Driving Apparatus on Flooded Roadways Safely and Effectively

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Appendices G through M Not Included. Please visit the Learning Resource Center on the Web at http://www.lrc.dhs.gov/ to learn how to obtain this report in its entirety through Interlibrary Loan.

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Abstract

Heavy apparatus are an integral part of the service delivery platform of any emergency response organization. The Fire Service utilizes an array of heavy apparatus that carry a variety of names or designations. Virginia Beach Fire & Rescue utilizes pumpers designated as Engines, ladder trucks designated as Ladders, heavy rescue squads designated as Fire Squads, and water tenders designated as Tankers. These apparatus must safely reach the scene of an emergency event, and be in operable condition in order to deliver the requested customer service.

The problem is that the Virginia Beach Fire & Rescue Department heavy apparatus are being damaged while responding on flooded roadways during severe weather events. This applied research project examines the type of damage, cost of repairs from the damage, and the need for direction and training from fire service organizations for the officers and drivers that encounter response during severe weather events that cause flooding. I utilized descriptive research methodology to address: 1) What are the major causes of the damage to the apparatus? 2) What vehicle components are being damaged? 3) What is the cost to the department to repair the damaged apparatus? 4) What can we do to minimize or prevent the damage from occurring?

The procedures used include a literature review and personal interviews with the Virginia Beach City Garage Fire Shop Manager, the Director of the Fleet Management Division of the Department of Public Works (FMD of DPW), and the President of Atlantic Emergency Solutions. Research through internal department papers, policies, and documents from the Fleet Focus program of the FMD of DPW are included. Electronic

E-mails were sent to various national, regional, and local department leaders requesting information on their department's similar problems and possible solutions. Apparatus manufacturers and private industry were also contacted for information and recommendations. Results determined this problem is not a common event encountered by departments across the nation and many organizations do not address, nor have experienced this type of event as it appears to be limited to coastal areas. The recommendations of this applied research project provide options to the Fire Chief and his Senior Staff of the Virginia Beach Fire & Rescue Department that will enable the organization to continue to effectively respond and meet the customer service needs of the community during inclement weather flooding events.

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Introduction

The City of Virginia Beach is located in the southeastern most corner of the Commonwealth of Virginia. As the most populous city in the Commonwealth, 42nd largest in the nation, it has 433,228 year round residents and the population density more than doubles during the summer season ("Virginia beach community profile," 2010, p. 3). Tourists routinely swarm to the 38 miles of Atlantic Ocean or Chesapeake Bay beaches contained in the 248 squares miles of the city.

The VBFD operates heavy apparatus to meet the mission of the organization. The apparatus are strategically located in 19 Fire Stations throughout the community. The frontline fleet consists of twenty Engines, seven Ladders, two Fire Squads (heavy rescue units), and two Tankers. In addition to the frontline fleet the VBFD recognized the need to have reserve apparatus that could be called upon to fill-in for the frontline units when they were out of service for routine and non-routine maintenance. The reserve fleet consists of five Engines, two Ladders, one Fire Squad, and one Tanker. An additional three Engines are assigned to the training division, and can be used as reserve Engines when the other five reserves are already in use. Normal preventative maintenance needs required for the frontline units necessitate the use of the reserve fleet on a regular basis, and any abnormalities can tax the system.

Fire service organizations across the nation rely on heavy apparatus to provide their service delivery to the community. The Virginia Beach Fire & Rescue Department (VBFD) operates a variety of apparatus to deliver the mission on a daily basis. On occasion the City of Virginia Beach experiences inclement weather conditions that are prone to the eastern seaboard communities. Called Nor’easters, these storm events charge in with winds, lightening, and rain causing roadways to flood, an increase in calls for service (CFS), and challenge the response capabilities of the public safety emergency service providers.

Virginia Beach Fire & Rescue operates from a mission based response matrix that includes the number of personnel required to handle an event plus the need for certain types of apparatus by design function of the unit. The Engine is the primary response platform and handles the most calls for service. Other apparatus including Ladders, Fire Squads, and Tankers are added to the response matrix for cases in which their special function is required. For example: a structure fire in a single family dwelling requires the response: 1 Battalion Chief, 4 Engines, and 1 Ladder. Upon declaration of a “working fire” a Fire Squad and the Shift Safety Officer are added to the response along with a second Battalion Chief. The other end of the spectrum involves a larger response of 1 District Chief, 2 Battalion Chiefs, 4 Engines, 2 Ladders, and 1 Fire Squad for a multi-story high rise structure fire.

The VBFD utilizes several different manufacturers of fire apparatus in the make-up of the fleet. Pierce dominates the fleet with 24 units including eight frontline Engines, five frontline Ladders, two frontline Fire Squads, and one frontline Tanker. In addition there are six reserve Engines, and two reserve Ladders that are manufactured by Pierce. Two more Engines and another Tanker are currently on order from Pierce. American LaFrance is credited with the next largest chunk of the VBFD fleet with 17 units consisting of 12 frontline Engines, two reserve Engines, one frontline Ladder, one frontline Tanker, and one reserve Fire Squad. Six of the American LaFrance pumpers are Tele-Squirts. There is also one reserve Tanker manufactured by Boardman and one reserve Engine of Emergency One origin.

Any abnormal event, such as vehicle accident or storm damage, causing a unit of the fleet to be out of service for an extended period of time will have a negative effect on the response capability of the department and tax the use of the reserve fleet. This is especially true of our specialty (Ladder and Fire Squad) apparatus. The limited number and specific function of these apparatus can be taxed by normal routine maintenance. There are occasions where the number of Ladders out of service has caused Ladder staffing to be placed on an Engine. This negative effect causes a Ladder from a more distant location to be sent into the vacated Ladder’s area to cover the calls for service and provide the specialty work performed by Ladder Companies. This also causes Engine Company personnel to do the Ladder function with the tools they carry which are not necessarily the tools needed to perform the work in the most efficient and timely manner if needed prior to the arrival of the more distant Ladder.

The problem is that the VBFD apparatus must respond to calls for service despite the weather conditions. We are the epitome of what the Postal Service implores as “rain, sleet, or snow” delivery. We must respond and provide the best of service during the worst of conditions. VBFD apparatus have been damaged, some extensively, from being operated on flooded roadways during response to meet the needs of the community.

Flooded roadways provide many hazards that need to be negotiated by the drivers, officers, and crews responding on the heavy apparatus to emergencies. These hazards include, but are not limited to: trouble seeing the road surface through the water, hidden obstacles under the water, and the negative effect of the water on the apparatus systems. Being an eastern seaboard community the added effects of salt water cannot be discounted, and are cause for additional concern.

In November of 2009 just such a Nor'easter moved in upon the City of Virginia Beach and surrounding communities. Heavy rains flooded the roadways, thunder boomed and lightning bolts spat down, and the normal caseload for emergency response increased the demands placed upon our heavy apparatus. During this storm VBFD apparatus encountered flooding on the streets that led to damage to many of the responding apparatus. The most extreme example occurred to Engine 1 (2009 Pierce Quantum pumper) as it was responding to a working house fire. Engine 1 entered a flooded portion of the road and was disabled when water entered the air intake on the engine and stopped the truck in its tracks. Not only were this unit and its crew unable to provide the needed service but the department was now faced with a huge repair bill on a piece of newer apparatus that in normal conditions was still under warranty. This damage was unexpected and caused a strain on an already burdened department budget.

The purpose of this research is to discover what can be done to minimize or prevent the damage caused by providing customer service during the flooding produced by severe weather events. This applied research project examines the type of damage, cost of repairs from the damage, and the need for direction and training from fire service organizations for their officers and drivers that encounter response during severe weather events and flooding. Descriptive research methodology is used to address: 1) What are the major causes of the damage to the apparatus? 2) What vehicle components are being damaged? 3) What is the cost to the department to repair the damaged apparatus? 4) What can we do to minimize or prevent the damage from occurring?

The procedures used include a literature review and personal interviews with the Virginia Beach City Garage Fire Shop Manager, the Director of the Fleet Management Division of the Department of Public Works (FMD of DPW), and the president of Atlantic Emergency Solutions. In addition, research through internal department papers and documents from the computerized Fleet Focus program of the FMD of DPW has been performed. Electronic e-mail requests for information were sent to various national, regional, and local department leaders for material on their department's similar problems and any solutions they may have in place. The policies of the VBFD were reviewed to determine applicability. Apparatus manufacturers were also contacted for information and recommendations.

It must be noted that this document is also breaking relatively new ground. There is a general lack of fire service generated information available for this venue of investigating public safety operations for driving on flooded streets. Information has been gleaned from the private industry to address needs of this document. Professional fire service organizations have been researched for additional information.

Results determined this problem is not a common event encountered by departments across the nation and many organizations do not address, nor have experienced this type of event as it appears to be limited to coastal areas. The recommendations of this applied research project provide options to the Fire Chief and his Senior Staff of the Virginia Beach Fire & Rescue Department that will enable the organization to continue to effectively respond and meet the customer service needs of the community during inclement weather flooding events.

Background and Significance

Virginia Beach Fire & Rescue utilizes heavy apparatus to deliver its service mission to the community. These apparatus are expensive to purchase. The last pumper Engine purchased by the VBFD cost $508,306 on delivery. A Ladder truck is even more expensive as they cost between $700,000 and $1,000,000 on average depending on the style (straight ladder, platform, tiller, etc.) selected. A mid-ship mounted platform Ladder (VBFD has one) cost an astounding $1.1 million. The associated cost to maintain and keep the heavy apparatus operational from routine maintenance is also rather cumbersome on a fire departments budget and normally does not include catastrophic events. The VBFD has its annual maintenance payment automatically deducted from its budget. Any abnormal events must be paid from the budget above and beyond this annual fee.

The VBFD works in cooperation with the Fleet Management Division of our Department of Public Works and the Finance Department to keep our heavy apparatus fleet in service at a cost that is palatable to the public trust. The VBFD, through an Apparatus Team, is pro-active in our replacement of apparatus that are no longer cost effective to keep in service and take full advantage of manufacturer's warranties to keep maintenance costs reduced. A Capital Improvement Plan (CIP) allows the VBFD to purchase two Engines annually and a Ladder or Fire Squad every three years; however, this is in jeopardy with the recession affecting our budget.

The Fleet Management Division of our Department of Public Works is our partner in maintaining our heavy apparatus. Through the City Garage most of our maintenance that cannot be performed at the station level is completed. As mentioned earlier in this document the VBFD pays a user fee to fund this service. This fee is based on an average cost for each of the vehicles in our fleet and includes numerous small vehicles as well as the heavy apparatus. The average cost to keep a Ladder truck maintained throughout the year, for example, is $14,820. An Engine costs $7,290 and a Fire Squad $2,344. The cost to maintain all of the vehicles in our fleet is tallied and the overall cost that averages over $700,000 annually is removed from the fire department budget on the first day it goes into effect and placed in the FMD of DPW City Garage coffers. This annual fee is used to keep our trucks serviceable and once it has been used up the department is then charged for the additional costs beyond the fee. This extra cost is a strain on the budget because it is unanticipated and difficult to project. Any event that causes an extraordinary expense is cause for concern and storm damage fits into this category.

In November of 2009 a Nor'easter came blowing into the City of Virginia Beach. The remnants of Hurricane Ida and a low pressure system off the coast combined for three days of very severe weather. High winds, abnormally high tides, and over ten inches of rain flooded roads and caused an increase in requests for service five times greater than normal that had to be met by the heavy apparatus fleet of the VBFD. This high call volume exposed the heavy apparatus fleet to the extremes of the storm, and challenged our officers and staff in ways that previous storms had not.

This storm caused excessive flooding of the depth and coverage area that had not been experienced in many years. Large sections of the city were under water that under normal storm conditions had remained dry in the past. The VBFD, on average, is a relatively young organization. Our heavy apparatus were commanded by young officers and piloted by even younger drivers that had no previous experience with this weather phenomenon. Some poor decisions were made on whether to drive the apparatus directly in to the scene or to walk in and check the situation first leaving the truck on “high ground” by these young professionals.

This poor decision making was partly due to the lack of experience of the personnel involved. One of the additional major contributors was the lack of training and direction provided by the department. The department does not have a policy to cover this type of event. The department also does not train our officers for this type of situation either. Vehicle maintenance training on the heavy apparatus was also determined to be lacking. Our operators and officers were not completely aware of the repercussions of driving the heavy apparatus through high water.

The flooded roadways had the “normal” effect on our apparatus that are encountered from driving through high water. Hubs filled with water and had to be serviced and seals replaced. Brakes were affected by the rapid heating and cooling and had to be replaced before their normal service times. Air horns were damaged from water entering their inner working parts. Transmissions, rear end differentials, and pump transfer cases had to be checked, drained, flushed, and re-filled with the proper fluids.

More severe damage was encountered by units that hit unseen objects in the water. Hydraulic lines were torn loose from components. One truck struck an object and damaged the front bumper. Another unit had water enter into the air intake and damaged the engine on a brand new apparatus. The overall un-projected cost for maintenance and repair to recover the fleet from the storm was $179,876.63 according to the Fleet Focus report from FMD of DPW.

This damage total came as a shock to the department's leadership and already overtaxed budget. The After-Action Report for the November 2009 Nor'easter that had been completed by the Emergency Management Battalion Officer for the VBFD listed the cost of the damage and maintenance toll upon our heavy apparatus fleet as $7,338.28. This was mainly due to the fact that this report had been completed before the comprehensive damage and maintenance needs could be accurately assessed and totaled.

The VBFD relies upon our personnel to perform routine maintenance of the heavy apparatus in the station. This apparatus maintenance is designed to follow the departments Vehicle Maintenance policy and relies heavily on mentoring from firefighters and officers to newer members. This policy had not been updated since July 1, 2000. The mentoring process is supposed to teach the four W's & H (who, when, where, what, & how) of vehicle maintenance that should be performed. There is no formal training offered by the department in this area.

A major concern is the lack of knowledge the VBFD members have on the vehicles they operate every day they are on-duty. In the old days we used to crawl under the trucks and perform maintenance with a red rag and "varsol" cleaning every nook and cranny and then greasing everything in site that was not painted navy gray. Today the city garage does all of our oil changes and under the hood work. The VBFD has taken for granted that our new members have some vehicle experience. This also assumes maintenance is understood. Employee actions demonstrates this is not accurate and many of our new members have not change their own oil, do not know what the third pedal (clutch) is for, and are not mechanically inclined. The VBFD has lost the knowledge, skills, and abilities (KSAs) needed to effectively and efficiently operate and maintain our vehicles. The current reality that many of our young driver operators have never even seen a vehicle with a standard transmission or changed their own oil have come full circle to identify that steps need to be taken to improve this area of vehicle maintenance.

The VBFD relied on our personnel to perform checks of the apparatus after driving through the flood waters and get their trucks to the City Garage for needed adjustments. This did not occur. The trucks were continually driven until problems affecting operation of the vehicle surfaced and this led to higher cost for the repairs and longer downtime out of service. A particular concern was encountered and identified with the Pierce Quantum apparatus in our fleet. As in the previous Engine 1 example the air intake for the engine is below and behind the front bumper. This intake position allows water to enter the engine and cause major damage. This damage voids the manufacturer warranty. In our case we were able to negotiate a continuance of the Detroit Diesel warranty, but only after agreeing to have the engine completely torn down at a higher cost so that water damage could be accurately assessed. The apparatus systems did their job and successfully shut the engine down before serious damage occurred.

Another problem that was encountered on our newer apparatus centered on the “multi-plex” electronic systems. On the apparatus a junction box of input/output nodes is located below the battery box on the driver’s side of the apparatus. A second box is on the driver’s side rear of the truck near the fuel tank. These “can bus” nodes allow the electronic systems to communicate with each other and synchronize all of the systems on the apparatus to maintain proper working order. The location of these electronic boxes allowed them to be submerged in the flood waters. The submergence of these junction boxes caused systems on the truck to stop working that could have threatened the safety of the responders. Even if the truck made it through the flooded streets to the scene of the event it was possible they would malfunction while operating or not function at all rendering them incapable of delivering the needed service. The malfunctions would range from radio communications failure, warning lights and systems failure, to the inability to place the unit in pumping mode to combat the fire.

The storms effect on our apparatus fleet was staggering. The number of units that had to be placed out of service until the fluids could be changed taxed the capabilities of the City Garage staff and the use of our reserve fleet. The Pierce Quantum problem became a top concern as this is the current apparatus cab and chassis design of choice for the VBFD because of the other numerous advantages it offers in comfort, operability, and spaciousness. We have several of these apparatus in our fleet so an investigation to seek a solution to this problem was enacted with the manufacturer.

It was quickly realized that the department also needed to provide some type of direction and/or training for our personnel in this arena. We would need to check with other departments, the private industry, and manufacturers for national standards, policies, and training curriculum to see if anything already exists that would meet our need to better prepare us for the future occurrences, or create our own.

This Applied Research Project (ARP) is relevant to the curriculum of the Executive Fire Officer Program (EFOP), *Executive Development* (NFA, 2006). There are links between this ARP and the course in the following units: Unit 1: Leadership, Unit 2: Teams, and Unit 3: Change Management (NFA, October 2006). This ARP relates to the United States Fire Administration (USFA) operational objectives: improve the fire and emergency services’ capability for response to and recovery from all hazards, and improve the fire and emergency services’ professional status.

Literature Review

The literature review focused on the effects of storm flooding on fire department heavy apparatus, and the need for direction or training to be provided to emergency responders for operating in this severe weather condition. To gain an understanding of how the flood waters affected our heavy apparatus, and to discover methods of improving the decision making actions of our employees four questions were established: 1) What are the major causes of the damage to the apparatus? 2) What vehicle components are being damaged? 3) What is the cost to the department to repair the damaged apparatus? 4) What can we do to minimize or prevent the damage from occurring?

The fire service relies on heavy apparatus to deliver the dynamic services demanded by the public they serve. It is vital, to the public and the safety of our own members that these units be maintained in proper working order. As stewards of the public trust we also owe an efficiency of cost to our tax-paying customers and an effective maintenance program and properly trained personnel play a vital role in the success of that effort.

During the heart of the storm after the flooding had moved onto our roadways and the call for service volume had begun to rise; our heavy apparatus were on the street driving through the flooded roadways. The crews on those Engines, Ladders, and Fire Squads were faced with decisions to make on whether “to go or not go” through the water to the location for which they had been dispatched. As stated earlier, the members were not prepared for this endeavor.

The VBFD trains our members in the Emergency Vehicle Operators Course (EVOC) provided by the Commonwealth of Virginia Department of Fire Programs (VDFP) curriculum. The training manual for this course is written utilizing information from International Fire Service Training Association (IFSTA), laws, codes, and the National Fire Protection (NFPA). This training is updated frequently and it depends on when our member attended the training as to which version they received. This training offers a basic knowledge of how the truck will handle under normal weather conditions. It includes a pre-trip inspection and daily check-off routine to assure the unit is ready to be driven, but leaves any maintenance procedures beyond the daily check-off up to the authority having jurisdiction (AHJ). This course also includes practical driving sessions for operating the heavy apparatus through various cone course scenarios at given predetermined speeds and times. The curriculum covers: motivation, the transportation system, the vehicle, the driver, the environment, legal aspects, response, and crash avoidance; however, no mention of inclement weather driving in floods is offered

(Virginia Department of Fire Programs and the Virginia Association of Volunteer Rescue Squads, Inc., 2004, p. 2). In-station training and a bi-annual department recertification are part of the training process given to our members to keep their operational skills fine-tuned. Neither this course nor the department's training efforts contain anything that will prepare our drivers and officers for the conditions they faced during storm flooding events.

The next training courses provided by the VBFD to our members in their career progression to be driver operators covers the operation of components on the heavy apparatus they will be driving. A pump operator course based on the VDFP curriculum is provided to the Engine and Ladder drivers (most of our Ladders are equipped with fire pumps). This course utilizes the latest IFSTA Handbook. This manual does not mention driving on flooded roadways under the Adverse Weather section (*Pumping apparatus driver/operator* handbook, 2006, p. 84). The handbook does speak to some KSAs the prospective driver/operator should possess: reading skills, writing skills, mathematical skills, physical fitness, and vision requirements (*Pumping apparatus driver/operator* handbook, 2006, p. 7-8). In addition, the Ladder drivers can attend the VDFP Aerial Operator Course; however, it is not a department requirement. Neither of these courses offers anything to prepare our drivers and officers for the storm conditions they faced during the Nor'easter.

In Virginia, fire service apparatus drivers may choose to seek a Commercial Driver's License (CDL). Many states do not require this licensing for drivers of fire apparatus. The VBFD does not require this license certification since it is not mandated by state code, and would cause an increase in the cost of our employee physicals under our Health & Wellness Program. The Commonwealth of Virginia Division of Motor Vehicles (DMV) offers this training through a variety of sources. In Virginia Beach, our internal city Occupational Safety Office offers this for city employees since it is required by other city departments for their drivers. The VBFD does not make it mandatory; however, it is recognized that the National Institute of Occupational Safety and Health (NIOSH) encourages fire departments to require their drivers to obtain this training or offer an AHJ similar course (*Fire Fighter Fatality Report*, 2008, p. 5). IFSTA also speaks to this as a recommended national guideline (*Pumping apparatus driver/operator handbook*, 2006, p. 10) but understands some states exempt drivers of fire apparatus. The training and testing curriculum is rather extensive and covers under the General Knowledge section driving in hazardous conditions including: night driving, fog, cold weather driving, hot weather driving, and mountain driving (*Virginia Commercial Driver's Manual*, 2010, p. 30). The remaining sections of the CDL training manual cover everything from carrying passengers to hazardous materials. Conspicuously absent is any mention of driving on flooded roadways.

The trucking industry has standards of performance for their vehicles and is striving to apply standards to their drivers as well. They promote these actions through many organizations and offer a number of publications designed for their special needs. Jim York, Assistant Vice President of technical services for Zurich Services Corporation Risk Engineering, states in his safety matters message in Fleet Owner magazine: "…ensure that your minimum driver hiring standards include experience and training elements that are appropriate to the exposure" (York, 2008, p. 40). He goes on to speak of the complexity of operations and equipment should be matched by a complexity of experience. This is a clear message that the VBFD needs to apply towards our driver operators. We must seek methods to establish and increase the training and experience levels of our members who drive our heavy apparatus.

The United States Fire Administration (USFA) offers training manuals covering many topics of interest to emergency responders and the fire service. The Federal Emergency Management Association (FEMA) published FA-272 Emergency Vehicle Safety Initiative in August of 2004. FEMA also published FA 248, Safe Operation of Fire Tankers in April of 2003. Both of these manuals contain beneficial information and sections highlighting driving surface factors and adverse weather conditions. Training program recommendations are also included. However, there is no information specific to driving on flooded roadways.

The National Oceanic and Atmospheric Administration (NOAA) offer information on several websites. The National Weather Service (NWS) is a branch of NOAA and promotes a special campaign on flood actions. The “Turn Around Don’t Drown” (TADD) program warns people of the hazards of both driving and walking through flood waters. They warn that flooding causes more deaths annually than any other weather event. The main rule they profess is: “If you cannot see the road or its markings, do not drive through the water” ("TADD," 2010, p. 1)

The International Association of Fire Chiefs (IAFC) published the *“Model Procedures for Response of Emergency Vehicles During Hurricanes and Tropical Storms.*” This procedure provides a model baseline policy, model operational guidelines that include preseason preparations, hurricane operations, and resuming operations after the hurricane. Under the Hurricane Operations section (International Association of Fire Chiefs [IAFC], 2008, p. 8) this procedure states:

- Before walking through water, members must use a pike pole or stick to ensure the ground has not washed away or collapsed.
- Use extreme caution when walking through water. Six inches of moving water can knock a person off their feet.
- Be aware of hazards in the water such as downed live electrical wires and wildlife, including snakes.
- Use extreme caution and limit speed when driving. Be especially cautious where the ground is saturated or flooded – the road could be washed away.

This information does not directly apply to drivers of heavy apparatus but can easily be modified to provide useful guidelines, policy, or procedures.

The National Fire Protection Association (NFPA) creates minimum standards for the fire service. These standards cover a wide range of arenas and are considered to be the “best business practices” that all departments should follow. NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program*s is a standard that covers the qualifications and training drivers of fire service heavy apparatus should be measured against. The training requirements section speaks to many facets including initial and proficiency needs for members based on the member’s assigned function (National Fire Protection Association [NFPA], 2007, p. 13) The standard speaks specifically about drivers stating they should be trained and licensed for the specific apparatus they will be operating, and communicates to some hazardous operations including use of the “wet road/dry road” switch but fails to mention operations on flooded roadways(NFPA, 2007, p. 14).

NFPA 1002 *Standard for Fire Apparatus Driver/Operator Professional Qualifications* is another training standard that further explains those recommendations listed in NFPA 1500 by speaking directly about the fire apparatus drivers. It declares the importance of maintenance, driving, and operating by specific types of apparatus. The maintenance portion does not detail any post trip inspection as a result of driving on flooded roadways. On certain types of apparatus it goes into detail explaining driving on or over: loose or wet soil, steep grades, limited sight distance, blind curve, vehicle clearance obstacles, limited turn around space, and side slopes, but does not mention flooding (National Fire Protection Association [NFPA], 2009, p. 11).

NFPA 1451*Standard for a Fire Service Vehicle Operations Training Program* is a standard that offers specific information for creating a training program for drivers. It covers information on: program needs, frequency, type, instructor qualifications, safety, records, laws and liabilities, emergency response, crash prevention and reporting, and vehicle and apparatus care (NFPA, 2007, p. 3). It does speak to the need for training, and the potential hazards of off-road driving with a need for SOPs covering the same, but does not specifically state anything about flooding (NFPA, 2007, p. 7).

The NFPA also has standards that apply to the apparatus. NFPA 1911 *Standard for the Inspection, Maintenance, Testing, and Retirement of In-Service Automotive Fire Apparatus* covers all facets of maintaining fire service heavy apparatus. There are many components involved when a heavy apparatus is driven through flood waters. The brakes, fluids, and wheels may be affected when they are heated from being driven and then encounter cold water. Some examples of the standards listed that need to be considered are listed below:

> 7.3.6 Wheels and rims shall be inspected for cracks, deformation, structural integrity, and corrosion.(National Fire Protection Association [NFPA], 2007, p. 17)
>
> 7.9.3 Transmission lubricants and filters shall be inspected for contamination, and lubricants shall be maintained at the level specified by the manufacturer.(NFPA, 2007, p. 18)

There are similar standards throughout the book that cover all of the fluids and components of an apparatus that require grease to effectively operate that must be checked and maintained after heavy apparatus are exposed to flood waters.

NFPA 1901 *Standard for Automotive Fire Apparatus* defines the performance criteria apparatus and its inherent components should meet. This guides the manufacturers and fire service specification writers on what they need to do to assure they are getting an apparatus that will meet the rugged demands of the service and the needs of the community. A section of this standard covers the air intakes:

> 12.2.4.3 The air inlet shall be equipped with a means of separating water and burning embers from the air intake system.(National Fire Protection Association [NFPA], 2009, p. 33)

A problem encountered by one of the VBFD Engines during the storm was water entering the air intake and causing the engine to shut down effectively removing the unit from the structure fire response for which it had been dispatched. Another concern discovered with the storm event concentrates upon the effects of water on the electrical “can bus” nodes. The NFPA 1901 standard states (NFPA, 2009, p. 36):

> 13.2.5 Wiring shall be restricted to prevent damage caused by chaffing or ice buildup and protected against heat, liquid contaminants, or other environmental factors.
>
> 13.2.7.1 Such devices shall be readily accessible and protected against heat in excess of the over current device’s design range, mechanical damage, and water spray.

The private industry can provide some valuable information that can easily be adapted to the fire and emergency service arena of operations. Insurance companies offer a wide variety of pamphlets covering most anything a person can imagine. Progressive Insurance offers in its Flood Safety Tips link on their corporate website tips that speak to not driving around barricades and attempting to use an alternative route. It also informs the driver operator that 12 inches of moving water can sweep the average automobile off the road. Of particular interest are the following driving tips ("Flood safety tips," 2010, p. 1):

- Do your best to estimate the depth of the water (if other cars are driving through, take note of how deep the water is).
- Drive slowly and steadily through the water.
- Avoid driving in water that downed electrical or power lines have fallen in – electric current passes through water easily.
- Watch for items traveling downstream – they can trap or crush you if you’re in their path.

- If you have driven through water up to the wheel rims or higher, rest your brakes on a clear patch of road at low speed. If they are wet and not stopping the vehicle as they should, dry them by pressing gently on the brake pedal with your left foot while maintaining speed with your right foot.
- If your vehicle stalls in the deep water, you may need to restart the engine to make it to safety. Keep in mind that restarting may cause irreparable damage to the engine.

State Farm had to be contacted to obtain their information as the websites normal navigation and links did not readily allow access to the information on flooding. A quick reply to my request provided the link to a flash video promoting the TADD program ("TADD," 2010). Nationwide (Nationwide Insurance, n.d) and All State (All State Insurance, n.d) replied to my inquiry on their website with an e-mail from their respective customer advocacy representatives that they did not have anything to offer on flood driving tips on their website or in pamphlets that could be requested through the mail. The National Safety Commission website (The National Safety Commission, 2009, p. 1) on dealing with flooded roads supports many of the Progressive tips listed above.

Apparatus manufacturers provide an operator's manual with the fire trucks that are purchased. In Virginia Beach the majority of the apparatus we operate are American La France (ALF) and Pierce. ALF provided the VBFD with an Operator's Manual Maintenance Manual combination book. A wide variety of information is provided; however, nothing is listed for driving the truck or operating on flooded roadways (Freightliner LLC, 2003). Inquiries with the manufacturer also went unanswered. Pierce provided information available from a website and through their Custom Chassis

Operator's Manual (part # PM-C-OM012-1110). Again, a wide variety of instruction and information is provided. The section on water fording capability advises time limits for the components to be exposed to water and recommends the lubricants be replaced (Pierce Manufacturing Inc. [Pierce], 2010, p. 94-95). This section speaks to the battery box distribution under the driver's side battery and warns that it should be accessed, checked for moisture, and allowed to thoroughly dry prior to using the apparatus after exposure to deep water. Pierce also cautions that the user should know the components on the truck and their location as "Low engine tunnel designs in some Pierce Custom Chassis models require the engine air intake port to be located at or below frame level. This configuration places inherent restrictions on the ability of the apparatus to negotiate areas of high water…Since the depth of water that can be safely traversed is a function of water depth and complex hydrodynamics, no definitive fording capability can be established…" without knowing the exact location of the various components that could be affected by deep water (Pierce, 2010, p. 94).

The problem that was experienced with the flood water and the Pierce Quantum custom apparatus used in Virginia Beach is not a new one. The Quantum chassis first appeared in the VBFD fleet back in 1996 and this water intrusion anomaly was studied at that time without a solution being offered by the manufacturer. The picture in Figure 1 demonstrates the current Quantum cab configuration used by the VBFD. The location of the air intake on the Quantum chassis is behind the bumper under the driver.

San Antonio, Texas, was able to work with Pierce Manufacturing to develop two options to address the water entering the air intake. The first option must be performed while the truck is being manufactured at the plant. This option adds a cost of $3,500 to

Figure 1

Figure 2

the unit and moves the air intake to the side of the truck over the passenger side front wheel (high side option). This option also includes the movement of the electrical junction box distribution nodes and the "can bus" nodes into a compartment of choice. The new nodes box is usually mounted in the top of a compartment to alleviate equipment banging into it and causing damage and provide easy access by mechanics. This option is not retro-capable to current units in the fleet. This option also takes up space in the cab that must be considered. This option is pictured in Figure 2 on the Tierra Verda Fire District apparatus.

The second option that was established is a more cost effective, as long as it is done at the time of the purchase, method for those that have limited funding for apparatus purchases. This design when performed on the apparatus while it is being built only adds $500 to the cost for the intake movement and an additional $1,617 to the price if you choose to move the electrical components. This second option method is also advantageous in that it can be retro-fitted to existing apparatus that are already in the fleet. It is more expensive than having it built in at the factory originally. The kit to move the air intake can be ordered at a cost of $1,623. Labor to perform the move and install the kit is extra and dependent on the dealer selected to perform the work. The electrical components cannot be moved during the retro-fit. The second option is featured in the picture Figure 3.

The need for a policy to define driving practices and maintenance procedures for an organization has been identified in the literature and standards mentioned earlier in this section. A review of the two policies offered by the VBFD for this arena revealed they lacked the necessary information to guide the members during this type of

encounter. The first policy investigated is SOP O/RM 6.03 *Operation of Fire Department Vehicles*. This policy speaks to emergency vehicle laws, vehicle operations for safe and prudent conditions, emergency & non-emergency response, incident scene and highway safety, risk assessment, using spotters, and backing. The risk assessment section speaks to the dangers of personnel operating around and in moving traffic and the need for high visibility vests (Virginia Beach Fire & Rescue Department [VBFD], 2010, p. 4). The safety benchmarks section lists 15 yardsticks for vehicle operations and none of it relates to flood or storm driving procedures.

The next policy was examined to determine if maintenance procedures were clearly outlined. SOP SS/RM 3.21 *Vehicle Maintenance* lists the procedures for the daily pre-trip inspection that include checking all of the apparatus systems and equipment carried on the apparatus to assure they are present and in proper working order. The maintenance section guides the member through the process of weekly, monthly, quarterly, semi-annual, and annual preventative maintenance. The policy even has an extensive list which states “the apparatus shall be placed out-of-service when any of the following defects or deficiencies has been identified which reduce the operational safety and performance of the apparatus” (Virginia Beach Fire and Rescue Department [VBFD], 2000, p. 6-9). The problem with the list and the policy is it relies on the reader to have the mechanical aptitude to understand how to check the items on the list to determine if they are deficient. Training for the member is required to be able to perform this function. The policy does not contain any other direction about post trip inspections after operating in water flooded roads.

Electronic e-mails were sent to several organizations asking if they had policies, standards, or rules for their organizations on driving in flood waters with their heavy apparatus. I also inquired as to whether they had experienced any problems similar to the VBFD. The people and organizations contacted came from across the country. Most of the respondents acknowledged they did not have any policies, nor had experienced the types of conditions we do during our Nor’easter storms. Tom Miner from Pierce County, WA, was in New Orleans and stated he witnessed a fully loaded military deuce and a half get moved by water; he recommends a policy of not driving through any water deeper than the axles as a result. Tom Ewald from Los Angeles County stated they do not address the driving, but their maintenance policy does state to check the lubrication on their apparatus after driving through flood waters.

Two respondents, from opposite sides of the country, did state they have a written policy. Our regional neighbor, Battalion Chief Harry Worley of Norfolk Fire & Rescue , Norfolk, VA, sent the following rather comprehensive SOP section that addresses both driving and maintenance needs:

Vehicle Operation – High Water Conditions

A. As a general rule, vehicles shall not be driven into standing water that is deeper than the centerline of the vehicle wheels. Vehicles should never be driven through swiftly moving water or into areas of standing water in which the operator cannot distinguish the boundaries of the roadway.

B. Vehicles should not be driven into standing water in which other similar sized vehicles have already been stranded. If it appears that it may be safe for the vehicle to pass through the area, the centerline of the vehicle wheels shall still be used as a reference point for the maximum depth of water in which the vehicle may be driven.

C. Before allowing the vehicle to be driven into the standing water, the officer or AIC shall conduct a risk/benefit analysis and take appropriate actions as dictated by the situation. When high water is encountered during an emergency response the officer or AIC shall immediately notify the dispatcher of the situation and request an alternative unit/company to respond if appropriate.

D. Before entering standing water, the operator shall bring the vehicle to a complete stop, and then proceed with caution at a slow rate of speed. Vehicle passengers should be assigned to observe the water depth from inside the vehicle. Every effort should be taken to drive the center or highest point of the roadway. If necessary, use warning lights to secure the right of way from oncoming traffic. If the water becomes too deep, the vehicle shall be stopped and backed out of the area. Note: The Fleet Maintenance advises that concerns about maintaining high engine RPMs to keep standing water from entering the exhaust system are no longer valid. In fact, driving through standing water at a higher rate of speed may present a much greater risk to the vehicle as this may create a wake, which may cause water to enter the air intake.

E. Upon leaving the standing water, the operator should check the vehicle brakes to ensure they are functioning properly after being submerged in water.

F. As soon as practicable after a high water event has passed, vehicles that have been driven through standing water in accordance with the procedures outlined in this SOP shall be scheduled for a service call to Fleet Maintenance for inspection and maintenance of axles, wheel bearings, drive shafts, rear differential and other equipment that may have been exposed to or damaged by water.

An accident investigation report obtained from the Bureau of Land Management (BLM) on the loss of Engine 3662 during a high water crossing of the Gila River supports the information in part D above. It is essential that crew members observe the water level as the unit slowly enters the water (Huntington, Shaw, LaRue, & Fitchner, 2009, p. 10).

Captain Eric Perry from the Tucson Fire Department in Arizona sent the following SOP section from their Emergency Operations Manual:

VII. Deep Water Fording

While operating apparatus and ambulances, you may encounter situations when deep water fording is necessary because of rapid rising water levels during monsoon season. As a reminder, if you are required to ford water higher than the axle centerline of your apparatus/ambulance; please be aware of the following areas of concern.

- Low engine tunnel designs in the Pierce Saber chassis require the engine air intake port to be located at or below frame level. This air filter design has the potential to allow water ingestion into the engine, which may hydrostatically stall your engine causing severe engine damage.
- The engine fan blade used on the Pierce Saber and Spartan Gladiator chassis is a direct drive design. This direct drive design limits the ability of the apparatus to negotiate areas of high water due to the rotating engine fan blade being placed directly into the water, resulting in possible fan and/or radiator damage.
- Temporary loss of full braking capability due to wet brake linings.
- Temporary loss of supplemental braking (Telma) due to wet electrical components.
- Water contamination of certain components.

Areas for possible water entry causing contamination on all apparatus include:

- Engine air filter
- Transmission vent
- Fire pump transmission vent

- Differential vent
- Wheel seals

Areas for possible water entry causing contamination on all ambulances include:

- Engine air filter
- Transmission vent
- Differential vent
- Wheel seals

If any apparatus or ambulance has been driven in high water conditions, or water contamination/ingestion is suspected, please contact Fire Maintenance at x3209 for inspection. If water contamination is found, wheel bearings and gearboxes will need to be flushed and air filters changed. The approximate time for repairs is four hours, depending on severity.

It can be easily distinguished that there is a difference in thinking between the two policies. The Norfolk version addressed driving practices as well as some maintenance. For maintenance it relies on the Fleet Maintenance group to take care of the truck once given to them; all the driver has to do is recognize the unit was in deep water. The Tucson version offers very little in driving practices and is designed to identify the maintenance needs and characteristics of the vehicle.

Procedures

This Applied Research Project used the descriptive research method to evaluate the options that are available in the area of heavy apparatus design to eliminate the problems caused by water intrusion into the components on our apparatus. In addition, procedures for providing direction for our members through training or policy were also sought. Research procedures followed in this ARP included:

- A request for information e-mail was sent to my fellow classmates of the Executive Fire Officer Program (EFOP) to determine: 1) if they have experienced flood conditions, 2) if they had training programs or bulletins that were used to train their drivers and officers for operating in the inclement weather conditions faced from flooding, 3) if their departments had general orders, policies, or procedures in place to direct members actions when encountering flooded roadways during apparatus operation. A sample of the e-mail questions is contained in Appendix F.
- A request for information e-mail was sent to a list of Federal Emergency Management Administration (FEMA) Urban Search and Rescue (USAR) team representatives to find out: 1) if they have experienced flood conditions, 2) if they had training programs or bulletins that were used to train their drivers and officers for operating in the inclement weather conditions faced from flooding, 2) if their departments had general orders, policies, or procedures in place to direct members actions when encountering flooded roadways during apparatus operation. A sample of the e-mail questions can be found in Appendix F.
- A request for information e-mail was sent to my fellow regional officers of the Hampton Roads Incident Management Team (HRIMT) to determine: 1) if they had training programs or bulletins that were used to train their drivers and officers for operating in the inclement weather conditions faced from flooding, 2) if their departments had general orders, policies, or procedures in place to direct members actions when encountering flooded roadways during apparatus operation. A sample

of the e-mail questions is in Appendix F. Hampton Roads, VA is a defined geographical area located in southeastern Virginia. It contains the cities of Chesapeake, Hampton, Newport News, Norfolk, Portsmouth, Suffolk, and Virginia Beach and is home to a population of 1.7 million residents (Hampton Roads, 2008).

- An interview was conducted with Fleet Management Division of the Department of Public Works Fire Shop Manager Doug Moss to determine the exact nature of the problem the water caused to our heavy apparatus fleet, the location of the air intake, electrical junction box and “can bus” nodes on the Quantum chassis. The interview questions can be found in Appendix C.
- An interview with the Automotive Services Director Reggie Padgett on the cost and effect of the damage to the VBFD apparatus from the Nor’easter of 2009 and any subsequent storms. The interview questions may be found in Appendix D.
- An interview with Joe Pack, President of Atlantic Emergency Solutions. To actively seek a solution for the Pierce apparatus being purchased by the VBFD to prevent the water from entering the air intake or affecting the electronics. The interview questions can be found in Appendix E.
- A review of IFSTA training manuals was conducted for information on operating vehicles on flooded roadways, training programs for drivers of fire apparatus, and maintenance procedures for the vehicles subjected to flood waters.
- A review of NFPA Standards to discover how they would apply to the driver of fire apparatus, training programs for drivers, and maintenance needs and procedures to be followed after being exposed to flood waters.

- A review of the VDFP training material being utilized to train our driver operators for information on driving in flood waters and any maintenance procedures to be performed that affect apparatus.
- A review of information offered through FEMA publications and manuals for maintenance procedures and driver training related to operating apparatus on flooded roadways.
- A review of information offered by the IAFC for storm operations, driver training, maintenance and preparations for operating apparatus during major storms.
- An internet search for information from insurance companies on precautions drivers should heed prior to driving on flooded roadways.
- A review of the Operators and Maintenance Manuals from the apparatus manufacturers for the apparatus utilized by the VBFD for information on driving on flooded roadways and maintenance procedures to be followed after the apparatus has been exposed to flood waters.
- A review of the After Action Report created by the VBFD from the November 2009 Nor'easter to determine the scope of damage and cost to the department from answering the calls for service during the storm.
- A review of the Accident Investigation Report from the Bureau of Land Management (BLM) loss of Engine 3662 at the Gila River Crossing for information and best practices during flooding.

The class roster from my EFO course was utilized to select the members representing their particular organizations. These members were sent an e-mail asking questions about their locality and their experiences with flooding. The first question determined whether or not they had experienced conditions similar to the VBFD. Information was requested as to whether they had policies in effect that provided direction to their members for driving on flooded roadways and the maintenance that would be required for their apparatus afterwards. I received a 100% response ratio from my classmates; however, the majority of them did not have any experience with this phenomenon. One classmate from Tucson did have a policy example that addressed vehicle concerns associated with operating in flood waters. Another classmate provided an accident investigation report from a BLM unit that was disabled while trying to cross a flooded portion of a roadway at a creek crossing.

I obtained a roster of the FEMA Urban Search and Rescue representatives from our VATF-2 office manager. These team representatives were sent an e-mail asking questions about their locality and their experiences with flooding. Information was requested as to whether they had policies in effect that provided direction to their members for driving on flooded roadways and the maintenance that would be required for their apparatus afterwards. I received a 50% response ratio and the majority of them had not experienced flood ops nor had applicable policies as a result, but some did offer personal insights and additional areas of information that could be researched.

An e-mail was sent to my counterparts in the Hampton Roads IMT requesting information. Based on my inquiries across the nation from the above sources it was determined the Nor'easter is a mainly east coast event and the entire sixteen HRIMT member organizations are east coast based. Only one of the localities Norfolk Fire and Rescue, had a policy directing the actions of its members as related to flood event operation and maintenance for their vehicles.

During the internet search through the web-sites of the various private insurance companies I was surprised to find that only a few addressed flood issues as related to driving. The Turn Around Don't Drown (TADD) program from Progressive appears to be the leading stance. One other private carrier also provided a link to that program.

In general the reviews of the manuals and publications provided by the IAFC, IFSTA, FEMA, VDFP, and the various manufacturers provided little helpful information. Most of them addressed the same types of information on driving in inclement weather or other hazards that could be encountered. All were relatively void of driving on flooded roadway recommendations.

The interview with Doug Moss, City Garage Fire Shop Manager, took place in his office and in the apparatus bays of his shop. The questions were answered and we went out to the trucks for some hands on interaction so he could show me the components that water affected and their location on the apparatus. He thoroughly explained the process for water entry and the resulting malfunctions that could be expected.

The interview with Joe Pack, President of Atlantic Emergency Solutions, provided information to resolutions the Pierce fire apparatus engineers had designed to alleviate water concerns for their Quantum Chassis apparatus. The interview began over the phone with the original inquiry and ended at the Pierce Plant located in Appleton, Wisconsin, during a site visit inspection of a pending apparatus shipment. The cab and chassis were inspected for each of the remedy choices so that a complete picture of the benefits, concerns, and limits could be examined.

The review of the VBFD 2009 Nor'easter After Action report identified a problem with the timing. The department was eager to obtain the information the report identified so it could work on the recommendations for improved actions in future events. The data on the effect of the storm flood waters on the apparatus proved to be premature. Most of the costs from the damage and preventative maintenance work to be performed had not been accurately tallied or realized. This resulted in a significant difference in the total cost to the organization and necessitated an additional interview with Mr. Padgett.

An interview was conducted with Reggie Padgett, the Director of Automotive Services, to obtain the more accurate costs and maintenance problems encountered for this report. It was held in his office at the city garage. This offered him complete access to his Fleet Management computer program (Fleet Focus) and allowed for accurate information to be obtained for each of the effected apparatus that encountered damage from the storm, or operated in the flood waters and needed preventative checks and fluids changes.

The suppositions of this research from the procedures used are focused on the materials that were obtained and the information provided by the respondents. It is assumed the information is unbiased and accurate. No preference should be inferred from the discussions on the particular apparatus manufacturers mentioned as the information is relative only because this is the apparatus used by the VBFD.

Results

The procedures section outlines the methods that were utilized to obtain the answers to the questions identified in the introduction of this ARP. The goal is to determine how the VBFD should address the prevention of water damage to heavy apparatus, training for our member's actions when encountering flooded roadways, and whether or not policy direction is needed to assure the members comply.

Question number one:

What are the major causes of the damage to the apparatus? The answer to this question was obtained from interviews with the Automotive Services Director, City Garage Fire Shop Manager, and the President of Atlantic Emergency Solutions, the company that sells the apparatus to the department. In addition, reviews of reports from the VBFD and Automotive Services Fleet Focus program highlighted the damage inflicted on each affected apparatus by the storm. The manufacturer's operations manuals and specifications sheets provided additional insight for the location of the affected vehicle systems.

Heavy apparatus (Engines, Ladders, Fire Squads, and Tankers) are used by the VBFD to deliver its service to the citizens in their time of need. This service delivery must be accomplished regardless of the weather conditions being encountered. Fire apparatus are professed by the manufacturers as being designed for this purpose. Most manufacturers believe they are doing a good job with this endeavor; however, history is resplendent with examples of improvements both in apparatus design, and fire service delivery through the ages as the profession has evolved. Specific events are researched and actions undertaken to improve the apparatus to make it more rugged and resistant for service delivery in order to stay ahead of the competition.

It was determined that the major cause of the damage to the VBFD heavy apparatus fleet was from water exposure. Water easily entered the various components of the apparatus as they were driven through the flooded areas in route to the calls for service. Most of the affected apparatus were able to continue the response oblivious of the effect to the apparatus. One apparatus was stopped in its tracks and unable to continue to the emergency when water entered the air intake and the safety systems built into the apparatus shut it down. The most costly apparatus event occurred when an Engine struck an underwater object. This unit continued to respond to events for the remainder of the storm.

The design of the fire apparatus was determined to be a contributing factor. The interviews conducted with the individuals responsible for building, purchasing, selling, and maintaining the apparatus included hands on demonstrations of the locations of the affected components with information on how the water entered or affected the vehicles. The interviews were conducted at the Pierce factory, the seller's offices, and the fire shop garage. The air intake on the Quantum chassis used by the VBFD is positioned in a location on the apparatus that makes it highly susceptible to water entry. Being placed behind the front bumper under the driver's feet causes it to be submerged in relatively shallow water or easily exposed to a wake from another vehicle where the water enters by force and continues onward to the engine. The electrical components that allow the apparatus to operate efficiently are also located in a susceptible position on the apparatus that allows for water entry after total submersion. The electrical junction boxes containing the "can bus" nodes are located under the battery box on the driver's side, and at the rear of the apparatus chassis near the fuel tank. These two locations also allow for easy submersion in water.

Another contributing factor to the damage to the apparatus was a lack of training provided to the members of the VBFD responsible for driving the apparatus. The driver should be accountable for the operational knowledge for his particular apparatus. Some of the drivers were new to the position and had not been properly trained so that they were aware of the location of the air intake, or the electrical components that the water affected. Periodic refresher training for the more senior members driving the apparatus was also lacking and contributed to them "not remembering" the location of the vital components the water would affect. The training that had been provided came from state programs that have been in effect for years and had previously proven as adequate. These programs are relatively void of flood operations and driving material. The deficiency of directly addressing the flooded roadways left the drivers lacking the knowledge, skills, and abilities required. Add a lack of experience from previous encounters and the driver was unprepared to assist their officer in the decision process for whether the apparatus should be used to continue response through the flooded streets or discontinued and an alternative solution sought.

Furthermore, the officers responsible for the decision to proceed or stop the response when the flooded roadways were encountered made some bad decisions. Some were new to the officer position and all, including veterans, were inexperienced with the type of conditions encountered. The VBFD had not adequately prepared them for this chance meeting with a severe Nor'easter. Alternative solutions such as continuing on foot, or calling for another unit to attempt to gain access from a different response route were lacking. The decision to proceed through the flooded roadways regardless of the depth of the water contributed to the vehicle damage.

The final contributing factor to the damage caused is a lack of a policy that covered driving on flooded streets. Policies contain the "best business practices" for a department and it members. A policy having been in place to provide direction would have assisted the apparatus officer and driver in possibly preventing damage. Best case scenario is it may have alleviated the extent of the damage by causing members to stop from entering the water. The existence of a policy would also have assisted with the absence of the training. Members will follow a policy even if they do not completely understand why it should be done.

Question number two:

What vehicle components are being damaged? To determine the answer to this question information was originally gleaned from the VBFD 2009 Nor'easter After Action Report (AAR). This report highlighted that water had entered the electrical systems on both Ladder 1(Pierce) and Engine 3 (ALF) causing severe electrical issues. It also stated that Engine 1(Pierce), Fire Squad 3 (ALF), and Engine 14 (ALF) had water in the front hubs. This damage to those units was reported as minimal and only required some preventative maintenance to be performed. The units were placed out of service and the fluids drained, flushed and changed. The wheel bearings were also checked and found to be undamaged. The most serious damage highlighted by this report involved Engine 21(ALF). This vehicle entered deep water and struck a submerged object causing damage to the front bumper, auxiliary cooler, and air horns. This unit also had water in the front hubs and rear differential.

As stated earlier, the timing on this report contributed to a false sense of wellbeing for the department. The Chief wanted a quick turn around on the After Action Report so the department could address the operational deficiencies identified and be ready for the next storm. This quick turnaround caused some significant vehicle damage related information to be missed. The most serious event missed involved Engine 1, a new 2009 Pierce Quantum Foam Pumper. The report highlighted that water had entered the front hubs, but that just scratched the surface of the extent of the damage. Actually this truck entered a flooded roadway and water entered the air intake traveling to the engine. The unit's safety systems shut it down on the spot and rendered it out of service. The time the truck spent sitting in the water contributed to the amount of water intrusion into the submerged components. This unit had to be towed from the location and then be sent outside the city to Western Branch Diesel to determine the severity of the damage to the engine components. Extra work had to be performed on this engine to save the factory warranty from being voided.

Additional damage began to be identified in the weeks following the storm and completion of the After Action Report. The storm began on Wednesday, November 11, 2009, and lasted three days concluding on Saturday, November 14, 2009. As piece meal information began to be reported by the companies, and the Fire Shop mechanics on the apparatus problems being discovered that rendered the units out of service was received; a hypothesis was developed questioning whether the damage had been related to the storm. The damage reports continued to come in long after the beginning of the 2010 calendar year. One unit with storm damage was not discovered and identified until June of 2010, almost 7 months later.

An interview was held with Reggie Padgett, Director of Automotive Services, in his office at city garage. He gathered some key staff members to gain a complete picture of the storm related damage. His department has an internal computer system called Fleet Focus. This system allows for readily accessible data on the type of damage that the units had encountered, the total cost for the needed repairs including labor and parts, and the total amount of time the unit was out of service as result of the repairs performed. His staff was key in explaining the report information and making it understandable. The reports can appear to be an overwhelming jumble of repetitive information to a member outside of the Automotive Services Division; so for this ARP the information has been gleaned from the system and placed into easily readable word tables.

This interview and the data from the Fleet Focus system painted a much more devastating picture of the damage to the VBFD heavy apparatus fleet than the After Action Report. Engine 1 was thought to have received the worst damage as it was a brand new vehicle (2009 Pierce Quantum Foam Pumper) and the warranty on the engine components was subjected to possibly being voided by Detroit Diesel. Engine 21, a much older apparatus, actually received the most costly damage. Due to the age of the vehicle, and the current mileage on it, City Garage could have easily determined this unit not worth fixing (Automotive Services uses a factor of total maintenance costs exceeding 2/3 of the original cost of the vehicle). This would have put an even more stringent strain on the city budget funds in order to have the unit replaced. The time it takes to order a replacement unit, have it built, and delivered under our current contract is just over 270 days. This would have caused the VBFD to pull a reserve unit forward into frontline service and definitely would have resulted in increased maintenance costs to keep the older unit on the frontline.

The data from Fleet Focus also included damage to the small vehicle fleet that this ARP is not addressing as a primary concern. It is mentioned as additional data to demonstrate the total effect on the organization. It was learned that an additional four station generators, one Chevrolet Suburban command unit, two sedans, one brush truck, and one hazardous materials command trailer had also suffered damage as a result of operations during the storm totaling $16,143.38 for repairs.

Several apparatus had electrical problems that shut down specific systems on the trucks. Water had entered the electrical junction boxes and drenched the “can bus” nodes. The affected units reported different problems. One unit lost warning lights and communications. This unit continued to respond “non-emergency mode” to calls for service and operated off of their portable radios. Another unit reported the truck throttle was surging and immediately placed the unit out of service on return to the station.

An American LaFrance Tele-squirt pumper reported every warning light and buzzer activating, but since the unit “seemed” to be operating okay they continued to respond to the call for service and did not place the unit out of service until they returned to the station after several additional incident responses. A contributing factor to this decision is the constant “false alarming” of system components. The new systems on the vehicles must be given a short amount of time to synchronize after starting the vehicle prior to activating warning lights and responding in order to allow the load manager to balance the electrical load and not damage the alternator (Pierce, 2010, p. 3-78). If this is not accomplished several systems may not activate and warning buzzers may sound.

The safety issue to the operating crews was completely missed by the drivers and their officers. The units that continued to respond to calls for service “non-emergency” mode and with the warning buzzers sounding never stopped to check if other vital systems on the truck had been affected. It was learned from the interview with Joe Pack, Atlantic Emergency Solutions President, and several Pierce engineers during discussions at the factory in Appleton, Wisconsin, that the trucks could have malfunctioned in much more serious situations. The engineers took us to the truck being purchased and demonstrated the location of each of the components and went over the affect water intrusion would have on the vehicle systems. Once the “can bus” nodes get wet certain systems on the vehicle will not be able to communicate with each other. A drastic example of how a possible failure scenario could unfold follows:

A fire unit responding to a structure fire has driven through deep water and arrived at the scene of the working fire. The crews pull their hose lines and perform front porch drills masking up to go attack the fire. The apparatus driver is going through his process of assuring the hose has cleared the bed and is ready to be charged with water when the pump kicks out and fails to operate. The electrical system has just failed and it will not reset. Hopefully the crews were not inside actively engaged in the firefight when the failure occurred and subject to injury or death.

Failures could come in other forms affecting each and every system on the apparatus. It just depends on which “can bus” nodes get wet. Aerial devices could fail to energize or other vital drive components could also fail allowing damage to occur without warning.

The information listed in Table 1 was drawn from the Fleet Focus system and highlights the total damage to the VBFD heavy apparatus determined to be from the storm. Each apparatus is listed individually by the date the damage was reported. The damage listed entails the work that was performed on the apparatus by the mechanics at the City Garage Fire Shop.

Unit	Date	Damage
146976 Ladder 1 (Pierce)	11/13/2009	Road Service Call, modules wet & lost contact with computer, dried out & tested
165201 Fire Squad 10 (Pierce)	11/13/2009	Road Service Call, modules wet & lost contact with computer, dried out & tested
165466 Engine 1 (Pierce)	11/16/2009	Road service call & towing, Water in hubs, replaced front seals, greased drive shafts, change & flush rear differential fluids, replaced turbo, engine disassembled & inspected, replaced bearings, piston rings, liner kits
F126 Engine 8 (ALF)	11/17/2009	Water in hubs, replaced front rotors, pads, axle seals, fluids, rebuilt air horns
165465 Engine 9 (Pierce)	11/17/2009	Water in hubs, replaced low coolant sensor, greased drive shafts, oil & filters replaced, replaced fuel filter
146902 Engine 3 (ALF)	11/19/2009	Electrical issues, replaced circuit nodules, replaced flushed fluids in front axle, pump transmission, rear differential
F150 Engine 21 (ALF)	11/19/2009	Water in hubs, cleaned bearings, replaced hub windows, changed fluids & flushed: pump transmission, rear end differential, rebuilt air horns, straightened front bumper, repaired cooling lines
F165 Fire Squad 3 (ALF)	2/10/2010	Water in pump transmission, road service call towing, replaced & flushed fluids, rebuild pump transmission
165202 Ladder 11 (Pierce)	7/30/2010	Road Service Call, High Water Air restriction, air intake cleaned

Table 1- Heavy Apparatus Damage

Patterns can be seen from the data on the more commonly affected components that will require preventative maintenance to be performed on them after each exposure to flooded roadways. The patterns also indicate this needed preventative maintenance is not apparatus manufacturer specific but will be needed by any apparatus as the affected components are common to all vehicles.

Question number three:

What is the cost to the department to repair the damaged apparatus? The information obtained to answer this question came from interviews with Automotive Services Director Reggie Padgett, Fire Shop Manager Doug Moss, and data obtained from the Fleet Focus computer system. Director Padgett and his staff provided information from the Fleet Focus system which identified the parts, labor, and costs breakdowns for the damage and associated repairs. Manager Moss provided in-depth demonstrations and exhibits of the damage using the actual vehicles as they were parked in his shop and were being worked upon.

Most of the apparatus simply needed preventative maintenance to be performed to remove the water from the drive train components through simple drain, flush, and replace the fluid actions. These repairs entailed minimal parts and labor to flush the water out of the components and replace the fluids and seals. Three units suffered more severe damage from:

- striking objects hidden under the water,
- water entering the engine,
- and water entering the pump transmission.

The 2009 Nor'easter After Action Report emphasized the total damage cost to the department of $7, 338.28. This information was gleaned from the same Fleet Focus computer system that the information for this ARP uses; however, the timing of the reported information is one cause for the discrepancy. Another cause is the confusion created by not knowing the layout of the reports provided by Fleet Focus. The author of the AAR did not have this knowledge and made assumptions about some of the data being repetitive when it was not. The AAR obtained the info on December 15, 2009. This date was before most of the ongoing repairs had been reported, tallied, and entered into the system. A valuable lesson learned by the organization is to allow time for an accurate and complete assessment of the fleet prior to reporting the damage costs.

The information for this ARP was obtained from Fleet Focus in July of 2010. The information has been transcribed into easily readable tables. Table 2 is built listing each heavy apparatus, the cost of parts, the cost of labor, and the total costs for each vehicle. The parts and labor combined for an overall cost to the department as a result of damage from the storm was $179,868.03. This total reflects the inclusion of the small vehicle fleet and station generators that had to be serviced as a result of the storm.

The information in Table 2 does not include the total effects on the department's budget. This ARP concentrates on the heavy apparatus toll; however, in order to understand the complete cost to the department the additional toll on the small vehicle fleet and station generators is included:

- Small vehicles – parts = $2,285.56, labor = $4,707.08
- Generators – parts = $3,267.90 , labor = $5,882.84

There was an additional $6,964.40 in equipment costs incurred from towing charges and onsite maintenance travel by mechanics.

Unit	Parts	Labor	Unit Total
146976 Ladder 1 (Pierce)	$3,530.79	$4,524.58	$8,055.37
165201 Fire Squad 10 (Pierce)	$5,375.14	$2,957.58	$8,332.72
165466 Engine 1 (Pierce)	$3,315.47	$14,809.48	$18,124.95
F126 Engine 8 (ALF)	$7,290.79	$8,465.54	$15,756.33
165465 Engine 9 (Pierce)	$1,642.23	$3,087.33	$4,729.56
146902 Engine 3 (ALF)	$6,601.09	$9,652.18	$16,253.27
F150 Engine 21 (ALF)	$28,748.46	$29,445.81	$58,194.27
F165 Fire Squad 3 (ALF)	$7,602.41	$15,357.12	$22,959.53
165202 Ladder 11 (Pierce)	$2,046.40	$2,307.86	$4,354.26
Totals	$66,152.78	$90,607.48	$156,760.26

Table 2- Heavy Apparatus Damage Cost

Question number four:

What can we do to minimize or prevent the damage from occurring?

To answer this question interviews and research was conducted to determine the specific causes of the damage that occurred. The cause for the damage has been determined to be in three specific areas:

- Apparatus design
- Driver and officer decision making
- Lack of a policy to offer guidance

Apparatus design played a role in the vehicles affected by the storm. The list of equipment that had to be placed out of service due to the storm damage drawn from the damage listed in Table 1 demonstrates that five Engines, two Ladders, and two Fire Squads were damaged during storm operations.

The first area of concern of when looking at apparatus design is the location of the electrical junction boxes for the Command Zone multi-plex systems (Pierce, 2010, p. 4-12) and the Electronic Fire Commander (Freightliner LLC, 2003, p. 2.32). On the American LaFrance manufactured apparatus an electrical junction box is located under the driver's step, the driver's side battery box, and the rear of the truck near the fuel tank. The Pierce apparatus has the junction box located under the driver's side battery box and the rear near the fuel tank too. The interviews with Manager Moss in his shop, and the Pierce engineers at their factory provided the location of these vital components. The first design need would be to discover how to relocate these junction boxes onto an area of the apparatus chassis that would protect the "can bus" nodes from water immersion and intrusion. At the time of the interviews, Pierce was very aware of the concern over this issue the VBFD had, and the engineers advised us they had worked out a set of optional solutions. They were willing to communicate it to us and took us around the factory to see the solution being built into new apparatus. Feedback from American LaFrance was lacking for this report. Repeated attempts to contact them and obtain information went unanswered.

The next area of concern for the apparatus design involves the air intake. The air intake for the Pierce Quantum chassis uses a snorkel system that is located directly behind the front bumper, just in front of and below the driver's feet. This places the air intake in a position that readily exposes it to the hazard of water intrusion. The arrangement is actually designed to keep moisture from entering the air intake system by collecting it at the base of the vertical pipe and allowing it to drain naturally during normal driving (Pierce, 2010, p. 4-21). The Pierce Dash and the American LaFrance chassis both have the air intake on the outside of the cab over the top of the wheel. This better protects the intake from water intrusion during operation on flooded roads. The caution to this design is to watch for oncoming vehicles, or your vehicle making a wave that would bounce back from striking a stationary object. The splash of the returning water wave entering the air intake is a possibility. The air intake design and location needs to be examined for a better system that protects the vital components of the apparatus. Again this concern was passed on to the Pierce engineers during the factory visit. They advised they were working with the San Antonio Fire Department on a solution which they readily showed us while at the factory.

Driver and officer decision making is the next area of concern that needs to be addressed. Risk management was lacking in the decisions the officers and drivers made to enter the deeper water without concern for the repercussions. The best way to address a lack of decision making ability and improve the risk assessment capability of the officers and drivers is with training and experience. The premier risk management tool is solid, realistic, ongoing, verifiable, training (SROVT) which introduces new ideas to the young and inexperienced and provides those more senior employees continuing education to keep them up to speed with new technology (Graham Research Consultants website, 2010).

The training programs used by the VBFD lack information on driving and operating vehicles in flood waters. Drivers and officers as drivers before being promoted are provided training for driving through cones courses to learn the apparatus reaction in tight and confined spaces. Over the road practical training is provided to assist with learning the capability and handling characteristics of the apparatus. Additional training is provided for operating the various components on the apparatus such as aerial devices, air brakes, generators, and pumps. Improvements in the training processes to include instruction for flood operations are needed.

Another area of concern for the drivers and officers is a lack of experience for operating in the Nor'easter floods. The nor'easter storm is a common occurrence on the east coast; however, the severity of the storms fluctuates. It had been some time since the streets and roadways had flooded from a Nor'easter storm as they did during the November 2009 event. A method of sharing this experience for current and future drivers and officers needs to be examined.

The vehicle maintenance process and training is in need of improvement. The VBFD relies on an unofficial mentoring process for vehicle maintenance training. This process allows the senior firefighters to teach the new members how to properly maintain the vehicles. As time has passed and the senior members have retired the formality of the process eroded to be almost non-existent. Some stations do a better job than others. The officer core has drastically changed with high turnover from retirements and promotions too. The officers in place lack the vehicle maintenance knowledge needed and are not an integral and valuable part of the process as the organization intends. This needs to be enhanced.

Apparatus have changed drastically over the years with technological improvements. The original training provided by the manufacturer on delivery of a new apparatus is given to the crew in the station at the time. The informal process kicks in again to for the members that received the training to pass it on to other members. This process needs to be enriched.

The organization also needs to remind the drivers and officers of the important role they play in protecting and maintaining the apparatus they drive and ride to calls for service. This was the backbone basis for the informal program. This is a value that the department holds as important. It must be re-communicated through the actions and training provided by the officers.

Finally, the VBFD does not have a policy that directs, guides, or holds members accountable for their decision making and operations during flood events.

VBFD SOP O/RM 6.03 (VBFD, 2010, p. 2) states:

Drivers of fire department vehicles shall be directly responsible for safe and prudent operation under all conditions. When the driver is under the direct supervision of an officer or acting officer, that officer shall also assume responsibility for the actions of the driver.

This statement in the policy could be used to hold the drivers and officers accountable for their actions during the storm that caused the damage to the apparatus, but would encounter some difficulty with enforcement when the lack of training provided to the members so that they would be able to recognize the situation being encountered as harmful is acknowledged.

The lack of a policy to guide members for driving and operating during storm flooded roads was discovered to be a common thread among all of the regions departments. Only one department, our oldest sister, Norfolk Fire and Rescue, had a policy in place that provided some excellent guidance and procedures for the officers and drivers to follow. The VBFD needs to strongly consider implementing a policy for this purpose.

The VBFD has a Vehicle Maintenance Policy in place that was last updated in 2000.

VBFD SOP SS/RM 3.21(VBFD, 2000, p. 5) states:

If a vehicle is found to be unusable due to safety or operational concerns, the driver should immediately notify their Company Officer, who should immediately make a decision as to whether the unit should be placed out-of-service. If the Company Officer is unsure or has any questions, he should contact the Automotive Services Pump Shop Supervisor for direction.

This statement offers some teeth to holding both the driver and officer of an apparatus accountable for preventative maintenance. The policy does not direct the members in maintenance procedures that need to be followed after a flood event. This contributed to some damage being more severe when it was discovered at the time the vehicle component failed from the lack of proper maintenance. The late damage being encountered identified that even though this policy is in place and provides direction for weekly, monthly, quarterly, semi-annual, and annual maintenance procedures the damage still occurred. It can be deduced that the members are not performing the maintenance, or they are performing it incorrectly. The VBFD maintenance policy also lacks direction for its members in assuring they learn and keep up-to-date on new technology. This policy needs to be up-dated to include direction to cover the identified areas. The department needs to provide training for members on all of the vehicle maintenance aspects indentified in the policy so they clearly understand and have the KSAs to carry out the policy direction.

Discussion

The intent of this research project was to identify the apparatus damage that was caused by the storms, determine the cause for this damage, and discover methods that would assist in keeping it from happening in the future. The interviews conducted, literature reviewed, and on-site visits provided a complete picture of the effects of the storm on the VBFD heavy apparatus fleet and delivered information to be considered in obtaining options for a solution. The results indicate that the VBFD:

- needs to work with the apparatus manufacturer to develop a design modification to alleviate the water intrusion into vital apparatus components
- needs a training program designed to prepare the driver operators and officers for storm operations,
- needs a training program designed to provide preventative maintenance on the apparatus fleet
- needs a policy to provide guidance on flood operations to its members and improved maintenance activities

The VBFD is compliant with the national standards when a new apparatus is purchased. Compliance with NFPA 1901, *Standard for Automotive Fire Apparatus* (NFPA, 2009) is assured by the manufacturer and the VBFD Apparatus Team during the specification and inspection processes. The manufacturer, per the standard, also requires the department to sign an affidavit of noncompliance for any items specified on the apparatus that are not in line with the standard. The VBFD will not do this and holds the Apparatus Team accountable to assure the vehicle is standard compliant.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program* (NFPA, 2007) is another standard that is met through the purchase specifications program. A department Safety Officer is part of the Apparatus Team and is responsible for this action. Again, the manufacturer and sales staff assist to assure the department is in compliance at the time of delivery.

The VBFD Apparatus Team is comprised of members of the organization and provides the research to determine that the apparatus selected adequately meets the needs of the department. This team make-up divides the research process into workable units to assure that no one member is overloaded and can concentrate on his area of concern. The current character of the team is as follows along with a brief description of each member's primary duties:

- District Chief to provide oversight, manage the team, and organizational decision making
- City Garage Fire Shop Supervisor is responsible for all of the chassis components for all the apparatus. He researches and provides information on the engines, transmissions, tires, and drive trains.

- Safety Captain to assure the safety considerations and needs are met
- Technical Rescue Captain to provide research and information for the Fire Squads
- Ladder Captain to provide research and information for the Ladder trucks
- Master Firefighter to provide research and information for the Engines. This individual also has the lights and warning devices for all apparatus.
- Master Firefighter to provide research and information on the building materials used in the apparatus construction. This individual is also assigned to a Ladder and assists the Ladder Captain member when needed.

The team members were well aware of the design problems and the apparatus components that would be damaged from water immersion. The mission of the team and the informal process of training members through pass down of knowledge allowed them to provide this information to the other members of the organization. However, the lack of a formal process for this interaction and passing on the knowledge only allowed for this to occur with the other members in which they interacted through the normal course of a duty day. The mission of the team needs to be expanded and be included in developing and providing apparatus training to the members.

The team members were well aware of the apparatus design problems. The team had been meeting with the sales group and apparatus manufacturer during each new apparatus purchase to seek a solution. Offers had been made and ideas presented, but this proved to be inadequate as the time provided to the team for this process was not available nor supported by the organization. Fortunately, the VBFD was not the only department seeking a solution. Other departments had experienced similar situations and apparatus complications. The combined voices moved the manufacturer to direct its engineers to work on a solution.

The air intake was the first difficulty tackled. Pierce Fire Apparatus now offers two choices for keeping the water out of the air intake per Joe Pack (personal communication on November 10, 2010). The choice selected depends on the preference for the department and takes into consideration budgetary constraints faced by many of their apparatus purchasers.

The least expensive solution offered by Pierce involves raising the air intake to a higher level yet keeping it in the same general location on the apparatus chassis. This solution can be observed in Figure 3 on page 30. The air intake can be placed just above the front bumper under the driver's side headlights. This design when performed on the apparatus while it is being built only adds $500 to the cost for the intake movement. This method is also advantageous because it can be retro-fitted to existing apparatus that are already in the fleet. A retro-fit is more expensive than having it built in at the factory. The kit to move the air intake must be purchased from the manufacturer at a cost of $1,623. Labor to perform the move of the air intake and install the kit is extra and dependent on the dealer selected to perform the work.

This solution offers the benefit of low cost and does raise the height of the air intake to a level on the chassis that would allow for traversing deeper water; however, it does have some disadvantages that must not be overlooked. This movement of the air intake alone does not solve the electrical component issue. The air intake sits on top of the front bumper and the bumper could actually contribute to providing a ramp for the water to easily travel across when water is forced up and over the bumper. This action can occur when an apparatus enters the flood water too quickly, or confronts another vehicle creating a wake and traveling in the opposite direction. Pierce is considering adding a small piece of material to the bumper in front of the air intake to prevent this, but is experiencing problems with the required air flow needed for the engine to operate efficiently. A major advantage to this method is that it does not take up any additional space or change the configuration of the inside of the cab for those departments that value the spaciousness provided by the Quantum.

Another solution for the air intake, albeit a more costly one, has been achieved for the Quantum chassis. This option can be observed in Figure 2 on page 28 of this ARP. This high side option places the air intake on the side of the apparatus at a higher location above the passenger wheel than has been previously used on the Pierce Dash chassis or the American LaFrance Eagle chassis currently in the VBFD fleet. This option must be performed while the truck is being manufactured at the plant, and adds a cost of $3,500 to the vehicle price. This option is not retro-capable to current units in the fleet. The advantage to this design is its ability to keep water from entering the air intake system. The air intake being mounted higher on the side of the vehicle keeps it above all but the most extreme water depths and wave splashing.

This option also has some disadvantages that should be considered. The cost is a prime concern along with the inability to retro-fit for those departments with Quantum apparatus already in the fleet. Some departments that like to keep their apparatus “standard” in order to assist the mechanics and shops with parts and labor concerns would be at a disadvantage for a short period while this option is phased in to their system. This would be especially true if a department decided to use both options at the same time to solve the new apparatus purchase and current units in the fleet.

The high side option has an air tunnel that travels through the cab just behind the officer’s seat. This tunnel eliminates cab space that may be needed for additional seating or equipment storage. The engine cover inside the cab is also larger and the shape has changed creating a “hump” just behind the officer’s left elbow. The hump eliminates the large flat space that the previous cabs had for equipment mounting. The VBFD used this space for mounting portable lights in chargers, paperwork and map book holders, and the communications equipment for the radio headsets. Any mobile data terminal computers may need to be relocated or different mounts sought and purchased too.

The next apparatus design feature that needed to be tackled involves the location of the electrical junction boxes containing the “can bus” nodes. Pierce now offers an option for relocating the boxes to an area on the apparatus that is more water intrusion resistant per Joe Pack (personal communication on November 11, 2010). This move should be done in conjunction with the air intake improvements.

While at the factory in Appleton, Wisconsin, the new location for the junction boxes was revealed. The junction box that was located below the battery box on the driver’s side of the apparatus, only about 18 inches above the ground, has been moved. The new location is on the front wall of the body, above the transmission, in front of the pump. This movement takes the box and places it about 5 feet above the ground. Being located up in the body prevents all but the harshest entry into standing water from splashing the connections. The only real concern for this location, so close to the pump, is that a pump leak spraying at operating pressures normally generated by the pump could cause some problems.

The electrical junction boxes located at the rear of the apparatus chassis under the body near the fuel tank can also be moved. The location selected for the box to be relocated to is dependent on the apparatus purchaser. The box can be moved to any compartment on the body near the rear of the truck at an additional cost of $1,617. The purchaser selects the compartment based on the location of equipment normally stored on the apparatus. The box can be placed on the rear wall or roof of the selected compartment.

The junction box movement is not retro-fit capable on existing apparatus. The junction box is protected inside the compartment from damage by the equipment by being enclosed in a sturdy box. The new inside the compartment location of the electrical junction box protects the “can bus” nodes from water intrusion. Easy access is maintained for the mechanic servicing the rig. All the mechanic has to do is open the compartment and go to work.

Risk management was not a priority for the officers during the storm. The premier risk management tool is solid, realistic, ongoing, verifiable, training [SROVT] (Graham Research Consultants website, 2010). The training should be used to introduce new ideas to the young and inexperienced and provide those more senior employees continuing education to keep them up to speed with new technology. During the storm the officers and drivers of the apparatus made some bad decisions that affected the severity of the damage to the apparatus.

Two of the officers had warning lights and buzzers sound on the apparatus and one of the units had systems on the truck cease functioning. Both officers directed the drivers to continue with the current response and even responded to several other calls for service without stopping to thoroughly inspect the vehicle for additional problems. As was learned from the Pierce engineers during a factory visit many of the systems on the truck could have ceased functioning and endangered the crews operating on the emergency scene.

The training that is used by the VBFD does not adequately prepare the officers for the command decisions about apparatus operations that need to be made during a storm of the magnitude faced from the 2009 Nor'easter. As with any fire service organization the training for the officers is based on administrative duties, fire and emergency incident operations, and other such functions as deemed necessary by the jurisdiction. Experience is gained by the officers as they are exposed to various aspects of the fire service and is relied upon for future decision making. The vehicle systems and maintenance training is usually obtained while the officer is a firefighter. Continuing education is needed for the officer to keep him abreast of new technology and changes to apparatus design. A method of sharing familiarity is needed to advertise experiences encountered so that all officers may learn from another officer's encounter. All of the above will allow the officer to be better prepared and more readily involved with participating in and assuring the members are properly maintaining the apparatus.

The training provided by the VBFD for the apparatus drivers was thought to be adequate for any situation they would encounter. NFPA 1002 *Standard for Fire Apparatus Driver/Operator Professional Qualifications* (NFPA, 2009) was used by the various training groups to assure the training provided was the best that could be delivered. The standard declares the importance of maintenance, driving, and operating apparatus (National Fire Protection Association [NFPA], 2009, p. 11).

NFPA 1451*Standard for a Fire Service Vehicle Operations Training Program* (NFPA, 2007) is another standard that offers specific information for creating a training program for drivers. It covers information on: program needs, frequency, type, instructor qualifications, safety, records, laws and liabilities, emergency response, crash prevention and reporting, and vehicle and apparatus care (NFPA, 2007, p. 3). It speaks to the need for training, hazards of off-road driving, and a need for SOPs (NFPA, 2007, p. 7).

In assuring the intent of the training standards is met the VBFD trains our members in the Emergency Vehicle Operators Course (EVOC) provided by the Commonwealth of Virginia Department of Fire Programs (VDFP) curriculum (Virginia Department of Fire Programs and the Virginia Association of Volunteer Rescue Squads, Inc., 2004). In addition a pump operator course based on the VDFP curriculum is provided to the Engine and Ladder drivers. In addition the Ladder drivers can attend the VDFP Aerial Operator Course; however, it is not a department requirement. Neither of these courses offers anything to prepare our drivers and officers for the storm conditions they faced during the Nor'easter.

The VBFD apparatus drivers may choose to seek a Commercial Driver's License (CDL) too even though it is not required for drivers of fire apparatus in Virginia. The VBFD does not require this license certification; however, it is recognized that the National Institute of Occupational Safety and Health (NIOSH) encourages fire departments to require their drivers to obtain this training or offer an AHJ similar course (*Fire Fighter Fatality Report*, 2008, p. 5). IFSTA also speaks to this as a recommended national guideline (*Pumping apparatus driver/operator handbook*, 2006, p. 10) but understands some states exempt drivers of fire apparatus.

The following sections of the literature reviewed and used to train our drivers speaks to all manner of driving hazards and conditions:

- The Adverse Weather section of the IFSTA manual speaks to icy roads, rain slick roads, and curves and intersections (*Pumping apparatus driver/operator* handbook, 2006, p. 84).
- The General Knowledge section of CDL covers driving in hazardous conditions including: night driving, fog, cold weather driving, hot weather driving, and mountain driving (*Virginia Commercial Driver's Manual*, 2010, p. 30)

Conspicuously absent is any mention of driving on flooded roadways. We must seek methods to establish and increase the training and experience levels of our members who drive our heavy apparatus.

The VBFD preventative maintenance training for our drivers includes a pre-trip inspection and daily check-off routine to assure the unit is ready to be driven. The maintenance training that is based on both of the aforementioned standards does not detail any post trip inspection as a result of driving on flooded roadways. This contributed significantly to the severity of the damage to the apparatus fleet since the vehicles were not checked for water intrusion after driving on the flooded roadways.

In-station training and a bi-annual department recertification are part of the training process given to our members to keep their operational skills fine-tuned for everything except vehicle maintenance. This has caused a lack of vehicle maintenance KSAs to be prevalent among our drivers and officers. The “unofficial” mentoring process of pass down knowledge being communicated from the senior members to the new members can no longer be relied upon. Doug Moss, the Fire Shop Manager states “The senior firefighters that had the knowledge are gone and the new guys do not possess the knowledge that needs to be communicated” (personal communication on December 12, 2010).

Standard Operating Procedures (SOP) are used by organizations to provide the path to be traveled when encountering known situations for which the policy was designed to address. These best business practices involve actions that have been proven from past encounters as able to solve the situation or condition at hand. The VBFD has policies in place that its members can draw from for their actions and many are known to have been created because a particular situation in which a bad decision was made resulted in an unacceptable outcome. The decisions made during the storm justify policy changes or creation of new policies to address the situation.

The VBFD does not have a policy in place to address driving on flooded roadways. The department has relied on past training and experience to guide the officers and drivers on any situation encountered that is not covered by a policy. The VBFD cannot continue to rely on this behavior for this type of storm situation any longer. The current policy for driving the fire departments heavy apparatus, SOP O/RM 6.03 *Operation of Fire Department Vehicles*, was updated last year after the Nor’easter by the departments Safety Office. The areas the policy covers were refined and recast to provide a clearer message to the members for emergency vehicle laws, safe and prudent operation, emergency response, highway operations, and backing (Virginia Beach Fire & Rescue Department [VBFD], 2010). The policy does not include any direction or information for driving on flooded roads. A policy update is needed to provide immediate guidance for driving on flooded roadways that the training has not prepared the members to face.

Recommendations

The following recommendations will serve as a way for the VBFD to prepare the drivers and officers for more prudent decision making when operating the heavy apparatus fleet in storm flooded roads. The recommendations will also serve the VBFD in obtaining a superior design for the heavy apparatus fleet so that the vehicles can carry out the desired mission in responding to calls for service. The endorsements will improve the policy direction provided to the members to assure common practices are followed that keep apparatus functioning properly and its members safe. The Fire Chief and Senior Staff of the VBFD must decide the extent to which it will support the necessary changes as some will be costly in terms of money, time, and devotion. The recommendations will provide a path the VBFD can follow to achieve:

- an apparatus design modification to alleviate the water intrusion into vital apparatus components
- create a training program designed to prepare the driver operators and officers for storm operations,

- create a training program designed to provide the needed preventative maintenance on the apparatus fleet
- policy updates to provide guidance on flood operations and vehicle maintenance duties for its members

Apparatus designs are now available for improving the vehicle and protecting it from water intrusion; however, it adds cost to the apparatus purchase. Two designs are presented in this ARP for moving the air intake on the vehicle. The best choice is to utilize the high side option with the movement of the electrical junction boxes into a compartment. This action will eliminate the water intrusion into the apparatus systems that quickly render the apparatus out-of-service.

The apparatus design change does not eliminate water from intruding into the drive train components on the apparatus. This can only be eliminated by a no response policy that prohibits units from entering water flooded streets. Non-response is not in tandem with the mission philosophy of the VBFD to provide the best customer service possible to its customers. Since response cannot be eliminated the preventative maintenance and post trip measures performed by the drivers under the direction of the officers needs to be improved. The officers must learn to grasp their role in providing direction, guidance, and training for their assigned subordinates to prepare them for the future scenarios they will encounter while providing service to the citizens.

Members will need to be trained to realize and understand all facets of required vehicle maintenance in order to have ownership in maintaining the vehicles. Departmental training is usually conducted by the staff assigned to the training division; however, the training staff does not have the expert knowledge required for this endeavor as evidenced by the problems identified in this ARP. The department needs to reach out to the Apparatus Team for this reverent knowledge.

The Apparatus Team's duties and responsibilities need to be expanded. The team should be utilized to enhance the training experience for vehicle maintenance duties. The team has researched and studied the various components on the apparatus to assure the VBFD purchases the best apparatus to meet the mission. This experience needs to be shared. The Team can be used to provide training to the members on the apparatus systems and how to properly maintain them. This training should include both "hands on" training where the procedure is demonstrated to the members and allow the member to perform it himself under the supervision of the instructor to assure the concept and practice has been adequately grasped.

The VBFD has a film production unit assigned as part of the training division. This film production unit should be involved in the training process for the members and record all of the training conducted by the Apparatus Team for the members. The video DVDs need to be placed in the stations where the apparatus are home based as part of the permanent training library. This action allows new members arriving to the station assignment to learn about the apparatus they will now be expected to drive and operate more efficiently. The videos can be used to enhance the training process and assure the correct information is being taught and for continuing education refreshers.

A process must be enacted to assure the members stay abreast of the information they are expected to perform. A formal process has been lacking in the VBFD to assure this is accomplished. This should be improved upon by the training staff. The department has just created a monthly training manual for the station personnel to use during the in-station training drills required each shift. This manual lacks any information for in-station drills in the area of vehicle maintenance. The training staff needs to involve the Apparatus Team to create these training drills and then place them into the new training manuals. The VBFD uses a Company In-service training format to provide training to all of the members on selected hot topics. Three of these training sessions are conducted each year by bringing groups of companies to the Fire Training Center to receive instruction. This format would be beneficial in delivering vehicle maintenance training to the troops as it promotes a "standard" message being delivered so that confusion can be held to minimum.

The current Standard Operating Procedures do not contain the information and guidance necessary for the members to achieve the intent of the organization. The two SOPs mentioned in this ARP need to be recast to include needed information. SOP O/RM 6.03 *Operation of Fire Department Vehicles* needs to be updated with a section added for driving apparatus in flooded streets. The policy must include assistance for the decision making process that the driver and officer must share together to allow the apparatus to perform as it was designed and carry the members forth in providing mitigation of calls for service.

The VBFD should adopt the policy verbiage, or something similar, provided in the examples contained in this ARP. The example provided from Norfolk Fire and Rescue and presented in the Literature Review section of this ARP contains the necessary information to properly guide the officer and driver in negotiating the flooded roadway. It also provides clear direction for ceasing response and requesting additional units to respond from another direction. An added advantage of adopting this policy as it is written is it benefits regionalism. The more policies that are alike between the regions departments; the more clear an understanding each organization will have of how the other department's members will react in an emergency situation. An updated draft of the *Operation of Fire Department Vehicles* SOP is included and can be found in Appendix L.

The policy example provided from Tucson can be utilized to craft a clearer understanding in SOP SS/RM 3.21 *Vehicle Maintenance* of many of the apparatus components that are affected when operating a vehicle in standing water. The maintenance needed before an emergency response and at the completion of the event should also be detailed. This policy should be updated to include the steps necessary to check an apparatus after it has driven through standing water to assure all of the components that require fluids to operate efficiently are checked for water intrusion. Finally, the policy needs to contain clear instructions of the Fire Shops ability to assist the driver and officer in the decision process for maintenance needs. A policy draft update including the new maintenance information is included with this ARP and can be found in Appendix M.

The Fire Chief and Senior Staff of the VBFD have to decide on the implementation schedule for the changes recommended in this ARP. Most should be enacted immediately; however, cost may prohibit some of the recommendations from going into effect until the funding can be secured. In order to assure the changes are meeting the needs identified for the organization an annual follow-up evaluation will need to be performed. This evaluation will serve to guide the department in adjusting the changes as necessary to assure the citizens, members, and visitors of Virginia

Beach are provided the best possible service at the most fiscally responsible price, in an apparatus capable of adequately delivering the mission.

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Appendix A

Virginia Beach Fire & Rescue

Apparatus Assignments

Station 1:

Engine 1 (165466) – 2009 Pierce Quantum 1500 GPM Foam pumper
Ladder 1 (146976) – 2007 Pierce Dash 105’ Rear Mount Ladder w/ 1500 GPM pump

Station 2:

Engine 2 (165463) -- 2009 Pierce Quantum 1500 GPM Foam pumper
Ladder 2 (F168) – 2005 Pierce Dash 100’ Rear mount Platform w/ 1500 GPM pump

Station 3:

Engine 3 (146902) – 2005 ALF Eagle Telesquirt 1500 GPM pumper
Fire Squad 3 (165649) – 2010 Pierce Quantum Heavy Duty Rescue (HDR)

Station 4:

Engine 4 (146901) -- 2005 ALF Eagle Telesquirt 1500 GPM pumper
Engine 34 (FO93) – 1998 Pierce Quantum 1500 GPM pumper

Station 5:

Engine 5 (F151) – 2003 ALF Eagle 1500 GPM pumper
Tanker 5 (F164) – 2004 ALF Freightliner 2000 Gallon Tanker w/1500 GPM pump

Station 6:

Engine 6 (146636) – 2006 Pierce Quantum 1500 GPM pumper
Tanker 6 (165488) – 2009 Pierce IH7600 3000 Gallon Tanker w/1000 GPM pump

Station 7:

Engine 7 (165464) -- 2009 Pierce Quantum 1500 GPM Foam pumper

Station 8:

Engine 8 (F123) – 2002 ALF Eagle 1500 GPM pumper
Ladder 8 (146635) -- 2006 Pierce Dash 100’ Rear mount Platform w/ 1500 GPM pump
Decon 1 (F165) – 2004 ALF Eagle Rescue Squad
Support 8 (165307) – 2008 IH4400 Air and Light

Station 9:

Engine 9 (165465) -- 2009 Pierce Quantum 1500 GPM Foam pumper
Ladder 9 (146637) -- 2006 Pierce Dash 105' Rear Mount Ladder w/ 1500 GPM pump
Ladder 31 (F167) – 2005 Pierce Dash 105' Rear Mount Ladder w/ 1500 GPM pump

Station 10:

Engine 10 (165648) – 2010 Pierce Quantum 1500 GPM Foam pumper
Fire Squad 10 (165201) – 2008 Pierce Quantum Heavy Duty Rescue (HDR)
Tech 1 (146753) – 2006 Freightliner w/Van Body

Station 11:

Engine 11 (F125) – 2002 ALF Eagle 1500 GPM pumper
Engine 14 (F126) -- 2002 ALF Eagle 1500 GPM pumper
Ladder 11 (165202) – 2008 Pierce Quantum 100' Tractor Drawn Tiller
Engine 33 (FO82) – 1997 Pierce Quantum 1500 GPM pumper

Station 12:

Engine 12 (F137) -- 2002 ALF Eagle Telesquirt 1500 GPM pumper
Engine 30 (FO80) -- 1997 Pierce Quantum 1500 GPM pumper

Station 13:

Engine 13 (165647) -- 2010 Pierce Quantum 1500 GPM Foam pumper
Engine 36 (7966) – 1984 Emergency One 1500 GPM pumper

Station 16:

Engine 16 (165200) -- 2008 Pierce Quantum 1500 GPM Foam pumper
Ladder 16 (F155) – 2004 ALF Eagle 95' Mid-ship Platform w/1500 GPM pump

Station 17:

Engine 17 (F132) -- 2002 ALF Eagle Telesquirt 1500 GPM pumper
Tanker 30 (FO26) – 1988 Simon Duplex Boardman 2000 Gallon Tanker Pumper w/1500 GPM pump

Station 18:

Engine 18 (146862) -- 2005 ALF Eagle 1500 GPM pumper

<u>Station 19:</u>

Engine 19 (F152) -- 2003 ALF Eagle Telesquirt 1500 GPM pumper
Engine 37 (FO94) – 1998 Pierce Quantum 1500 GPM pumper

<u>Station 20:</u>

Engine 20 (F138) -- 2002 ALF Eagle Telesquirt 1500 GPM pumper
Engine 35 (FO79) – 1997 Pierce Quantum 1500 GPM pumper

<u>Station 21:</u>

Engine 21 (F150) – 2003 ALF Eagle 1500 GPM pumper
Ladder 21 (146977) – 2007 Pierce Dash 105' Rear Mount Ladder w/ 1500 GPM pump
Ladder 30 (F166) – 2005 Pierce Dash 105' Rear Mount Ladder w/ 1500 GPM pump

<u>Fire Training Center:</u>

Engine 31 (FO81) -- 1997 Pierce Quantum 1500 GPM pumper
Engine 32 (F122) -- 2002 ALF Eagle 1500 GPM pumper
Engine 38 (F124) -- 2002 ALF Eagle 1500 GPM pumper

** 30 Series vehicles are Reserves

Appendix B

Fire Department that participated in this ARP

1. Anchorage, Alaska
2. Appleton, Wisconsin
3. Arvada, Colorado
4. Benton, Arkansas
5. Beverly, Massachusetts
6. Biloxi, Mississippi
7. Carson City, Nevada
8. Chesapeake, Virginia
9. Fairfax County, Virginia
10. Hampton, Virginia
11. Larkspur, Colorado
12. Lenexa, Kansas
13. Los Angeles (City), California
14. Los Angeles County, California
15. Merrimack, New Hampshire
16. Miami, Florida
17. Miami Dade, Florida
18. Missoula, Montana
19. Montgomery County, Maryland
20. Moscow, Idaho
21. Newport News, Virginia

22. Norfolk, Virginia
23. Novato, California
24. Phoenix, Arizona
25. Pierce County, Washington
26. Portsmouth, Virginia
27. Providence, Rhode Island
28. Riverside, California
29. San Antonio, Texas
30. Suffolk, Virginia
31. Tempe, Arizona
32. Tualatin Valley, Oregon
33. Virginia Beach, Virginia
34. Watertown, South Dakota
35. West Feliciana, Louisiana

Appendix C

Interview questions for the Fleet Management Division Fire Shop Manager

Doug Moss

1. What were the damages caused to our heavy apparatus fleet by being driven in the flood waters?
2. Where is the air intake located on the Quantum chassis?
3. Where is the air intake located on the Dash chassis?
4. Where is the air intake located on ALF Eagle chassis?
5. What problems were encountered due to this air intake location?
6. What electrical problems occurred?
7. Where are the main electrical components located on our apparatus that were affected?
8. Were these affects from water exclusive to only to the Pierce apparatus?

Appendix D

Interview questions for the Fleet Management Division Director

Reggie Padgett

1. What were the damages caused to our heavy apparatus fleet by being driven in the flood waters?
2. What was the cost to the department?
3. What in your opinion could be done to lessen the cost in the future?
4. Were these affects from the storm exclusive to the Pierce apparatus?
5. What can we do for the Pierce apparatus to lessen the extent of the damage in the future?
6. What can we do for the American LaFrance apparatus to lessen the extent of the damage in the future?

Appendix E

Interview questions for the President of Atlantic Emergency Solutions

Joe Pack

1. What can be done to limit the damages caused to our heavy apparatus fleet by being driven in the flood waters?
2. What are the advantages of the high side air intake versus the front bumper option?
3. What are the advantages to relocating the electrical junction boxes in to the compartments?
4. What will be the cost to the department for the design changes?
5. What can we do for the current Pierce apparatus in the fleet to lessen the extent of the damage in the future?

Appendix F

E-mail questions for

FEMA USAR Representatives

Hampton Roads IMT Representatives

EFO Classmates

1. Has your organization ever experienced flooding that affected your response to call s for service?
2. How does your organization train your members for this event?
3. Does your organization have a policy, procedure, or general order to address vehicle operation during floods that you can send?