMS's were and still are available to alert motorists approaching the bridge. This option is rarely exercised, however. The Florida Highway Patrol assigns a patrol vehicle to this site 24 hour a day.

Currently the toll plaza workers notify the Highway Patrol if they think the fog situation is bad, and the Highway Patrol makes a subjective decision as to whether the bridge should be closed (no delineators or visibility detectors are used). The closed circuit cameras are still in place, but they are no longer monitored 24 hours a day in the toll plaza control center. Originally they were multi-purpose cameras, to be used in traffic accidents, fog events, and to verify situations reported in on the motorist aid phones along the bay bridge. The motorist aid phones have been removed and they now rely on cell phone reports. These go to the Florida HP dispatch center. The surveillance system was shut down because it was not cost effective. As a possible future project, the surveillance cameras may be linked to the Florida HP dispatch center so they check on reports coming in through motorist calls and verify fog problems.

After a severe crash on December 27, 1996 involving 54 vehicles on the Sunshine-Skyway Bridge, there was talk of a more automated system, but nothing was ever implemented. The Center for Urban Transportation Research (CUTR), which is associated with the University of Southern FL, made a detailed fog study of the entire Tampa Bay area (see Evaluation of Motorist Warning Systems for Fog-Related incidents in the Tampa Bay Area). Based on their conclusions, a driver education program was launched, including public service announcements, pamphlets (Know Your Fog Facts: Staying safe in Tampa Bay), and enhanced traffic reporting by local radio and television stations.

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Georgia

The system, on a 14-mile stretch of I-75 in southern Georgia, is not yet operational. This particular location in southern Georgia has always been a problem area for fog. In 1992 farmers were burning off weeds and debris in the surrounding boggy areas, preparing them for cultivation. These lowlands have ponds that evaporate in the dry season and have rich soil for cultivation, but must be cleared before they can be used. The smoke from the clear burning combined with fog to form pea soup-like smog. There were several very serious accidents.

When complete, the fog system will consists of 4 LED VMS's, 19 Vaisella fog detectors, 5 sets of loop detectors, 5 CCTVs, and fiber optic connections between the on-site components. Most of the components have been installed with the exception of the VMS's, which are being specially modified to have walk in cabinets. The software is also being completed.

There is a particularly fog-prone 2-mile stretch of this road where 15 of the 19 fog sensors are located. The fog detectors are spaced at 1/8-mile intervals in this 2-mile stretch. Two of the VMS's will be located inside the fog area, each facing a different direction of traffic, and the other two VMS's will be located before the fog area, each facing a different direction of traffic. The outer VMS's will inform motorists of conditions ahead and are strategically located so they can be used in road closures to divert traffic to alternate routes. Road closure displays are not automatic, while all other messages are. They are contemplating the use of variable speed limits but do not have anything definite at this time.

The system is linked to the Transportation Management Center (TMC) located in downtown Atlanta, and will also be linked to the Georgia Tech Research Institute. The TMC is the primary monitoring agent of the system. The closed circuit cameras are primarily used by the TMC to verify that the VMS's are displaying the correct message. (It has become standard operating procedure for Georgia to install a CCTV system at the same location as any new VMS to allow GDOT to double-check the VMS.) One CCTV will be located at each VMS and the fifth CCTV will be located at the hub of the fog system, where it will be pointed as highlighted targets, to give the TMC staff a better understanding of the situation.

The specifics of the activation algorithm are still being developed. Information from the loop detectors will be used to determine averaged speed. If a variable speed limit is approved in the final stages of this system. The onsite computer will automatically determine which messages will be displayed by the VMS's.

The project began under the Federal Highway Administration (FHWA) Demonstration program in 1993. There was funding available to build a prototype for a fog countermeasure system. Georgia Tech and GADOT collaborated to make a request for the Federal funding. The original project was to evaluate the use of airport fog sensors on the highway. The FHWA determined that it liked Georgia's bid and another from Utah, so it evenly divided the funding between the two programs, with each getting $400,000. Over time, the Georgia project grew from the modest evaluation of fog sensors to the development of a full-scale system. The FHWA agreed, and at this point GADOT kicked in its own funding. The total cost of the system is $3 million, but this price includes the research and development costs. Actual cost of the initial design and equipment is between $2 and $2.5 million.

The primary maintenance activity for the system will be recalibrating the fog detectors, a function that must be performed every six months. Keeping vegetation from growing over the equipment will also be a large maintenance expense. A contractor did the preparation and installation of the system. Georgia Tech was in charge of instruments and software.

LED VMS's were chosen because they are brighter than the flip-disk version, and might be more visible in fog conditions. The LED signs require less maintenance and have a longer expected lifetime. One special modification that was made to the VMS's is that they use amber lights rather than the standard white ones used in all other Georgia VMS's. This is because it is easier to see amber than white light in low visibility conditions.

The system should be operational by November 2000, and a three-month study will be conducted once it is in place.

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Hawaii

No countermeasures.

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Idaho

There are two systems in Idaho. The first is on a bridge in eastern Idaho on Rt. 20, on which the Idaho Department of Transportation (IDT) is planning to install an RWIS that will automatically activate parapet-mounted, fog guide lighting on the bridge. The system will be linked to the IDT for monitoring. The IDT is the only controlling agency for the system. State police are not called in and do not have access to the system.

The fog in this area occurs at a very specific spot on the bridge, which runs over a premier fly-fishing stream. After meeting with environmental groups, it was decided light cast into the stream could be detrimental. By using this system they can provide guidance to the drivers in foggy conditions and not have the lights on unnecessarily.

The visibility detector is a Belfort Digital Visibility Sensor, Model 6100 that cost $6962.00. The lights are NuArt POC series pedestrian fluorescent underpass lighting. They will be installed under the bridge rail parapet so they are of 2.8 feet above the road. The will be angled to shine at the road at a 45degree downward angle through a slat, to avoid the possibility of refraction and glare. Communications consist of dial-up phone lines connecting to a central computer from the Remote Processing Unit (RPU).

SSI, the contractor, will furnish a complete and operational RWIS site, bridge lights, conduits, and labor. The estimate was for the total cost is $41,403.00. This is a Federal Aid project with standard state participation.

The second system is a test system on I-84. The primary focus area is a 20-mile section in the northwestern portion of the interstate. There are three systems installed on this segment -- two operational systems there and one that was planned but later scrapped. The SCAN system consists of a Belfort visibility sensor and a precipitation/visibility sensor. It focuses on measuring visibility, wind speed and direction, air temperature, relative humidity, type and amount of precipitation and pavement conditions. The

HANDAR System also uses a Belfort visibility sensor. It uses its visibility sensor and focuses on weather measurements similar to the SCAN system. The LIDAR System consists of a special laser/radar visibility sensing system that covers a larger area. This system was dropped from the test due to extensive technical and reliability problems. Weather data is sampled every 5 minutes from each sensor. One of the primary objectives of the test was to evaluate various visibility sensors at a single location. SSI provided pavement sensors at no cost to the project

A video system (also located at the sensor site) was used for event confirmation. Weather data is sampled every 5 minutes from each sensor. If visibility drops below 1200 feet at either of the sensors, maintenance crews are notified. VMS messages used were primarily "High Winds," "Low Visibility," or "Road Closed." These messages are not displayed automatically. Idaho stipulated that they did not want automatic links between the system and the VMSs so if there were false detections, the system would not loose credibility with motorists. The system was completed in the fall of 1993. Some upgrades have occurred over the years.

Communication is primarily by standard phone lines (a combination of leased and owned lines). The major problems were poor power and phone lines in extreme rural area. System integration of the three systems was initially a significant challenge and required extra effort up front (beyond what was originally anticipated).

The budget was $1.2 million, which included research, testing, maintenance and installation. The components were purchased so long ago that that information would not be appropriate now. It was a 65% Federal 35% state split.

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Illinois

No countermeasures.

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Indiana

Although not designed for fog detection, Indiana does have a roadway visibility system on a 1/2 to 3/4 mile stretch of the southbound lanes of I-69 near Ft. Wayne, mainly for snow and white out conditions. The curvature of the land in the area causes whiteout conditions only in the southbound lane. The system works very much like other fog detection systems and detects a drop in visibility, whether it is from fog or snow. The system consists of one JayCor visibility sensor, LED VMSs, a local controller, and wireless communications. The total cost for the system was about $135,000, with the VMSs being the most expensive part of the project at $35,000 each. (Interestingly, after planning to use the Sunray model VMSs, they were taken off the approve list for Indiana, since they were advertised as displaying 8 characters per line, but in actuality only displayed 7 1/2 characters per line.)

The onsite system is part of a much larger statewide system called the Automated Traveler Information System, which has two separate dedicated servers to record incidents and provide a flow of specific responses for an incident. The field sensor site measures visibility using the JayCor 1200 visibility sensor and communicates the actual visibility in feet to a local field processor. Once calibrated, visibility is measured from 50 to 2000. The sensor itself reads ambient visibility and temperature and takes a running average of the readings over a 10 sample period, one sample every 30 seconds for 5 minutes total. After the 10 samples are read, the threshold set inside the sensor determines if action should be taken. This threshold is programmable and the value will be optimized later this year. The threshold for activation now is set at 500 feet. Maintenance personnel are paged if there is an incident.

Once the system becomes fully operational, the local field processor will dial into one of two central ATIS sites to report the reduced visibility condition. This is actually accomplished in the same manner as if an incident is report by field personnel by specifying the following:

- Roadway affected (roadway)
- Roadway Location (mile marker)
- Direction (Northbound, Southbound, Eastbound, or Westbound)
- Lanes affected (Including shoulders and ramps)
- Problem (Closed, Moving very slowly, slippery, low visibility stopped traffic)
- Cause (Maintenance, construction, accident, heavy traffic, weather...etc.)
  * Consequence (Expect Delays, Seek Alternate Routes)
- Anticipated Duration (<= 20 min....to 3 days)

The ATIS Expert System servers will then determine which field resources (VMS's, HAR, and pagers) are in the area of influence of the reported incident. The server will then communicate to each effective device, which, in turns, will display the incident information to motorists. In the case of the I-69 system, the VMS's would be dialed up and would display the appropriate message. The message will continue being displayed until the field processor calls again to cancel or terminate the incident. Iron Mountain Systems, Inc. and INDOT are planning on a field test of the visibility system later this year.

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Iowa

No countermeasures.

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Kansas

No countermeasures.

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Kentucky

Kentucky does not have any areas that are particularly prone to fog. The state had a system that was set up in the late 1970's on a bridge over the Kentucky River, but it was dismantled in the mid 80's. It consisted of one Scientific Technology backscatter fog detector linked to static signs. It was an automatic system that activated whenever visibility dropped below a certain threshold. The system was dismantled when it was found to be having too many malfunctions to be considered a useful warning system. Also, there was a general lack of interest, and because the very early fog detection equipment was fragile and difficult to calibrate, maintenance was too intense for a project that no one really cared about.

Currently, Kentucky has 7 RWIS systems around the state to alert the DOT as to possible weather problems so they can coordinate the work of road crews. They are linked to the state maintenance garages.

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Louisiana

Louisiana's system is on the same interstate as Alabama's fog system: I-10. It hugs the shoreline of the Gulf of Mexico, and passes through numerous swamps. The three sections of the road that are especially bad are around Shreveport, on either side of New Orleans, and the stretch between Baton Rouge and Lafayette.

In 1986, there were several fog-related crashes in these areas and the NTSB became involved. They recommended building crossovers for emergency vehicles. In the early

90's, there was a similar fog-related accident. A multi-agency committee investigated the situation and drafted a report on what should be done.

The first phase was to improve all weather pavement markings, including reflectorized markers, rumble stripping, and 1/10-mile markers to make identifying the location of accidents easier. This phase is completed. The second phase involved designing a visibility system including VMS's and weather stations. LDOT has completed planning for this system and are currently deciding on specs for the bidding process.

Originally, the system was designed to have seven VMS's, but political and other changes have occurred. The Transportation Secretary decided to expand the system to include variable speed limits. The chief engineer wanted three more VMS's for icy conditions in Shreveport. The state police wanted a few more signs in one particular area to make road closure possible. The system now consists of 12 VMS signs (7 for fog, 2 for detours, and 3 for ice), 38 variable speed signs, three RWISs (one at each of the three sites), and a control server for the entire roadway, to be located at a Louisiana Department of Transportation Center. The State Police can verify low visibility alerts, based on the number of mile markers visible to the officer (the markers are set every 500 ft.).

Originally, the state did not want to use fiberoptic communications due to Louisiana's high water table and because this would double the cost of the project. However, a fiber optic trunk line is being laid now between the Louisiana DOT Headquarters office and the State Police Center. For the variable speed limits they are looking primarily at dial up connections. The weather stations will be located near microwave sites so they can transmit data (and closed circuit television signals) directly to the State Police Center.

The cost of the project is $2.4 million. The funding for this system comes from Federal funding (STP and Hazard Elimination funds, specifically). The Federal funding will cover installation, and state funds will be used for subsequent maintenance. (The contractor who wins the project will maintain the system for the first 5 years.)

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Maine

The have some fog on the coast, but all they have are static signs to warn motorists. They are not planning on having anything more than that for now.

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Maryland

There are driver information systems on two bridges in Maryland: the Frances Scott Key Bridge and the William Preson Lane, Jr. Memorial (Bay) Bridge. Both are for general information and not specifically intended for fog. Both are manual and there are no plans for a more automated system in the future. The Key Bridge is located near industrial sites, so the main problem there is smog, not fog. At the Bay Bridge, fog is not a key issue

A state trooper, who is on duty seven hours a day, will radio in to the Authority Operating Center at the FSK Bridge to report fog. The AOC will send out the signal to the VMS's using the leased line connection to the VMS's to display "Fog Ahead." The troopers make a subjective decision; there are no delineators to judge sight distance in the fog or comparable standard for judging.

All funding comes from tolls from the Maryland Toll Authority. No Federal money is used.

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Massachusetts

Massachusetts has a few areas where fog occurs, but fog does not occur very frequently, and is not considered much of a problem. The only countermeasures in place in these areas are static signs warning drivers that they are entering a fog area.

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Michigan

Between 1992 and 1994, Michigan had one fog visibility sensor installed in one of their roadway weather systems. It was used without much success, and there was no real need for it. The sensor was part of a FHWA demonstration and was purchased from the manufacturer of their other roadway weather systems, SSI. There are 11 of the RWISs in use, and they are connected to one of five central computers, depending on location.

The RWIS systems were estimated at about $30,000 a system for four roadway sensors and four atmospheric sensors.

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Minnesota

No countermeasures.

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Mississippi

While fog forms along the coast, there is no specific limited area where fog tends to develop. The only countermeasures they have installed are static signs warning drivers to watch for fog.

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Missouri

They are currently installing an RWIS system in a fog-prone area. Currently, the hardware is installed but the system is not up and running. Eventually they hope to link that with VMSs to warn drivers of fog, but they cannot think about doing that until after the RWIS is functional. Currently all they have is a static flashing light sign warning drivers of fog. The sign flashes continuously.

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Montana

They do have some fog-prone areas near a few rivers in Montana, but the only countermeasures in place are static signs and normal HAR. The HAR is allowed 4 frequencies per sign. The radio station has to work for 70 miles. The station has to transmit a weather warning every 15 minutes.

Contact: DeWayne Williams (406) 444-9452

Nebraska

No countermeasures.

Contact: Dave Martin (402) 479-4519

Nevada

They have one visibility sensor tied into an RWIS on I-80 about 10 miles east of Reno. This visibility sensor is lined to 4 variable speed limit signs (2 in each direction). Due to various installation problems, they do not expect the system to be operational until about April 2001.

Contact: Tracey Larkin (775) 834-8300

New Hampshire

No countermeasures.

Contact: DOT General Info (603) 271-3734

New Jersey

New Jersey was planning for a fog system for the Palisades Parkway. However, before planning could begin, attention was shifted to the Wanaque Bridge on Rt. 27 and about $150,000 intended for the Palisades project was diverted. (An accident study involving crashes since 1985 later noted that there was some question as to whether most of the Wanaque Bridge crashes were actually due to fog.)

SSI is now designing a system for the bridge (for about $20,000). The system will include1 visibility sensor, 2 VMSs, 2 sets of loop detectors, weather sensors, and CCTV. Rutgers was in charge of developing the algorithm for activation. When fog is present, a message is transmitted via phone lines to the VMS and to the operations center, where an operator will verify the situation via camera. Advisory speeds are then set.

The component installation is completed, and the power hookup should be complete by fall of 2000. The total cost of the project will be $104,000, which does not include the cost of the VMSs (which NJDOT already owns).

Contacts: Kaan Ozbay, at Rutgers University (732) 445-2792
Nancy Webber, at NJDOT (609) 530-6456

New Mexico

New Mexico has a problem with dust storms. They do not have any countermeasures in place, but are currently looking for an ITS solution. However, they have yet to find anything suitable, claiming that systems they have looked at do not provide the response times they need for an effective system.

Contact: Bill Berringer (505) 246-6410

New York

No countermeasures.

Contact: Joe Daugherty (518) 485-7271

North Carolina

The Haywood County visibility system extends along a five-mile stretch of I-40 near a paper mill. The system consists of three Belfort visibility sensors, two VMS's, and a remote processor signals the VMSs and communicates with the central office. The onsite system elements are interconnected with fiberoptics and there is also a dial-up connection from the central office to the remote processor. The VMSs are located one mile before the fog area in each direction of traffic. The fog sensors are placed strategically in three locations based on 15 years of accident data, and interview with highway patrol officers and DOT staff members who know the area.

During normal working hours, the DOT just monitors the situation in fog events. DOT maintains the system, and during times when it is not activated, they can use it to warn of construction ahead or other maintenance/repair conditions. The Highway Patrol is the first line of response in fog and controls the system; the warnings from the remote processor go to their central office about 40 miles away, and the officers control the VMS's. The VMS's will automatically display "Low visibility, slow speed" when the first visibility threshold is crossed. From then on, there are preplanned scenarios for handling the different thresholds of visibility, but the officer monitoring the system makes these determinations. In the future, there are plans of installing three CCTVs for verification of low visibility. Initially, the system issued false alerts due to noise, static, or EMI coming down the communications lines to the central office. There have also been problems in interfacing software with the VMS's.

In 15 years, there have been only three multi-vehicle accidents attributed to fog, but one involved some 60 vehicles, so the North Carolina DOT decided to take a proactive stance and prevent any more multi-vehicle accidents. There have not been any studies in the reduction of crashes since the sample size was so small to begin with.

The visibility sensors cost $30,000 each, and the VMS's cost $125,000 a piece, including the structures, required poles, etc. The entire project cost $1.1 million. It was funded using Federal money (specifically STP funds).

Contact: Greg Fuller (919) 733-8021

North Dakota

No countermeasures.

Contact: DOT General Info (701) 328-2500

Ohio

No countermeasures.

Contact: George Saylor (614) 752-8099

Oklahoma

No countermeasures.

Contact: DOT General Info (405) 521-2861

Oregon

There is no system in yet, but there is a system in the planning stages (to begin in FY 2001) for Highway 97, which cuts north/south through the central part of the state, and that includes some mountainous areas. The corridor runs about 100 miles from Madras to the Oregon-Washington border. There are six sites that have been identified by maintenance personnel as areas prone to dangerous conditions and where ODOT is investigating installing systems. .

This system will consist of wind and visibility warnings, and its main purpose will be to close the highway to trucks if conditions warrant. ODOT is investigating two main setups. The first would be a simple and closed system that would have a nanometer and a visibility sensor that would react automatically and display an appropriate message. The system would page maintenance personnel to alert them to the system's activation. Given the rural location of this highway, getting power and communication links from a centrally located operating center to the system are problems that using a totally local, closed system would avoid. The other option is using a standard RWIS that reports back to a central computer. Since there are huge gaps in cellular communication, there is a chance that the system would not operate continuously. In addition, the cost differences would be rather large. The simple system would require about $10,000 a site whereas the RWIS linked to a central computer would cost around $50,000 per site. ODOT has a fairly constrained budget, so they could either do all simple systems at each of their six sites, or install an RWIS system at one or two sites. Regardless of which system type is chosen, variable speed limits would not be used because Oregon law prohibit this.

State police are not very active in roadway condition monitoring in Oregon and would probably not take part in this system. They have limited resources in this capacity. However, they are co-located at the local ODOT traffic operations center and could be called in.

ODOT will be using Federal matching funds (probably from an ITS grant) for this project.

Contacts: Galen McGill	(503) 986-4486
Kevin Haas	(503) 986-3612

Pennsylvania

Pennsylvania currently as a fog detection system set up on an almost 2 mile segment of US 22 over Crescent Mountain near Altoona that is prone to fog, high winds, and white-out conditions in the winter. The system was installed in response to a 1996 24-car pileup involving four fatalities that occurred during white-out conditions. The press and politicians highlighted this crash, and PennDOT officials felt that they act immediately. As a result, the initial request for proposals was hastily put together, and when the bids went out for the VMS's, the specifications were misinterpreted. Unfortunately, the project was constructed with flip disk VMS's rather than the fiber optic ones intended.

The system now consists of an SSI RWIS, VMSs, and Highway Advisory Radio (HAR). All of the system components operate independently and require manual coordination. PennDOT is considering moving to a more automated version than the current system. An improvement project is currently being bid on to install a CCTV system and to lay fiber optic connections between the components.

During the winter, a dispatcher in the maintenance office controls the system, getting information from the RWIS, the Highway Patrol, and a PennDOT truck on duty 24 hours a day. (The truck treats ivy patches of the roadway in order to keep it.) Both drivers manually radio in to report bad weather and the dispatcher then chooses a message for the VMS's to display from a library of messages. There are protocols for each type of weather.

PennDOT paid for the original system. FHWA paid for the HAR and the new VMS's with ITS funds. These most recent improvements cost $1.2 million.

Contact: Tom Bryer (717) 787-7350
Michael Pastore, Asst. District Traffic Engineer, PennDOT, Engineering District 9-0 (814) 696-7238

Rhode Island

No countermeasures.

Contact: John Nicholson (401) 222-1362 x4803

South Carolina

When the Cooper Rover Bridge on I-526 was being planned and environmental studies were being performed, the owner of a nearby paper mill voiced concerns about placing a bridge at the same height as the stacks for his paper mill. This area was already known to be prone to foggy conditions. The paper mill brought a suit against SCDOT and the federal judge in the case decided that the bridge must include a fog mitigation system.

The Cooper River Bridge opened in 1992 with all components of the fog mitigation system operational. The system includes fixed signs, raised reflectorized pavement, lighted pavement markers, a weather station, five forward scatter type fog sensors, and eight closed circuit cameras. The contractor, Parsons Brinckerhoff, had subcontractors from scientific firms put together recommendations for the judge to rule on. The judge made the final decision on what to include and not to include in the system.

On the whole the system has been reliable. There have been some minor problems and false detections. In the early years of the system's operation SCDOT was working with electronic components that were not suited for the hot, humid environment. The microwave communication system that was struck by lightning was replaced with fiber optic relays between all the sensors and the weather station. The heat in the cabinet where the electronics were stored was extremely high and an air conditioning unit had to be installed. Originally the system jumped back and forth between activation and non-activation if there were plumes of smoke from the paper mill, but it has since been modified to average out spikes in readings from the fog detectors. Maintenance costs were high -- the lighted markers filled up with dirt and had to be cleaned about once a month. Since the bridge shook so much, the ballast often had to be readjusted. The fog detectors had to be cleaned about once a month.

If weather conditions are suitable for fog, or if the visibility sensors detect fog, the system sends an alarm to the dispatch center, and appropriate action is taken, depending upon fog density. In conditions of light fog (visibility between 700 feet and 900 feet), VMS's alert drivers that there is light fog ahead, truck speed is reduced to 45mph, and trucks are required to move to the right lane. As the fog becomes denser (450 feet to 700 feet), the speed limit for all vehicles is reduced to 45mph, and lighted pavement markings are activated. In severe visibility conditions (300 feet to 450 feet), overhead street lighting is turned off due to glare produced by the refracted light, and speed is reduced to 35mph. In critical conditions (visibility less than 300 feet), speed is reduced to 25mph, and, if warranted, the bridge is closed and traffic rerouted. The operator must acknowledge the detection of an incident and accept or decline the computer's course of action. The closed circuit cameras were installed to verify the conditions reported by the computer.

Originally the Highway Patrol and the Department of Transportation were in the same department, but after a statewide restructuring program a couple years ago they are now separate. State troopers are not normally called in during fog incidents, but the office where they system computer is located is at the dispatch office for the highway patrol, so it is easy to use them if necessary.

The bridge was originally part of a federal construction project and exclusively used federal interstate funds. When it was determined that a fog system would be necessary, the system was included in the federal funding. Operations are funded through federal and South Carolina funds. They have a maintenance contract for about $5,000 a month for preventative maintenance on the communications system and component repair is done on an hourly rate.

The initial cost of the system was $5 million, but it is unclear whether that figure includes other construction items for the bridge. The system was overhauled a few years ago for about $1 million. This overhaul included running new fiber on the bridge to the new hub building under the bridge, replacing the fog detectors and the weather station, and rehabbing the VMS's and cameras. The software was also re-written.

Contact: Robert Clark (843) 740-1665 x118

South Dakota

No countermeasures.

Contact: John Adler (605) 773-3174

Tennessee

There were two major fog crashes on the 19-mile stretch of I-75 between Knoxville and Chattanooga that precipitated the development of a fog system. The first crash occurred in the late 70's and involved 50-vehicles, but no fatalities. The second crash occurred on December 11th, 1990, and involved 99 vehicles involved and 12 fatalities. Between those crashes, there were no other major fog related incidents.

A nearby paper mill was hit with several lawsuits after the 1990 crash, blaming the settling ponds near the road for causing the fog. The paper mill closed its settling ponds close to the road and settled out of court. The TN Department of Transportation and the TN Department of Safety formed a task force to study the problem and to make recommendations. A committee of public safety, traffic operations, design, construction, and maintenance officials, as well as FHWA representatives responded to the recommendation to build a fog system and developed the design. Building was completed in 1992, and the system was activated in 1993.

The components of the system include fog detectors, two RWISs, 44 speed detectors, ten VMS's, ten changeable speed limit signs, six swing gates, six fixed signs with flashers, and two HAR systems (one for the northbound lane and one for the southbound lane). The fog detectors are HSS brand, VF500 models. The VMS's are hybrid flip disk and fiber optic lighted Matrix Media brand. The speed detectors are Wheelen Engineering brand, TDW10 models. Four of the fog detectors are near a bridge in the fog zone, and the other four are spread out at about 1/2 mile intervals. The speed detectors are spaced at about 1/4 mile intervals. Fiber optic communications are used between the components on scene, and a 2GHz microwave system is used to connect back to the control center in Tiftonia, Tennessee. There is a standard phone line connection to the system for backup if the microwave system fails. It also has a power backup system for interruptions in power supply.

If speed falls below 45mph, or if visibility falls below 1320', an alert is sent via microwave to dispatch and a trooper is sent to assess the situation. Also, if visibility falls below 1320', a message is automatically sent to the VMS saying that there is potential fog ahead. The sign changes to fog ahead after visual verification by a trooper. They also use variable speed limits after the situation is verified. If visibility is between 480'-1320', speed is set to 50mph. If visibility is between 241'-480' the speed is set at 35mph. If visibility is 240' or below, the road is closed and traffic is detoured onto a nearby U.S. highway. If five cars pass by with an average speed of less than 45 mph, the dispatcher is notified and he sends a trooper to investigate. This part of the system is not necessarily for fog, but is helpful in detecting wrecks and other incidents on the highway. Also, 365 days a year, a trooper is assigned to fog prone area between 5 and 10AM, which are the times at which fog is most likely. In addition, public service announcements were aired to inform the public of the system (what it is, how it works, etc.) and fog pamphlets were made available. Once a fog situation is verified, dispatch advises local media that the system is activated.

Early on in the system's life, there were problems with communication. The overhead VMS's were not communicating with the rest of the system due to a bad interface. There were problems with the microwave communications system. They would lose alignment anytime the wind would blow, so they had to be stabilized for wind. There were problems with lightning strikes, so lightning arrests were installed. Tennessee is currently installing a more powerful microwave system to make communications more stable. Also some of the detectors were placed too close to the road and when it rained, passing trucks splashed them, registering as reduced visibility. These have been moved back off the road by 50 or 60 feet.

There has only been one crash during a fog incident, but the cause of the crash was not reduced visibility. From December of 1993 to January of 1995 there were 77 activations for fog. All of those activations required a lowering of the speed limit to 50 mph. Ten of those activations required a further lowering of the speed limit to 35 mph. There have been two road closures. One was due to toxic smoke from a fire at a nearby chemical plant, and the other one was due to severe fog. During road closures, the highway patrol works with local sheriffs' officers, who close down on-ramps.

The system is run and monitored by the highway patrol, but it was installed by and is presently maintained by the TNDOT. Georgia Electric was the contractor for installing the system. A trooper is on duty every day of the year to patrol the stretch of I-75 from 5 a.m. to 10 a.m., the hours most prone to fog development. The original contract for the system cost $4.5 million. Included in that was a 4 year maintenance contract with Georgia Electric for $28,000.

Contacts:	Captain John Savage, Tennessee State Police Headquarters	(423) 634-6898 x2200
	Bill Clouse, District Engineer	(423) 892-3430
	Ray Rutger	(423) 892-3430
	Don Dahlenger, Engineering Manager	(615) 741-2027
	Joe Holt, Project Overseer	

Texas

No countermeasures.

Contact: DOT General Info (800) 558-9368

Utah

Project Adverse Visibility Information System Evaluation (ADVISE) is located on Interstate 215 south of Salt Lake City, near a golf course and several drainage ponds. This system consists of four Present Weather 660-120 model, HSS brand forward scatter fog sensors, two bulb-matrix type VMSs using AdTronic components, and six loop detectors. This is a fully automated system.

The two lowest visibility readings from the fours sensors are averaged, and if this average is below the threshold, then the alarm is tripped and a signal is sent directly to the VMS's to display the appropriate message. The system also incorporates variable speed limits. If visibility is above 250 meters, then no message is displayed. If the visibility is between 200 and 250 meters, then the message "Fog Ahead" is displayed. If the visibility is between 150 and 200 meters, then "Dense Fog" is displayed, alternating with "Advise 50 mph." If visibility is between 100 and 150 meters, "Dense Fog" is displayed, alternating with "Advise 40 mph." If visibility is between 60 and 100 meters, "Dense Fog" is displayed, alternating with "Advise 30 mph." If visibility is less than 60 meters, then "Dense Fog" is displayed, alternating with "Advise 25 mph." This is an advisory system, and the recommended speeds are not enforceable. However, data have shown that speed variance decreases by 22% when the ADVISE system is activated.

As with many other fog systems, several multi-vehicle fog crashes highlighted the need for the Utah System. In 1988, there was an accident involving 66 vehicles, and in 1991 there were 10 accidents involving three fatalities, all on the same day in the same area. In 1993, the FHWA requested fog countermeasure study proposals and both Utah and Georgia were awarded grants. Phase I of the Utah system was the installation of 4 fog sensors and 6 traffic recorders, completed in 1995. The VMS's were installed and the system was completed in 1996. Reported problems with the system include VMS malfunction, communication problems, and the lack of traffic count data due to repaving over loop sensors.

A UDOT technical advisory committee designed the system using guidelines recommended in the NTSB report on the 1991 Tennessee accident. There are a few system improvements that UDOT wants to make. One will be using the loop detectors as part of an incident warning system rather than just using them for data collection. They also want a weather and pavement sensor to help aid the system in determining conditions. In addition, they want to update the VMS's, replace the RF communications with fiber optic, and involve the Traffic Operation Center in the system, perhaps to verify conditions and correct VMS message display.

UDOT originally was awarded $400,000 by the FHWA for the study. They have supplemented the project with State Planning and Research (SPR) funds for other aspects of the study. Rockwell International developed and installed the ADVISE Fog Warning System. Since the Rockwell bid was $399,832, most of FHWA's funds were used to develop the initial system. It should be noted that UDOT paid for the installation of the detector loops (the Automatic Traffic Recorders were supplied by Rockwell) and UDOT also supplied the HSS weather sensors (approximately $34,700). Maintenance costs are estimated at $1,000 per month for two VMS signs (this was only during fog season, so it might be less per month for an annual cost) and maintenance costs have been estimated at $1,500 per year for all four HSS weather sensors. Rockwell International had also included a one time $19,914 maintenance fee for entire two-year period following installation.

In addition to the ADVISE project, Utah is also working on a fog dissemination project. This project examined releasing CO_2 gas into the air to disperse fog. This only works on super-cooled fog (below 0 degrees Celsius). Some UDOT trucks have been outfitted with CO_2 dispersal units, but the method has not been tested, as there has been a lack of super-cooled fog in the area over the past few years.

Contact: Sam Sherman (801) 965-4196
Email: ssherman@dot.state.ut.us

Vermont

Vermont has a 2-3 mile segment of interstate that is susceptible to fog and blowing snow. They have a fixed sign with flashing lights warning motorists to reduce speed during fog or snow that is activated by remote dispatch. Normally, snowplow drivers and motorists report conditions back to dispatch.

Contact: David Scott (802) 828-2663

Washington

No countermeasures.

Contact: Rick Molds (360) 705-7988

West Virginia

On US 19, WVDOT has installed fog delineators on a bridge. In addition, preliminary designs have been drawn up for stages for a system on I-64 just west of Charleston on the Kanawha River Bridge at the Nitro interchange. There was an accident in the spring of 2000 involving two fatalities (one child) at this interchange, which sparked interest. They are looking into installing two VMS's and four fog sensors, plus an interface so that a single message can be displayed by the VMS's. Variable speed limits will not be considered. This simple system will be operational sometime during the first half of 2001. WVDOT is estimating the cost in the range of $200,000 and $300,000.

Contact: Ray Lewis (304) 558-8912

Wisconsin

There are two fog-warning systems in the Green Bay area - one system set up on Interstate 43 over the Fox River heading out of Green Bay and the other on USH 41 near Oshkosh over Lake Butte des Morts. The Green Bay Police Department operates the IH 43 system and the local county sheriff's department operates the USH 41 system. Both are similar. They consist of two static signs with attached flashers that are manually activated through a dial-up phone line connection at each location. The local phone company set up the software for a system so the controlling agency can dial up the flashers to activate them or deactivate them. There is also the option to test if the flashers are active so the agency can test to see if they are operating correctly.

The IH 43 system uses a "Watch for Fog" sign. The USH 41 signs read, "Watch for Fog and Blowing Snow." The police in Green Bay and the Sheriff's Department in Winnebago County make subjective assessments and act accordingly (There are no delineators on the side of the road to measure visibility so the decisions are entirely subjective). Winnebago County seems to use a higher threshold for system activation then Green Bay. Also, the Green Bay staff sometimes forgets that the signs are activated, and Wisconsin DOT personnel have had to turn them off. The USH 41 signs have been in place longer than 10 years. The IH 43 signs have been present for about 7 years.

The phone service costs about $20.00 per month per installation for a total of $80.00 per month. The electrical runs about $15.00 per month per installation for a total of about $60.00 per month. Initial installation costs are not available. They were not really tracked. The USH 41 system probably cost around $5000 per location.
However, much of the equipment was on hand for some older purpose and utilized here. The sign cost is about $10.00 per square foot ($1500/sign).

At this time WDOT is not looking at specific upgrades. However, they are looking at ITS applications and might replace the signs with VMSs in the future. There is no timetable for this operation.

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Wyoming

No countermeasures.

Contact: Bruce Burrows (307) 777-4439