Swept Away: Reducing the risk from motorist entering flooded roadways

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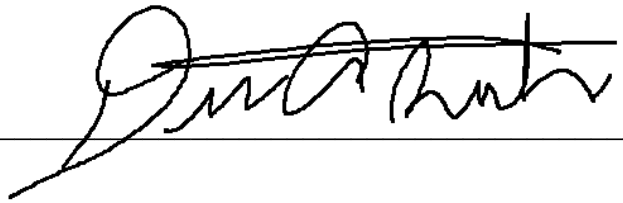
Signed: 

Abstract

The problem was swift water rescue events created by motorists entering flooded roadways during periods of high rain accumulation creates a high risk for citizens and emergency responders in Fairfax County. The purpose of this research was to develop a community risk reduction plan to minimize the risk to citizens and emergency responders created when motorist enter flooded roadways during high rain events in Fairfax County. Action research was used to complete this applied research paper (ARP). The research questions were: (a) What roadways are at high risk of swift water rescues created by motorists entering flooded roadways during high rain events?, (b) What are the elements of a safety education program to prevent motorists from entering flooded roadways?, (c) What engineering improvements are needed to prevent swift water rescues from motorists entering the identified high risk roadways during high rain events?, (d) What policies exist within other state and local agencies to prevent motorists from entering flooded roadways in Fairfax County?, and (e) What is the current knowledge level of Fairfax County Fire and Rescue personnel to safely respond to multiple, simultaneous swift water rescues created by motorists entering flooded roadways? Through literature research, interviews, and knowledge assessments this applied research paper identified Fairfax County's high risk roadway flooding locations, disparity between training standards and the current knowledge of fire department first responders, existing and needed elements of community education, and identified engineering improvements that can improve the safety of motorists and first responders from swift water rescues created by motorists entering flooded roadways. Based on these findings the recommendations were: develop community education, install engineering improvements, improve first responder training, and to enact and enforce legislation to deter motorists from entering flooded roadways.

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Swept Away: Reducing the Risk from Motorist Entering Flooded Roadways

Annually Fairfax County and the Washington DC metro area experience severe weather events resulting in a large amounts of rain in short intervals. These events result in roadway flooding throughout Fairfax County. During these events the Fairfax County Fire and Rescue Department (FRD) experience a large number of swift water rescue emergences created by motorists entering flooded roadways. The problem is swift water rescue events created by motorist entering flooded roadways during periods of high rain accumulation create a high risk for citizens and emergency responders in Fairfax County.

The purpose of this research is to develop a community risk reduction plan to minimize the risk to citizens and emergency responders created when motorist enter flooded roadways during high rain events in Fairfax County. Action research will be used to complete this applied research paper (ARP). The research questions are: (a) What roadways are at high risk of swift water rescues created by motorists entering flooded roadways during high rain events?, (b) What are the elements of a safety education program to prevent motorists from entering flooded roadways?, (c) What engineering improvements are needed to prevent swift water rescues from motorists entering the identified high risk roadways during high rain events?, (d) What policies exist within other state and local agencies to prevent motorists from entering flooded roadways in Fairfax County?, and (e) What is the current knowledge level of Fairfax County Fire and Rescue personnel to safely respond to multiple, simultaneous swift water rescues created by motorists entering flooded roadways?

Background and Significance

Fairfax County is a 391 square mile county located in northern Virginia, immediately southwest of Washington, DC. The FRD was established in 1949 to meet the increasing emergency service needs of the rapidly growing county. Today the department provides fire suppression, technical rescue, swift water rescue, hazardous materials management, emergency medical services, and other all hazard emergency services to the over 1,137,500 residents of Fairfax County (U.S. Census Bureau, 2015). Through established mutual and automatic aid agreements the FRD also routinely responds to provide emergency services to an additional three million residents of six adjacent jurisdictions (U.S. Census Bureau, 2015).

To provide these services the FRD is staffed by nearly 1,400 full-time, uniformed paid staff, 355 operational volunteers, and 180 civilian support staff. All uniformed paid staff are trained firefighters and at minimum, Emergency Medical Technicians - Basic Life Support (BLS). The department's operations bureau operates with 38 fire stations. Each fire station staffs a minimum of one Advanced Life Support (ALS) ambulance and one ALS engine company. Strategically dispersed across the 38 station are also 14 areal units, 8 heavy rescue squads, and 2 hazardous material units. The 8 heavy rescue squads all perform standard fire ground and vehicle extrication duties, however, they are divided in half based on their special service. Each is staffed and equipped to perform their assigned special service, either hazardous material (HazMat) response or technical rescue.

In Fairfax County, all operational personnel in the department are trained at the basic swift water awareness level. However, swift water rescue emergencies fall under the purview of the technical rescue operations team (TROT). Fairfax County does not recognize the level I, or

operations level rescuer as defined by NFPA 1006. All members of the TROT team are trained to the level II swift water rescuer level, also known as swift water rescue technician, as defined by NFPA 1006 (National Fire Protection Association, 2000, p. 35). At the time of this paper, only 150 of the 1365 operational staff are qualified members of the TROT program.

Operationally, TROT resources are placed strategically across the county for optimal response based on access and special hazards (Appendix A). TROT resources staff heavy rescue squads and are part of the engine company staffing at five fire stations, one of which supports the National Park Service's Great Falls Park which is located in their primary response area. These five stations make up the department's swift water rescue resources. These stations have swift water rescue boats and equipment available for the TROT personnel staffed on the engines or heavy rescue squads. The swift water boats are not independently staffed unless deemed necessary by the Operations Bureau.

Within Fairfax County is the City of Fairfax, an incorporated city occupying 6.2 square miles in the heart of Fairfax County, operating a two station fire department (U.S. Census Bureau, 2015). While organizationally separate, Fairfax City Fire Department operates on the same dispatch system and 911 call center as Fairfax County. Similar to Fairfax County, the city staffs a rescue engine and unstaffed swift water resources.

The operational dispatch for a swift water rescue event in Fairfax County is an engine (4 personnel), an aerial (4 personnel), a TROT heavy rescue (4 swift water technicians), two swift water boats (either with the rescue already assigned or another unit with TROT personnel), two ALS ambulances, an EMS supervisor, a battalion chief, and a safety officer. This standard dispatch brings at minimum 17 personnel, four of which are qualified as swift water technicians.

This dispatch model is designed to provide all the roles necessary to operate a uncomplicated swift water rescue event. Once on scene, the incident commander has the ability to expand the event as required by the scene dynamics. This strategy works well on a single, isolated swift water incident.

Fairfax County and surrounding jurisdictions in the Washington, DC region receive periods of high rain accumulation that result in significant roadway flooding. In 2010, the FRD with the assistance of Fairfax County Police and the Department of Public Safety Communications compiled a list of 60 roadway locations that routinely flood during these high rain events (Appendix B). During such episodes, the FRD and most of the region, quickly become inundated with weather related events such as downed electrical wires, fallen trees, motor vehicle accidents, and fire alarms. With the added element of roadway flooding a large number of 911 calls come in for swift water rescues as a result of motorists entering flooded roadways.

Appendix C shows the timeline of swift water rescue incidents during a sample rain event. With a high number of working incidents and multiple swift water rescues it becomes difficult or impossible to provide a timely response of the prescribed basic swift water rescue assignment (Appendix C). This places company level officers in a position to make the rescue decision to either delay rescues and thus increase the danger to the public or to enter the water with no technical training and minimal on scene support, endangering themselves and their crews. The risk then exists to both the victim(s) in their vehicle(s) and to the rescuers, as half of all flood-related deaths occur from a motorist entering a flooded roadway (National Weather Service, n.d.). This number is seconded only by deaths from people who are walking into or near flood waters, such as rescuers (National Weather Service, n.d.).

This applied research project (ARP) is designed to meet the goals of both the U.S. Fire Administration (USFA) and the Executive Analysis of Community Risk Reduction (EACRR) course. This ARP will achieve the USFA goal to reduce risk at the local level through prevention and mitigation as well as improve local planning and preparedness (Federal Emergency Management Agency, 2015, p. IX). This ARP also achieves the EACRR course goals of focusing on risk reduction in the local community and reducing line-of-duty deaths (LODDs) among firefighters (Federal Emergency Management Agency, 2015, p. IX).

Literature Review

Roadway Flooding Safety

In the United States the principle authority on flooding on and off the roadway is the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS). The NSW's mission is to protect life and property from weather related events (NOAA, n.d.). 2014 national statistics reveal that over the last ten years, the United States averages 71 fatalities from flooding annually (Appendix E). Of these, over half of all flood related deaths are the result of motorists driving their vehicle into the flood waters (NWS, n.d.).

In the early 2000's members of the NWS and local firefighters came together out of concern for public safety, to develop strong public safety initiatives to curtail this threat. Out of design to find a catchy slogan easily remembered by the public, the group developed "Turn Around, Don't Drown" (Weather Ready Nation, 2014). In 2014, this public safety slogan turned 10 years old, requiring the trademark to be renewed. During the assessment phase of the trademark process it was shown that this slogan was being used nationally in all forms from signage, literature, media and the like (Weather Ready Nation, 2014). Some states and

communities have even embraced the flood safety awareness concept and declared a Flood Safety Awareness Week, commonly during the middle of March (WNEM, 2015).

In addition to public safety education and messaging, the Federal Highway Administration publishes a series of case studies to guide communities entitled *Best Practices for Road Weather Management* (2012). While the bulk of the document discusses topics not relevant to this applied research paper, one case study discusses routine roadway flooding from overflowing streams or culverts near roadways. The Texas Department of Transportation (DOT) utilizes a High Water Detection System (HWDS) in stream beds where roads and streams cross (Federal Highway Administration, 2012). This system uses either a standpipe or other such detection device to be mounted on the base of the bridge or in a culvert. The device detects the rising water level and triggers a signal to a nearby receiver that has the ability to activate a flashing warning sign and send a notification to local working crews to barricade the road. This communication is done with cellular technology (Federal Highway Administration, 2012). Similar technology has been researched for applications in notifying local drivers for early detour planning to avoid traffic congestion (Hashim, Hamdan, Zakaria, Hamzah & Salleh, 2013).

First Responder Safety

The National Fire Protection Association (NFPA) is a global, nonprofit, technical and educational association whose mission is to protect life and property from fire and other hazards through the development of standards and public education (NFPA, 2015). Fairfax County Fire and Rescue and many other fire departments use the NFPA's standards as the gold standard and best practices for the fire service. In a review of NFPA standards pertaining to fire department

operations during swift water rescues during flooding two standards were found to have the most pertinence: NFPA 1006 and NFPA 1670.

NFPA 1006: Standard for Rescue Technician Professional Qualifications (2013) is the standard for the minimum job performance requirements for the fire service and other emergency response personnel for technical rescue operations (p.6). This standard outlines the specific requirements for the level I and level II rescuer. The level I rescuer is trained to identify hazards, use equipment, and apply limited techniques (NFPA, 2013, p.14). The level II rescuer is also trained to identify hazards and use equipment, but in addition, is responsible to apply advanced techniques as outlined in the specific hazard section of the standard (NFPA, 2013, p.14). Within Fairfax County the FRD only recognizes level II for technical rescue operations. The majority of operational personnel in the FRD, over 1300 personnel, only possess awareness level training and fall below level I and level II.

NFPA 1670: Standard on Operations and Training for Technical Search and Rescue Incidents is the second NFPA standard identified as applicable to first responders responding to swift water and/or flood water rescue. This standard identifies the requirement that all personnel who are part of an organization responding to a technical search and rescue operation, such as swift water or flood water rescues, shall be minimally trained at the awareness level (NFPA, 2014, p.12). NFPA 1670 (2014) also requires that the organization perform an annual evaluation of performance and internal training programs based on the standards outlined for the awareness level (p.13). Personnel at the awareness level of swift water rescue are required to have the knowledge, skills and ability to implement the following procedures:

1. Recognizing the need for water search and rescue;
2. Implementing the assessment phase;

3. Identifying the resources necessary to conduct safe and effective water operations;
4. Implementing the emergency response system for water incidents;
5. Implementing site control and scene management;
6. Recognizing general hazards associated with water incidents and the procedures necessary to mitigate these hazards within the general search and rescue area (NFPA, 2014, p18).

Procedures

In order to answer research question (a) - what roadways are at high risk for swift water rescue events created by motorists entering flooded roadways during high rain events? - geospatial analysis of previous swift water rescues in Fairfax County was conducted. All incident report data for swift water rescues, designated as RSWIFT in the FRD's incident reporting system, for a five year period (November 1, 2011 – November 1, 2015) was extracted. The specific data elements for incident number, incident location, time of call initiation, time of first unit on scene, time of first TROT unit on scene, time full initial assignment arrived on scene, number of units assigned in initial response, and time the incident was closed, and unit incident narrative were used for analysis.

No specific incident report question identified the number of victims that were rescued during an event. To determine if a rescue occurred and the number of victims removed from the water a manual review of each incident report was conducted. After identifying specific incidents with swift water recues a list of both common locations of rescues and responses was compiled to glean a list of which roadways routinely flood and result in an emergency response for a reported swift water rescue.

To answer research question (b) - what are the elements of a safety education program to prevent motorists from entering flooded roadways?- a search of existing public safety programs in other communities, at the state, and at the federal level was conducted. To conduct the research multiple electronic tools were utilized: ProQuest Research Library, Google, Yahoo, Bing, and the U.S. Fire Administration's National Emergency Training Center Library. Keyword search included but not limited to: Roadway flooding safety, flooding safety programs, and motorist safety flooding.

To answer research question (c) - what engineering improvements are needed to prevent swift water rescues from motorists entering the identified high risk roadways during high rain events?- research was conducted to identify existing engineering improvements to prevent roadway flooding or prevent motorists from entering flooded roadways. Each of the identified roadways in research question (a) for being at high risk for flooding and resulting in a swift water rescue emergency was analyzed for what engineering improvements could benefit each individual roadway. To conduct the research multiple electronic tools were utilized: ProQuest Research Library, Google, Yahoo, Bing, and the U.S. Fire Administration's National Emergency Training Center Library. Keyword search included but not limited to: Roadway flooding safety devices, roadway flooding safety programs, and motorist safety flooding systems.

Research question (d) -what policies exist within other state and local agencies to prevent motorists from entering flooded roadways in Fairfax County?- was answered by conducting both internet research and conducting interviews with other agencies to identify what if any programs already existed for education, engineering improvements, enforcement, or economic initiatives to prevent roadway flooding or motorists from entering flooded roadways in Fairfax County.

The final research question (e) -what is the current knowledge level of Fairfax County Fire and Rescue personnel to safely respond to multiple simultaneous swift water rescues created by motorists entering flooded roadways?- was answered by developing a knowledge assessment test based on NFPA 1670's standard for swift water awareness as identified in section 9.2.3 (Appendix G). The test was administered using Surveymonkey.com and the solicitation (Appendix F) to take the assessment was disseminated via Fairfax County's internal email system. The Surveymonkey.com site was utilized to ensure the anonymity of the human subjects participating in the assessment. Any utilization of departmental online/distance education systems or written assessments would risk connecting the participant with their assessment results.

Results

After reviewing incident reports in order to answer research question (a) - what roadways are at high risk of swift water rescues created by motorists entering flooded roadways during high rain events? 145 incidents were identified to meet the criteria. Five of these incidents were excluded due to their location in Fairfax City, and not under the jurisdiction of Fairfax County. Of the 140 remaining incidents there were 93 unique locations. Ten locations were identified as locations with multiple responses, each were locations where live rescues also occurred within the review period of incident reports. The identified locations are:

- Lawyers Rd/ Hunter Mill Rd (13 incidents with 10 total rescues)
- Prosperity Ave/Arlington Blvd (9 incidents with 9 total rescues)
- Richmond Hwy (8 incidents with 11 total rescues)
- Spicewood Rd/Woodburn Rd (5 incidents with 7 total rescues)

- Fox Mill Road (4 incidents with 8 total rescues)
- Brown Mill Road (4 incidents with 3 total rescues)
- Cinder Bed Road (4 incidents with 13 total rescues)
- Besley Rd/Old Courthouse Rd (4 incidents with 5 total rescues)
- Miller Rd/Windsong Dr (3 incidents with one total rescue)
- Walney Rd (3 incidents with 5 total rescues)

To answer research question (b) - what are the elements of a safety education program to prevent motorists from entering flooded roadways?- a search of existing public safety programs in other communities, at the state, and at the federal level was conducted. After extensive research the primary community messaging is to deter motorists from entering flooded roadways. The most common theme identified is the use of the NWS's "Turn Around, Don't Drown" (US Fed News Service, 2013; WNEM, 2015; Weather Ready Nation, 2014). The NWS's public safety education program not only carries the message but tries to dispel common misinformation. One such educational point is that regardless of a vehicles weight, the physical force of buoyancy can cause any vehicle to loose traction and get swept away (Appendix D) (National Weather Service, n.d.).

To answer research question (c) - what engineering improvements are needed to prevent swift water rescues from motorists entering the identified high risk roadways during high rain events?- research was conducted to identify existing engineering improvements to prevent roadway flooding or prevent motorists from entering flooded roadways. After extensive research, the principle engineering methods identified are either early warning systems or barriers. As discussed in the literature the use of water detection technology to activate local warning signs is considered best practice by the Federal Highway Administration (2012). Most

applications of these devices require a detector in the water. However, The Traffic & Parking Control Company (TAPCO) recently received the American Traffic Safety Service Association innovation award for designing a complete system that not only uses an improved in-water detector with fiber optic technology, but also an elevated ultrasonic water sensor that is ideal for roadways without an immediately adjacent culvert or stream (TAPCO, 2015). TAPCO's system is solar powered and is equipped to send web based alerting via email or SMS (TAPCO, 2015).

While no specific examples were found of use in roadway flooding, gates have been used in other roadway hazard scenarios. In Wisconsin, the State Patrol and the Department of Transportation have installed collapsible gates that can be deployed to shut down roadways during severe weather, such as a snow storm (Heine, 2008). Tennessee also utilizes gate systems with inclement weather. The Tennessee DOT Low Visibility Warning System is a multi-tiered system used to improve roadway safety during the states characteristically low visibility fog events. The applicable portion of the system is the utilization of electronically controlled swing arm gates to remotely close down interstate onramps during low visibility events (Federal Highway Administration, 2012).

Other technology options identify flood water restricting or barrier systems. In 2012 the University of Kentucky performed an extensive evaluative study of temporary flood water barrier technology. Their final report identified six temporary flood barriers and projected time and cost of deployment. Of these six all take extensive time to deploy and thus require hours, if not days, of early warning to properly deploy (University of Kentucky, 2012). One of the options with the most rapid deployment is the Continuous Sand-Filled Tubes. This system is to replace the use of individually filled sandbags and utilized 1,000 foot long woven polypropylene tubes with sand. The cost of the tubes and the sand is inexpensive. However, the system

requires the use of a proprietary vehicle, the CAS Off-Road Environmental Series Track Machine, to fill and lay the bags at the site of the flooding (University of Kentucky, 2012). These machines have an estimated cost of $428,000 per unit (University of Kentucky, 2012).

Investigation for research question (d) -what policies exist within other state and local agencies to prevent motorists from entering flooded roadways in Fairfax County?- revealed five primary agencies or departments at the state or local level with a direct impact to motorists entering flooded roadways in Fairfax County:

The Virginia Department of Transportation (VDOT) has the primary responsibility of maintaining all state owned roadways throughout the Commonwealth of Virginia and thus Fairfax County. VDOT only has the responsibility to maintain the state owned roadway and not flood plains or other causes of flooding that impact the roadway. In a multiagency strategic planning meeting on roadway flooding in Fairfax County, VDOT identified 95 state maintained roadways within the county that were identified as being prone to flood (I. Gregoire, Personal Communication, November 24, 2015). For the purposes of this ARP the individual location's VDOT site ID number, location, identified problem, VDOT's proposed solution, and whether or not VDOT held the location as a high priority location where extracted from VDOT's data table on the identified 95 locations (Appendix H).

Fairfax County Department of Public Works and Environmental Services' (DPWES) Stormwater Planning Division is responsible for the management of stormwater runoff in Fairfax County. Stormwater runoff is the excess water from with weather events such as rain or melting snow that is unable to be absorbed into the ground. This excess water is harmful to the environment through ground erosion and pollution and causes damage to personal property and

poses a risk the health and safety (Fairfax County DPWES, 2015). DPWES primarily manages the water drainage systems throughout the county. Within the last year, DPWES has started a project to evaluate the use of water detection signage similar to those described in the technology section of research question (c). Currently DPWES has two in place and are evaluating cost benefit to Fairfax County (D. Lacquement, Personal Communication, November 20, 2015).

The Fairfax County Police Department (FCPD) has no role in the prevention of flooding. Under the current Fairfax County common operating procedures, the FCPD is the only public safety agency that can shut down roadways prior to a hazardous condition being present. The FCPD has no formal policy requiring the routine proactive restriction of roadways prior to flooding. Roadway closings are managed at the individual station level and are typically performed after an officer determines a flood hazard is present (I. Gregoire, Personal Communication, November 24, 2015).

The Fairfax County Office of Emergency Management (OEM) is the local agency responsible for emergency mitigation, preparedness, response and recovery in Fairfax County. OEM's function in preventing motorists from entering flooded roadways is primarily community outreach or public education. The majority of OEM's flooding responsibility is to provide services to whole communities who are prone to flooding, such as Fairfax County's Huntington and Belleview neighborhoods. On a routine basis OEM provides public education for preparation of major events such as flooding. To prepare for roadway flooding OEM provides a list compiled in 2010 of the most common locations of roadway flooding in Fairfax County (Appendix B). During the thunderstorm season OEM also partners with the Office of Public Affairs to put out to a public safety message designed around the NWS' Turn Around, Don't Drown campaign (P. Lupe, Personal Communication, November 23, 2015). During an

emergency OEM also manages the Fairfax Alerts system that sends out emergency messaging to the public via phone, text, and email.

Fairfax County Department of Transportation (FDOT) is the local level agency, similar to VDOT at the state level, responsible for maintaining roadways in Fairfax County that are not maintained by the state or other private party. Within the county, most primary and secondary roads are the responsibility of VDOT. Many communities within Fairfax County and their roadways are maintained by their own community or homeowner's association. Very few roads are the responsibility of FDOT and other than basic maintenance, there is no formal program to prevent motorists from entering flooded roadways.

The final research question (e) -what is the current knowledge level of Fairfax County Fire and Rescue personnel to safely respond to multiple simultaneous swift water rescues created by motorists entering flooded roadways?- was answered by administering a knowledge assessment based on the NFPA standards for swift water awareness. After keeping the survey active for one week 198 personnel submitted responses (Appendix I). Of the respondents 72.2% (n=143) were at the non-officer rank of Master Technician or below, 27.8% (n=55) were unit officers at the rank of Lieutenant to Captain II, and no respondents were at the Battalion Chief level or higher. Additionally, 88.9% (n=176) of the respondents are trained at the awareness level and 11.1% (n=22) are swift water technicians in Fairfax County.

The results of the survey found that 84.8% (n=168) of the respondents properly identified the initial actions of the first arriving unit on the scene of a victim in fast moving flood waters. Survey question two revealed 71.2% (n=141) of respondents do not know the typical mental state of victims. This directly ties into the crew's ability to assess and plan for rescue operations.

Survey question three shows that 93% of respondents do not know the minimum number of personnel required to perform a swift water rescue as prescribed in the regional operations manual. Further analysis shows that 100% (n=55) of the company officers did not answer this question correctly, all underestimating the number of personnel required.

Question four identified two essential safety and operational elements. First, 53.6% (n=106) of respondents do not know that department policy requires any rescuers operating from a ladder above swift or flood waters are required to be a swift water technician. Second, 45% (n=89) of respondents did not know that tying a rope to a rescuer in a swift water rescue operation is a significant safety hazard and is outlined as being prohibited in both department policy and training material. However, 94.4% (n=187) of respondents were able to correctly answer the correct location of establishing the hot zone for hazard isolation in question five. 83.3% (n=165) of respondents also knew the correct initial action to perform if they, themselves, fell into the swift water as identified in question six.

Question seven was the final knowledge assessment question in the survey. The question assessed the respondent knowledge of what factors are a factor when assessing a victim's viability. This ability directly correlates to a rescuers ability to make the critical risk-benefit decision on whether or not to endanger themselves and crew to effect a rescue. 56.6% (n=112) of respondents did not correctly identify the factors relevant to evaluating a victim's viability. The distractor added to this question was designed to have an emotional connection. Each of the incorrect respondent identified that patient's age as a factor for consideration on whether the victim was viable for a rescue attempt.

The final question in the survey asked the respondent when their most recent swift water awareness training was completed. This question was to evaluate the respondents against the NFPA 1670 (2014) requirement that annual performance assessment be completed to ensure all personnel meet the minimum awareness level for all technical search and rescue incidents the jurisdiction may encounter (p. 12). 79.3% (n=157) of the respondents indicated it has been over a year since they had received any awareness level training. 34.9% (n=69) of the respondents indicated their last training was over three years ago. Only 20.7% (n=41) of respondents indicated they had received swift water awareness training within the last year.

Discussion

The risks created from motorists entering flooded roadways is apparent with this hazard being responsible for half of all flooding related deaths each year (NWS, n.d.). Fairfax County has equally recognized this hazard and the risk it presents to its residents and guests. In previous years the locations of routine roadway flooding has been identified and made public in an effort to reduce the risk by increasing public awareness (Appendix B). Despite this attempt, seven of the ten locations for multiple annual rescues are also locations that have been previously identified by Fairfax County as locations of routine roadway flooding. This method of influencing motorists has not deterred the public from entering these known flood hazard locations.

Fairfax County OEM and the Office of Public Affairs partner to operate an annual public safety education program to prevent motorist from entering flooded roadways. The program operated is the NWS's Turn Around, Don't Drown campaign, which has been the national gold standard for over a decade (Weather Ready Nation, 2014). This program is conducted during the

Virginia thunderstorm season and is primarily presented with local media and county social media. These platforms are narrow in audience as they only capture those individuals subscribed for county government information or who are attentive to local news. As a result, there is no true metric to ensure the target audience, those motorists that uses the identified roadways, receive the public education messaging.

The current body of knowledge prescribes signage on roadways near the site of routine flooding to warm motorists of the potential danger (Federal Highway Administration, 2012). However, permanent roadside signage can lose its effect as time passes and motorists stop reading the sign. To contend with this affect, engineers have designed emergency warning flashing lights affixed to signage that activates when the water is detected to have risen beyond an established level (TAPCO, 2015). The added effect of the lights would bring acute attention to the sign. Fairfax County DPWES has recognized the utility of these new advanced warning signs and have started the process of installing them at a number of locations (D. Lacquement, Personal Communication, November 20, 2015). DPWES currently has no plan to investigate the more advanced detectors with integrated cellular technology to send notification of a signs activation (D. Lacquement, Personal Communication, November 20, 2015). This addition has a utility and has the potential application of creating an automatic trigger for the counties existing notification system, Fairfax Alerts.

There are also currently no locations utilizing any gate systems. Currently roadway closings are conducted by the police department and are completed by trailer based cones or small wooden barriers (I. Gregoire, Personal Communication, November 24, 2015). The benefit of using permanently installed gate should be evaluated. The Wisconsin model would allow the roads to be closed faster as the gates is already installed at the location of deployment (Heine,

2008). The only requirement is that a person must respond to the location to physically deploy the gate. The benefit of the Tennessee DOT Low Visibility Warning System design is the ability to remotely deploy the gate (Federal Highway Administration, 2012).

This ARP also evaluated the potential utilization of flood water barriers. A recent report from the University of Kentucky (2012) gave an in-depth look into the functionality and practicality of these as a resource. As discussed in the results suction, these options take extensive time and resources to implement. The roadway flooding in Fairfax County caused by thunderstorm rain is relatively short in duration, lasting only a few hours. The flooding is also primarily contained to streams and roadside culverts that overflow onto roadways. The flood water barrier systems are a more practical solution for large flood waters, such as a river, and protecting or redirecting the flood waters.

The primary identified long term solution in all of the identified location are roadway improvements. Most of the problem locations are identified on VDOT's list of frequent flood locations (Appendix H). Each of these locations have been identified as needing maintenance or significant improvements to meet the water volume experienced during large thunderstorms. This maintenance falls not only under VDOT or FDOT, based on road ownership, but also Fairfax County DPWES (I. Gregoire, Personal Communication, November 24, 2015; D. Lacquement, Personal Communication, November 20, 2015). Once the stormwater runoff leaves the roadway it will enter the stormwater management system. While not yet identified as a problem, it is essential to ensure this network is maintained and meets the capacity needs once roadway improvements have been made.

The final consideration is that even with modern infrastructure and safety improvements as well as the use of well established safety programs, the potential for swift water rescues from motorists entering flooded roadways will still exist. As the risk can never be entirely removed it is essential that the operational members of the FRD maintain an appropriate level of training to safely mitigate these incidents. NFPA 1006 (2000) and NFPA 1670 (2014) have outlines the industry standard for the training and knowledge requirements for swift water and flood water technical operations. The standard holds that all operational personnel should be trained to the awareness level for technical operations the organization could respond to. The results of the survey based on the NFPA awareness level reveal significant discrepancies in the level of knowledge of the operational staff. The NFPA requirement also requires an annual assessment of the department's preparedness to respond to these emergencies safely (NFPA, 2014, p. 12). The survey revealed that the majority of operational personnel have done no training on swift water operations in over a year. This undoubtedly is a contributing factor to the lack of knowledge reflected the knowledge assessment (Appendix I).

Recommendation

The purpose of this research was to develop a community risk reduction plan to minimize the risk to citizens and emergency responders created when motorists enter flooded roadways during high rain events in Fairfax County. With over half of all flood related deaths being created from motorists entering flooded roadways, the risk is obvious (NWS, n.d.). To reduce this risk, recommendations were drafted based on this ARP's research to target each of the five risk-reduction strategies identified as the five E's: Education, Engineering, Enforcement, Economic Incentives, and Emergency Response (Federal Emergency Management Agency, 2015, p. SM 3-43). For application the recommendations of this ARP have also been formatted

into an implementation and evaluation plan (Appendix J). Based on this research the following recommendations were derived:

1. The FRD should develop and deliver a social media campaign to raise awareness of motorist on roadway flooding safety. This campaign should target the residents and guests of Fairfax County and should be conducted in coordination with other agencies with similar public education programs identified in this ARP. This campaign should be given immediately prior to and into the flood season.
2. The FRD, with the cooperation of other stakeholders, should install safety signs at all roadways identified as high risk locations of roadway flooding. The signs should have the modern improvement of emergency lighting signals that activate automatically with water rise meters.
3. The FRD, with the cooperation of other stakeholders, should install flood safety gates at all roadways identified as high risk locations of roadway flooding. The signs should activate automatically with water rise meters and send notification to the local EOC of their activation.
4. The FRD should target homes and businesses within a half a mile of the roadways identified as high risk locations of roadway flooding and deliver a seasonal Safety in Our Community (SIOC) education on motorist roadway flooding safety (Appendix K).
5. The FRD should develop and deliver an annual training program for swift water awareness training based on the NFPA standards to all operational staff.
6. The FRD should develop a training program based on NFPA standards, departmental policies and regional operational manuals to improve officer risk-benefit analysis and decision making on technical operations incidents.

7. The FRD should push for local legislation that prohibits motorists from bypassing flood safety gates and work with the Fairfax County Police Department and the county prosecutor's office to ensure the law is enforced.
8. The FRD should push for local legislation the holds motorist who enter flooded roadways criminally and financially liable for rescue operations to rescue themselves and occupants of their vehicle.
9. The FRD should work with VDOT to ensure each of the roadways identified as high risk locations of roadway flooding are on their list as high priority for engineering improvement to prevent the cause of roadway flooding at each location.

References

Fairfax County DPWES. (2015). What is stormwater management?. Retrieved from http://www.fairfaxcounty.gov/dpwes/stormwater/whatis_swm.htm

Fairfax County Fire and Rescue. (n.d.). Swift water rescue training guidebook. Fairfax, VA: County Printing Office.

Fairfax County Fire and Rescue. (2013). Communications Manual. Fairfax, VA: County Printing Office.

Fire Departments of Northern Virginia (2010). NOVA inland water rescue and emergencies. Fairfax, VA: County Printing Office.

Federal Emergency Management Agency. (2015). Executive analysis of community risk reduction: Student manual (FEMA/USFA/NFA Publication No. EACRR-SM). Emmitsburg, MD: National Fire Academy.

Federal Highway Administration. (2012). Best practices for road weather management. Retrieved from http://www.ops.fhwa.dot.gov/publications/fhwahop12046 /fhwahop12046.pdf.

Hashim, N.M.Z., Hamdan, N.B., Zakaria, Z., Hamzah, R.A., Salleh, A. (2013). Flood detector emergency warning system. *International Journal of Engineering and Computer Science, 2(8)*, 2332-2336.

Heine, G. R. (2008). Gates positioned to close highway when needed. Retrieved from http://www.gazettextra.com/news/2008/nov/02/gates-positioned-close-highway-when-needed/

National Fire Protection Association. (2000). NFPA 1006: Standard for rescue technician professional qualifications. *Quincy, MA: NFPA*

National Fire Protection Association. (2014). *NFPA 1670 Standard on Operations and Training for Technical Search and Rescue Incidents*. National Fire Protection Association.

National Fire Protection Association. (2015). About the NFPA. Retrieved from http://www.nfpa.org/about-nfpa.

National Weather Service. (n.d.) Turn around don't drown. Retrieved from http://tadd.weather.gov/

NOAA. (2015). Natural Hazard Statistics. Retrieved from http://www.nws.noaa.gov/om/hazstats.shtml

NOAA. (n.d.). Floods cost lives and billions of dollars in property damage each year around the United States. Retrieved from www.noaanews.noaa.gov/stories2006/s2601.htm

TAPCO. (2015). High water warning system. Retrieved from http://cdn.tapcoapps.com/pdfs/solar/1005-00011-High-Water-Warning-System.pdf.

University of Kentucky. (2012). Temporary flood barriers. Retrieved from http://www.ktc.uky.edu/files/2012/12/KTC_12_14_SPR_448_11_1F-Temporary-Flood-Barrier.pdf.

U.S. Census Bureau. (2015). State & county quickfacts: Fairfax county, Virginia. Retrieved from http://quickfacts.census.gov/qfd/states/51/51059.html.

U.S. Census Bureau. (2015). State & county quickfacts: Fairfax city, Virginia. Retrieved from http://quickfacts.census.gov/qfd/states/51/51600.html.

US Fed News Service. (2013). Charlotte county emergency management offers flooding safety tips. Retrieved from

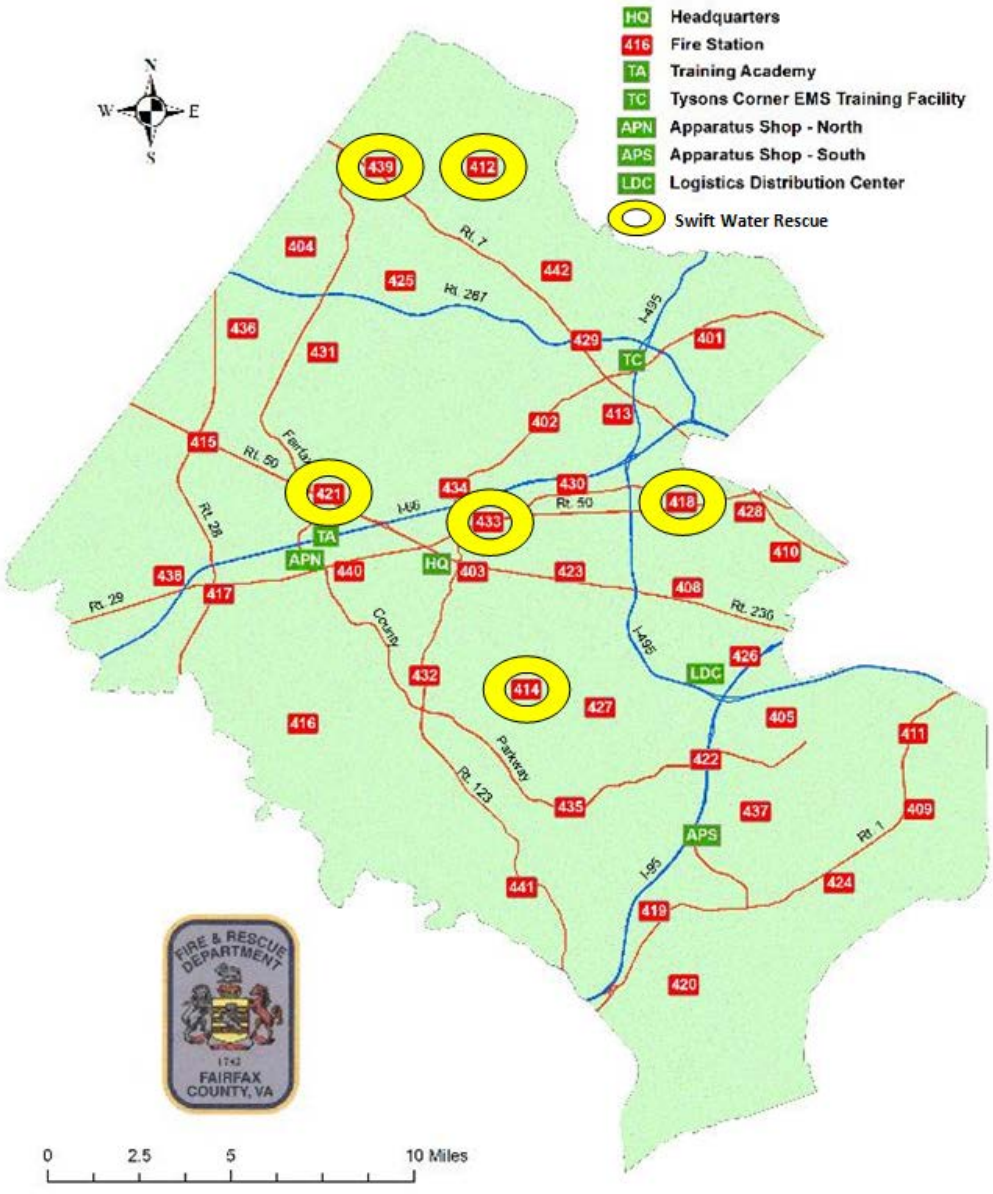
http://proxygwa.wrlc.org/login?url=http://search.proquest.com.proxygwa.wrlc.org/docview/1437089993?accountid=33473.

Weather Ready Nation. (2014). The national “turn around don’t drown” program turns 10 years old in 2014. Retrieved from http://www.nws.noaa.gov/com/weatherreadynation/news/140207_turn.html#.Vng4DKAo6mQ

WNEM. (2015). National flood safety awareness week is March 16-20, 2015. Retrieved from http://www.wnem.com/story/28466724/national-flood-safety-awareness-week-is-march-16-20-2015

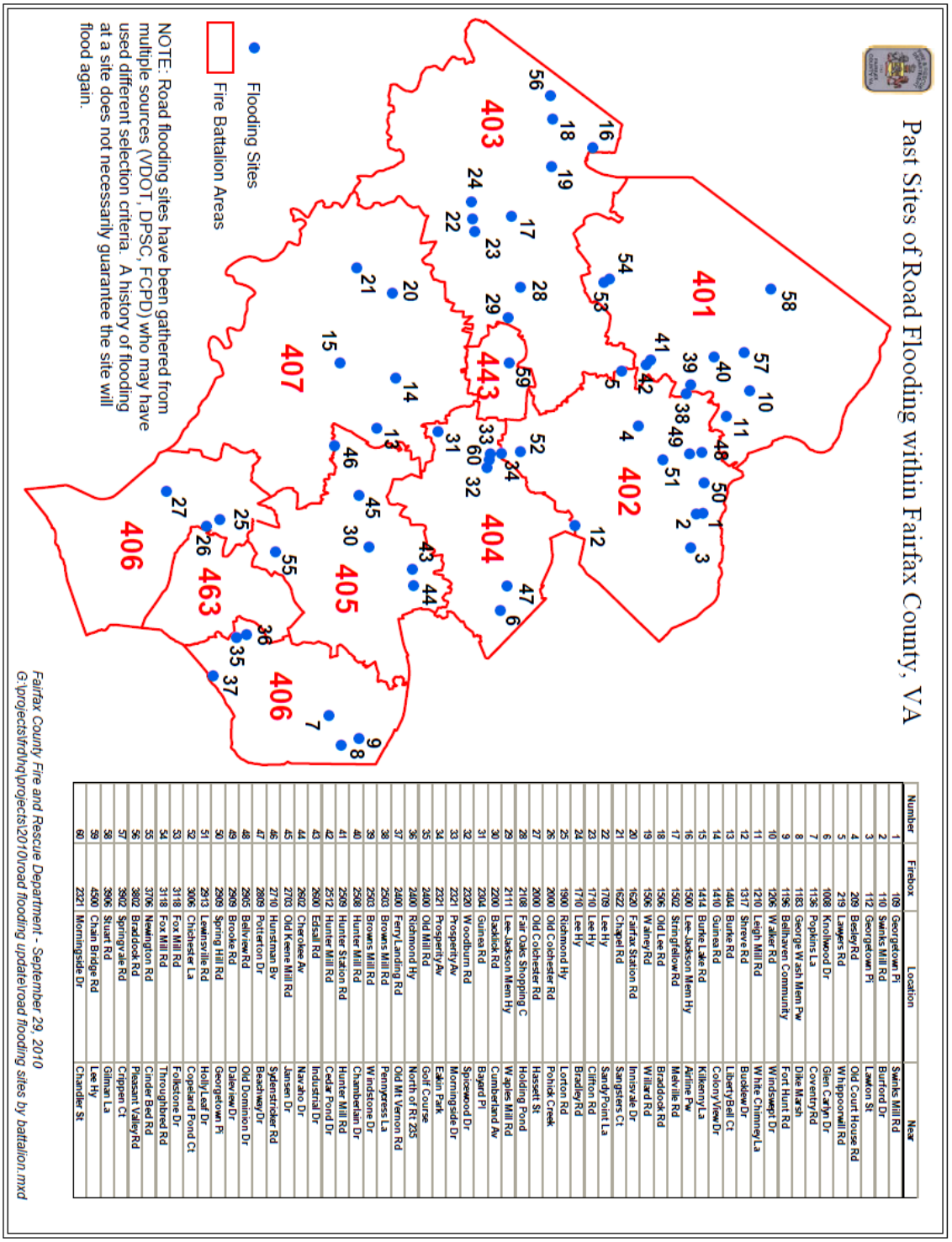
Appendix A

Fairfax County Fire Stations and Swift Water Rescue Map



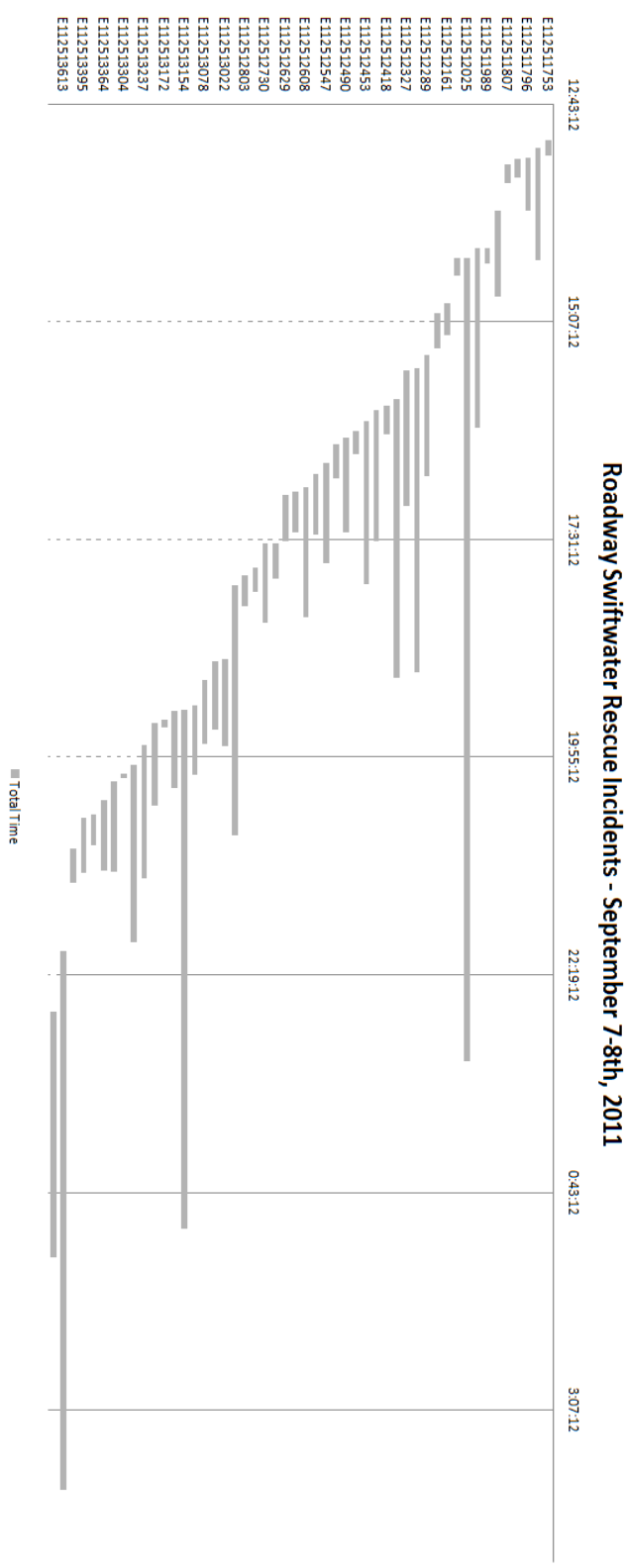
Appendix B

Past Sites of Road Flooding within Fairfax County, VA



Number	Firebox	Location	Near
1	109	Georgetown Pi	Swirks Mill Rd
2	110	Swirks Mill Rd	Burford Dr
3	112	Georgetown Pi	Lawton St
4	209	Besley Rd	Old Court House Rd
5	219	Lawyers Rd	W hippodrill Rd
6	1008	Knollwood Dr	Glen Carlyn Dr
7	1136	Popkins La	Coventry Rd
8	1183	George W ash Mem Pw	Dike Marsh
9	1196	Bellhaven Community	Fort Hunt Rd
10	1206	W alker Rd	W indswept Dr
11	1210	Leigh Mill Rd	W hite Chimney La
12	1317	Shreve Rd	Brookview Dr
13	1404	Burke Rd	LibertyBell Ct
14	1410	Guinea Rd	ColonyView Dr
15	1414	Burke Lake Rd	KilkennyLa
16	1500	Lee-Jackson Mem Hy	Airline Pw
17	1502	StringfellowRd	Malvi lle Rd
18	1506	Old Lee Rd	Braddock Rd
19	1506	W alney Rd	W illiard Rd
20	1520	Fairfax Station Rd	Innisvale Dr
21	1622	Chapel Rd	Sangsters Ct
22	1709	Lee Hy	SandyPoint La
23	1710	Lee Hy	Clifton Rd
24	1710	Lee Hy	BradleyRd
25	1900	Richmond Hy	Lorton Rd
26	2000	Old Colchester Rd	Pohick Creek
27	2000	Old Colchester Rd	Hasset St
28	2108	Fair Oaks Shopping C	Holding Pond
29	2111	Lee-Jackson Mem Hy	W aples Mill Rd
30	2200	Backlick Rd	Cumberland Av
31	2304	Guinea Rd	Bagard Pl
32	2320	W oodburn Rd	Spicewood Dr
33	2321	ProsperityAv	Morningside Dr
34	2321	ProsperityAv	Eakin Park
35	2400	Old Mill Rd	Golf Course
36	2400	Richmond Hy	North of Rt 235
37	2400	FerryLanding Rd	Old Mt Vernon Rd
38	2503	Browns Mill Rd	Pennygress La
39	2503	Browns Mill Rd	W indstone Dr
40	2508	Hunter Mill Rd	Chamberlain Dr
41	2509	Hunter Station Rd	Hunter Mill Rd
42	2512	Hunter Mill Rd	Cedar Pond Dr
43	2600	Edsall Rd	Industrial Dr
44	2602	Cherokee Av	Navaho Dr
45	2703	Old Keene Mill Rd	Jensen Dr
46	2710	Huntsman Bv	Sydenstricker Rd
47	2809	Potterton Dr	BeadlewayDr
48	2905	Ballview Rd	Old Dominion Dr
49	2909	Brooke Rd	Daleview Dr
50	2909	Spring Hill Rd	Georgetown Pi
51	2913	Lewinsville Rd	Holly Leaf Dr
52	3006	Chichester La	Copeland Pond Ct
53	3118	Fox Mill Rd	Folkstone Dr
54	3118	Fox Mill Rd	Throughbred Rd
55	3706	Newington Rd	Cinder Bed Rd
56	3802	Braddock Rd	Pleasant Valley Rd
57	3802	Springvale Rd	Crippen Ct
58	3906	Stuart Rd	Gilman La
59	4500	Chain Bridge Rd	Lee Hy
60	2321	Morningside Dr	Chandler St

Appendix C


Roadway Swiftwater Rescue Incidents - September 7-8th, 2011
E112511753
E112511796
E112511807
E112511989
E112512025
E112512161
E112512289
E112512327
E112512418
E112512453
E112512490
E112512547
E112512608
E112512629
E112512730
E112512803
E112513022
E112513078
E112513154
E112513172
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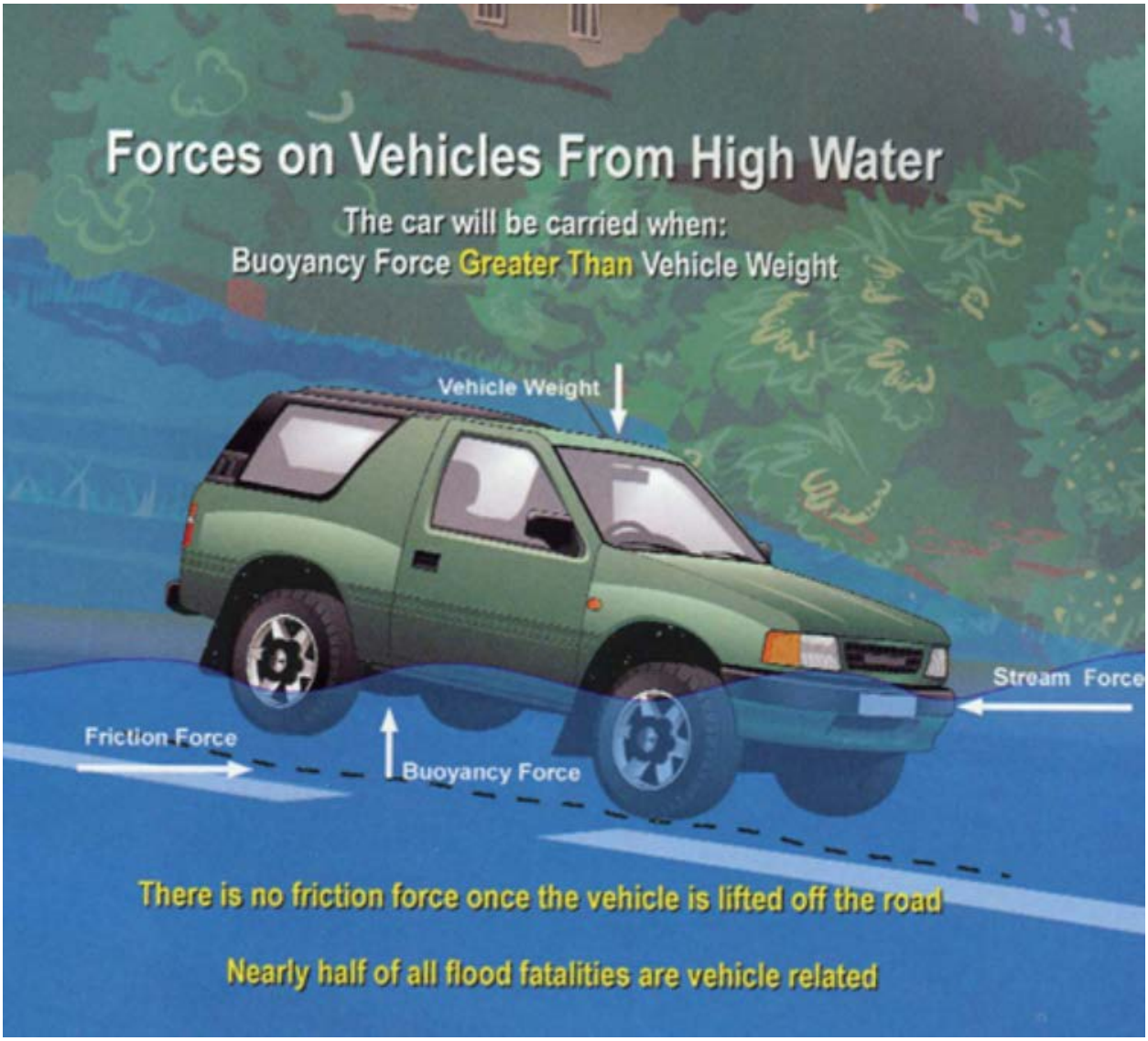
E112513304
E112513364
E112513395
E112513613
12:43:12
15:07:12
17:31:12
19:55:12
22:19:12
0:43:12
3:07:12
TotalTime

Appendix D

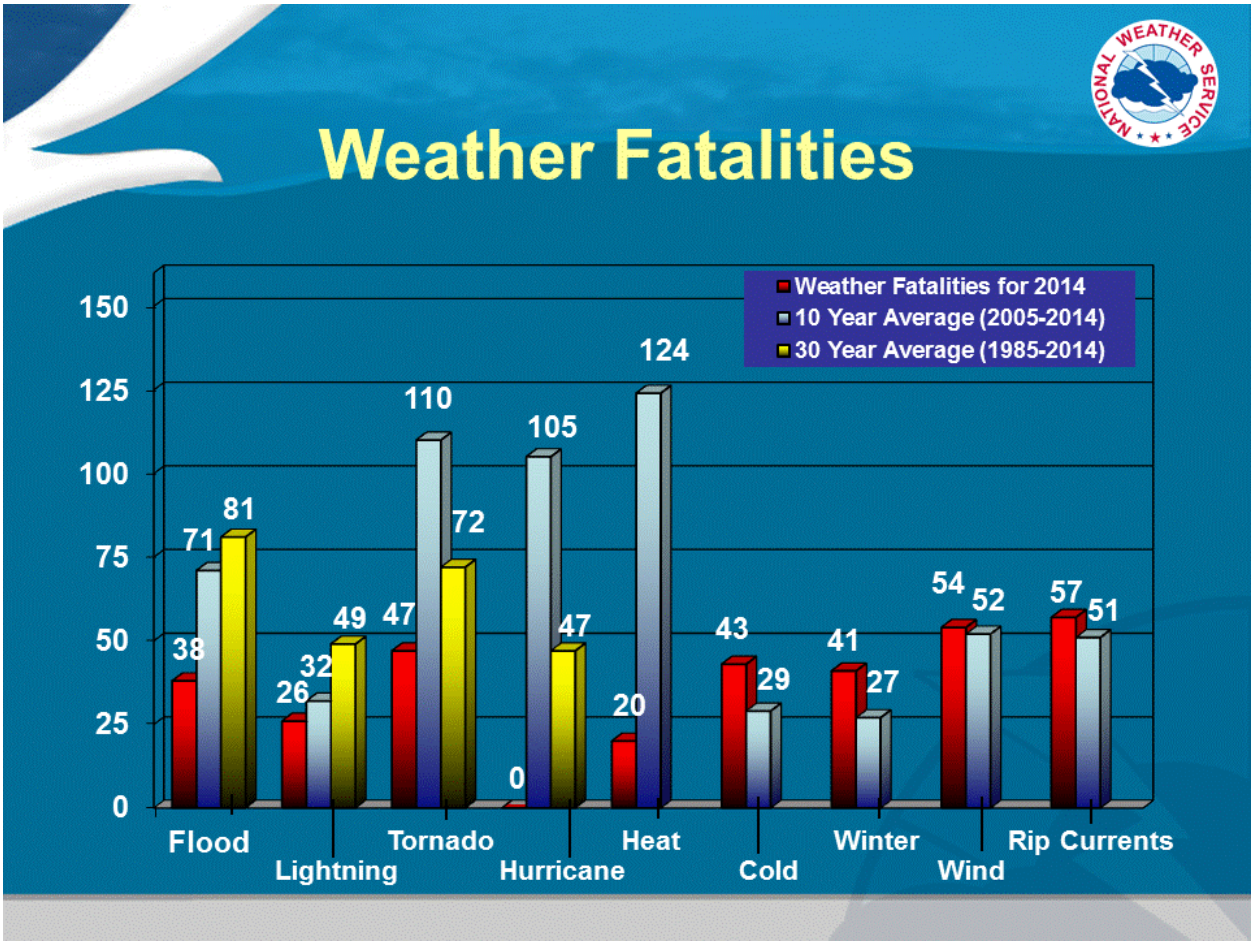
Forces on Vehicles from High Water



(National Weather Service, n.d.)

Appendix E

Weather Fatalities NOAA



(NOAA, 2015)

Appendix F

Solicitation for Internal Survey

I am working on an applied research project with the NFA Executive Fire Officer Program evaluating Fairfax County Fire and Rescue's level of preparedness to respond to multiple swift water rescues due to vehicles entering flooded roadways. The following survey asks questions based on NFPA 1670 awareness level rescuer and are derived from departmental manuals or training material. Please complete the survey independently with no use of knowledge aids or research. This survey is relatively short and should take less than 5 minutes to complete. Thank you in advance for completing the survey.

Survey: https://www.surveymonkey.com/r/3R37WF9

David Winter

Captain

Fairfax County Fire and Rescue

Appendix G

Internal Swift Water Awareness Survey

NFPA 1670 9.2.3	Organizations operating at the awareness level at water search and rescue incidents shall implement procedures for the following:
(1) Recognizing the need for water search and rescue	
The first arriving unit on scene of a victim in fast moving flood waters should take which action(s)? a. Identify the location of the reported victim or witnesses to their last location b. Assess the victim's physical and mental state to self-rescue c. Evaluate if the individual needs rescue d. All the above *Fire and Rescue Departments of Northern Virginia Emergency Operations Manual Volume III- Other Emergencies, Book 8: Inland Water Rescue and Emergencies p. 16	
(2) *Implementing the assessment phase	
Most victims in a swift water rescue will be: a. Confused and panicked b. Able to communicate and assist in self-rescue c. In a condition of counter panic and frozen with fear d. None of the above *Swift Water Rescue Training Guidebook p. 25	
(3) *Identifying the resources necessary to conduct safe and effective water operations	
In general, how many rescuers are needed to safely fill all essential roles and rescue a single victim from moving water during daylight hours? a. 6 b. 12 c. 16 d. 20 *Fire and Rescue Departments of Northern Virginia Emergency Operations Manual Volume III- Other Emergencies, Book 8: Inland Water Rescue and Emergencies p. 19	
(4) *Implementing the emergency response system for water incidents	
All individuals operating above flood water on an aerial ladder should: a. Have a radio	

b. Be a swift water technician

c. Have a rope tied off to their waist

d. All the above

* NOVA inland water rescue and emergencies p. 22

(5) *Implementing site control and scene management

Initial units on scene should establish cold, warm, and hot zones. What is the warm zone considered?

a. 5 feet from shore to 1 foot inside the water

b. Water's edge and out 10 feet

c. Within 25 feet of moving water

d. The first 5 feet of water

*Fire and Rescue Departments of Northern Virginia Emergency Operations Manual Volume III- Other Emergencies, Book 8: Inland Water Rescue and Emergencies p. 16

(6) *Recognizing general hazards associated with water incidents and the procedures necessary to mitigate these hazards within the general search and rescue area

If you happen to fall into moving water what should your first actions be?

a. Immediately try to swim to shore

b. Try to waive your arms high to create a large visible profile

c. Roll onto your back and point your feet downstream

d. Radio a mayday to command

*Fire and Rescue Departments of Northern Virginia Emergency Operations Manual Volume III- Other Emergencies, Book 8: Inland Water Rescue and Emergencies p.42 & Swift water rescue training guide p. 21

(7) Determining rescue versus body recovery

When evaluating a victim's viability all should be considered except?

a. Length of time victim has been submerged

b. Water temperature

c. Age of the victim

d. When the victim was last seen

*Swift water rescue training guide p. 16

(8) What is your current rank?

a. Master Technician or below

b. Lieutenant – Captain II

c. Battalion Chief or above
(9) What is your current level of swift water rescue training in Fairfax County? a. Awareness b. Technician
(10) When was you most recent swift water awareness training (initial or update)? a. Within the last 12 months b. 1-3 years c. 3-5 years d. 5+ years

Appendix H

Virginia Department of Transportation (VDOT) Roadway Flooding Assessment

SiteID	Location	Problem	Proposed Solution	VDOT Priority
DC01	10729 Greene Dr	Blocked twin RCP road culvert. Leaves and debris are blocking inlet.	Maintenance project	
DC02	11054 Stuart Mill Road @ Birdfoot	Flood waters exceed capacity of stream; flood bridge and road. No blockages.		
DC03	11226 Beach Mill Rd			Yes
DC04	11701 Waples Mill Road @ Bronzedale	Flood water exceed culvert capacity	Upgrade culvert	
DC05	1224 Beach Mill Rd	Low lying area; creek cannot handle volume of water	Close to bridge replacement project	Yes
DC06	13101 Lee Hwy @ Stringfellow	Flood waters exceed culvert capacity	Upgrade culvert	
DC07	13135, 45, 55 Compton Road			
DC08	13273 Stone Heather Drive @ Lady Bank	Flood waters exceed culvert capacity. No signs of flooding in the field.	Upgrade culvert	
DC09	1800 Pimmit Dr	Flooding issue during Tropical storm Lee from VDOT structure in street.		
DC10	2512 Pegasus Lane			
DC11	Fox Mill Road @ Lake James, Thoroughbred and Westwood Hills	Flood waters exceed culvert and channel capacity. Evaluate entire channel.	Upgrade culvert – flood plain	
DC12	2791 Fox Mill Rd at Crossfield School	Undersized CMP culvert	Upgrade culvert – flood plain	
DC13	2841 Brook Dr	Project Completed to Install twin 36” RCP culvert		
DC14	3306 Kaywood Place	Undersize pipe in ROW helps create surcharge in rear yard		
DC15	4509 Exeter St	1 complaint of road	Not an ongoing	

		flooding during Tropical storm Lee	problem, will be removed from the list	
DC16	4520 Dolphin Lane			
DC17	4843 Chowan Ave	Wasnot visited – property located in flood zone	Meet with the homeowner to confirm that no action will be taken	
DC18	5211 Kings Park Drive	Conveyance system issue. Ongoing evaluation by MSMD		
DC19	5214 Kings Park Drive	Conveyance system issue. Ongoing evaluation by MSMD		
DC20	5701 Tremont Drive			
DC21	6496 Windham Ave	Sediment deposition in roadside ditch and roadside culvert prevents positive flow to grate inlet causing flooding in the roadway	Maintenance will resolve	
DC22	6600 Rutledge Dr			
DC23	7135 Tyler Ave	One undersized drop inlet for a distance of approximately 900 linear feet, unable to handle sheet flow in heavy rain events	More inlets to capture water	
DC24	7421 Belmont Landing			
DC25	7555 Park Lane	Erosion problem, not on state ROW – 60 ft to the problem	Problem determined to be a private issue and was communicated to property owner	
DC26	7716 Lee Hwy	Box culvert installed to solve flooding issue		
DC27	8801 Winthrop Dr			
DC28	Balls Hill Rd south of Old Dominion	No inlets or defined roadside ditches	Research installing conveyance system	
DC29	Bellview Rd	Low lying area; creek cannot handle volume of water	Raise roadway elevation	
DC30	Bellview: West Wakefield at Old Towne	Concrete channel in a tidal zone. Water levels are determined by rainfall amounts and the Potomac River	Proposed solution is to remove beaver dam, other solution?	

DC31	Besley Road at Old Courthouse			
DC32	Beulah Road	Creek cannot handle volume of runoff water	Project?	
DC33	Blair Rd at Col Pike	Issue concerning drainage pipe	Project identified	
DC34	Brook Daleview	Completed project		
DC35	Brown Mill Road	Low laying area; road floods with an inch of rain	Raise roadway elevation	Yes
DC36	Burke and Liberty Bell	New arch CMP culvert observed in field		
DC37	Burke Lake Road between Rt 123 and 286	At lake, road floods due to undersized pipes; road needs to be raised with double barrel boxed culverts installed	Raised roadway elevation	Yes
DC38	Chapel Road at Frosty Meadows	Raised roadway elevation (project)		
DC39	Cherokee Ave an Navajo Dr	Culvert capacity issue		
DC40	Cinder Bed Rd/ Newington Rd	Cross-over pipe too small	Ultimate solution requires project; interim – upgrade pipes and reditch	
DC41	Compton at Bay Valley	Very large culvert with no obstructions. Drainage study for new design – Location in the flood plain	Police Department input on amount of time the site was visited for the problem?	
DC42	Dead end of Colchester Road south of Tunnel	Larger bridge and higher approaches needed		
DC43	Electronics Dr	Water backs up from drain and goes under I395; due to trash and grade. Pipe under Electronic Drive is undersized.		
DC44	Fairfax Station Rd	Replace box culvert w/ bridge before Innisvale road		
DC45	Fowlers Lane	Water runoff into property homes are in the flood plain		
DC46	Fox Mill and Folkstone			Yes
DC47	Fox Mill and			Yes

	Thoroughbread			
DC48	Ft Hunt and Route 1 east side	Box culverts are blocked with sediment and vegetation/debris	Is this a maintenance problem	
DC49	Georgetown Pike (old Dom/Towlston) 6818 Georgetown Pike		Potential emergency project	
DC50	Holmes Run/SleepyHollow	Cross-over pipe too small		
DC51	Hunter Mill and Cedar Pond			
DC52	Hunter Mill Road	Pipe is too small	Raise roadway elevation	Yes
DC53	Hunter St and Hunter Mill		Raise roadway elevation	Yes
DC54	Huntington area: Fenwick and Arlington Terrace	Area is receiving a tidal/flood gate to prevent flooding	Project identified	
DC55	Huntington Ave by entrance to metro ED lanes	Inlets are unable to handle the quantity of flow. Only 2 inlets capture water in/at the intersection	Police- what's happening when it floods?	
DC56	Lawyers and Hunter Mill			Yes
DC57	Lawyers Road @ Hunter Mill	Flood waters exceed capacity of stream and downstream culvert	Upgrade culvert – requires drainage study	
DC58	Lee Highway at Clifton Road	Up-size pipe structure at Clifton Road		
DC59	Lee Hwy at Sandy Pt	Up-size pipe structure at Clifton Road		
DC60	Lee Hwy and Union Mill	Current bridge project to address drainage issues		
DC61	Leesburg Pike at Colvin Run	Creek cannot handle volume of runoff water	Project identified	
DC62	Leigh Mill Rd and White Chimney Lane	Culvert capacity issue		
DC63	Loisdale Rd ½ mile before Newington	Need cross-over pipe	Upgrade pipe will fix	
DC64	Montgomery St	Two rusted out crossover pipes need to be replaced		
DC65	Morningside Dr	Culvert under roadway too small		
DC66	New Guinea and			

	Colony View			
DC67	Newman Road	Replace double-barreled pipes with box culvert or conspan		
DC68	Norton Rd	Pipe has collapsed; requires replacement. Tail ditch on private property needs to be cleaned out	Interim solution – maintenance upgrade and county assistance	
DC69	Oak St & Providence St	Water does not drain; ditches already very deep	Interim solution – routine maintenance	
DC70	Old Colchester Rd/ Hassett	Creek bed requires dredging due to sediment build-up	May need to raise road elevation	
DC71	Old Columbia Pike/Sleepy Hollow	Small culvert that feeds County creek needs clean out	Ultimate solution requires project – interim flush pipe	
DC72	Old Lee Road at Braddock Rd	Raise roadway elevation (Project)	Project moving forward	
DC73	Old Mill and Patton	Blocked road culvert causes roadside ditches to overflow	Should this be moved to maintenance only	
DC74	Old Mill at golf course/ Dogue Creek	Possible wrong location	Police can you confirm location?	
DC75	Pleasant Valley and Braddock	Low Flat area with no drainage system	Project identified	
DC76	Potterton and Beachway	No evidence of flooding in field. Relatively new bridge		
DC77	Prosperity Ave	Two bridges flood; address creeks that runs to culverts/ up-size culvert		
DC78	Route 1 and Giles Run	Needs bigger cross-over pipe		Yes
DC79	Route 1 at Accotink (part of widening)	Part of ongoing project	Project identified	
DC80	Route 1 at Dogue Creek south of Sacramento	Blockages and Erosion in creek have led to poor drainage and flooding in that area	Police- how many incidents?	
DC81	Route 236/ Lee Place	Pipe on Lee Place is undersized and needs to be replaced		
DC82	Rt 50 – Prosperity to Cedar	Poor drainage along roadway. No evidence of flooding from the channel	Very expensive to correct, raise elevation of road and upgrade	

			drainage culvert	
DC83	Scotts Run Rd/Box Elder Ct	Debris washes down from FFX Co drainage easement and fills Dl box, covering road with debris	Ultimate solution requires undefined project; interim – routine maintenance	
DC84	Springvale Rd	Creek cannot handle volume of runoff water		
DC85	Stringfellow and Melville	Current road widening project	Project underway	
DC86	Swinks Mill at Burford			Yes
DC87	Swinks Mill at GP	Pipe is not adequate to handle volume of water		Yes
DC88	Swinks Mill Rd	Creek cannot handle volume of runoff water		Yes
DC89	Telegraph Road; Old Telegraph to Marl Pat	Driveway pipes are rusted out and ditches need regrading		
DC90	Towlston Rd	Creek cannot handle volume of runoff water		
DC91	Walker Rd and Windswept Dr	Culvert capacity issue		
DC92	Walney Road at Flatlick	Road widening/bridge replacement		
DC93	Wayne Road at Annandale	Problem in junction box installed when subdivision built; causes major flooding		
DC94	Woodburn Road	Bridge Floods	Raise roadway elevation	
DC95	Woodford Rd/Woodford Ct	Water does not drain; stands year round	Interim solution – routine maintenance	

Appendix I

Internal Swift Water Awareness Survey Results

Quest #	1		2		3		4		5	
A	30	15.1%	119	60.1%	107	54.0%	95	48.0%	0	00.0%
B	0	00.0%	57	28.8%	57	28.8%	14	07.0%	187	94.4%
C	0	00.0%	12	06.1%	34	17.2%	11	05.6%	11	05.6%
D	168	84.8%	10	05.0%	0	00.0%	78	39.4%	0	00.0%

Quest #	6		7		8		9		10	
A	21	10.6%	11	05.6%	143	72.2%	176	88.9%	41	20.7%
B	0	00.0%	15	07.6%	55	27.8%	22	11.1%	88	44.4%
C	165	83.3%	86	43.4%	0	00.0%			34	17.2%
D	12	06.1%	86	43.4%					35	17.7%

Appendix J

IMPLEMENTATION/EVALUATION PLAN

Fairfax County Roadway Flooding Community Risk Reduction Program

Vision: To protect and enrich the quality of life for the people, neighborhoods and diverse communities of Fairfax County.

Problem Statement: The problem is swift water rescue events created by motorist entering flooded roadways during periods of high rain accumulation create a high risk for citizens and emergency responders in Fairfax County.

Goal: To decrease the risk to motorists and emergency responders from roadway flooding during high rain events.

Outcome Objectives

As compared to baseline data, the following changes will have occurred:

By July 2016, there will be an 80 percent increase in the knowledge of Fairfax County Fire and Rescue operational staff on swift water awareness. Evaluation methods: post course knowledge assessment.

By December 2016, there will be a 100 percent reduction in the number of swift water rescues created by motorists entering flooded roadway at the identified high risk locations. Evaluation methods: CAD data, department incident report data.

By December 2016, there will be a 40 percent reduction in the total number of swift water rescues created by motorists entering flooded roadways. Evaluation methods: CAD data, department incident report data.

Impact Objectives

By August 2016, the life safety and public education section of the Fairfax County Fire and Rescue Department will begin delivering the social media campaign to raise awareness of motorists on roadway flooding. Evaluation methods: social media campaign has started. Intervention: Education.

By August 2016, all high risk roadway locations in Fairfax County will have roadway flooding safety signage based on the national Turn Around, Don’t Drown program. Evaluation methods: physical site inspection. Intervention: Education, Engineering, and Enforcement.

By August 2016, all homes and businesses within half a mile of an identified high risk road flooding location will have received the Safety In Our Community (SIOC) seasonal messaging for roadway flooding safety. Evaluation methods: SIOC Daily Activity Logs. Intervention: Education.

By August 2016, all operational personnel of the Fairfax County Fire and Rescue will have completed swift water awareness update training. Evaluation methods: all personnel have documented attendance in training. Intervention: Education and Emergency Response.

By August 2016, all Fairfax County Fire and Rescue officers will have completed risk/benefit decision making training for technical operations. Evaluation methods: all personnel have documented attendance in training. Intervention: Education and Emergency Response.

By December 2016, the Fairfax County Board of Supervisors will have adopted legislation prohibiting motorists from passing flooded roadway safety gates. Evaluation methods: Notice of change in public law. Intervention: Enforcement and Economic.

By December 2016, the Fairfax County Board of Supervisors will have adopted legislation holding motorists who enter flooded roadways financially liable for the cost of rescue operations to rescue occupants of their vehicle. Evaluation methods: Notice of change in public law. Intervention: Enforcement, Economic.

By January 2017, the Fairfax County Police Department will begin enforcing the prohibition of motorists from passing roadway flooded safety gates. Evaluation methods: Incident and case review with police department. Intervention: Enforcement, Economic.

Process Objectives

By July 2016, the life safety and public education section of the Fairfax County Fire and Rescue Department will have developed a social media campaign to raise awareness of motorists on roadway flooding. Evaluation methods: social media material developed. Intervention: Education.

By July 2016, all high risk roadway flooding locations in Fairfax County will begin receiving roadway flooding safety signage based on the national Turn Around, Don’t Drown program. Evaluation methods: instillation begun. Intervention: Education, Engineering, and Enforcement.

By July 2016, the Fairfax County Fire and Rescue Department will have drafted legislation prohibiting motorists from passing flooded roadway safety gates. Evaluation methods: legislation drafted. Intervention: Enforcement.

By July 2016, the Fairfax County Fire and Rescue Department will have drafted legislation holding motorists who enter flooded roadways financially liable for the cost of rescue operations

to rescue occupants of their vehicle. Evaluation methods: legislation drafted. Intervention: Enforcement.

By July 2016, Fairfax County Fire and Rescue will begin delivering the Safety In Our Community (SIOC) seasonal messaging for roadway flooding safety to all homes and businesses within half a mile of an identified high risk road flooding locations. Evaluation methods: start of seasonal SIOC. Intervention: Education.

By July 2016, all operational personnel of the Fairfax County Fire and Rescue will begin swift water awareness update training. Evaluation methods: start of training. Intervention: Education.

By July 2016, all Fairfax County Fire and Rescue officers will begin risk/benefit decision making training for technical operations. Evaluation methods: start of training. Intervention: Education.

Formative Objectives

By June 2016, the Fairfax County Fire and Rescue Department will have established a multiagency coalition to fund the installation of flood safety signs and gates at the high risk roadway flooding locations. Evaluation method: coalition establishes funding.

By June 2016, the Fairfax County Fire and Rescue and Virginia Department of Transportation will complete a cost-benefit analysis for each high risk location to identify ability and need to install flood safety gates and/or signs. Evaluation methods: analysis complete.

Appendix K

Flooded Roadway Motorist Safety Door Hanger

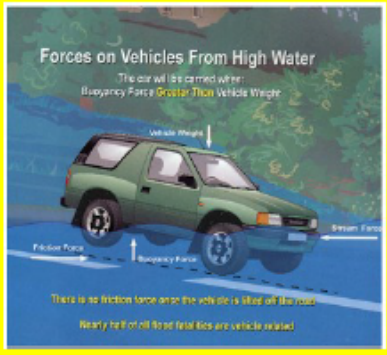
FIRE & RESCUE DEPARTMENT
1742
FAIRFAX COUNTY, VA

Safety In Our Community

The Fairfax County Fire and Rescue Department is sorry we missed you! We stopped by to offer you a FREE smoke alarm inspection and discuss seasonal safety issues. If you would like us to return please call 703-246-2126

Turn Around Don't Drown

Motorists and pedestrians choosing to enter flood waters is the leading cause of flood-related death. It is NEVER safe to walk or drive into flood waters! 6 inches of water is enough to knock an adult off their feet and 12-24 inches is enough to carry most vehicles away.



Help prevent roadway flooding, ensure storm drains are clear of leaves and debris. Report roadway flooding to the Storm Water Planning Division 703-324-5500.

FAIRFAX ALERTS

In the know, on the go. Register today. If we can't reach you, we can't alert you!
http://www.fairfaxcounty.gov/alerts/

This document is available in an alternate format upon request. Please direct your request to Public Affairs and Life Safety Education at 703-246-3801, TTY 711.