Career Captain Drowns After Running Out of Air During Technical Rescue SCUBA Dive—North Carolina

A career captain drowned after running out of air while searching for a civilian drowning victim during a technical rescue deep dive. Photo taken from Dive Boat 38 showing the bow of FD 4's dive boat and divers having to surface swim to the descent buoy. Photo taken before the drowning.
(*Photo Courtesy of mutual aid dive team.*)

Executive Summary

On June 6, 2016, a 28-year-old male, part-time, career fire captain died after running out of air and suffering a pulmonary embolism during a technical rescue deep dive. The victim was a member of a local fire department dive team that was trying to recover the body of a civilian who drowned the day before. The captain (Diver 4 and victim) ran low on air at a depth of 80 feet. After communicating with surface crews, he and his dive partner (Diver 3) ascended to a depth of 12-14 feet. He then experienced an uncontrolled out-of-air emergency and was unable to switch over to his or his partner's redundent air system. Diver 3 tried unsuccessfully to assist Diver 4, but Diver 4 pulled Diver 3's mask off forcing Diver 3 to kick away and swim to the surface while Diver 4 descended. According to the medical examiner, Diver 4 experienced an arterial gas embolism, most likely from holding his breath on ascent and subsequent rupture of alveoli and drowned. Mutual aid technical rescue divers located Diver 4 on the lake bottom and removed him approximately 2 hours later, and he was pronounced dead at the scene. Mutual aid technical rescue divers then recovered the civilian victim.

Contributing Factors

- *Pre-dive safety check*
- *Air management*
- *Uncontrolled out-of-air emergency (not being able to use redundant air supply)*

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- *Panic/rapid uncontrolled ascent while holding breath*
- *Training and experience*
- *SCUBA equipment issues affecting buoyancy control*
- *Lack of a safety officer trained in technical rescue SCUBA diving during the event.*

Key Recommendations

- *Fire departments should ensure that public safety divers always complete a pre-dive safety check (including adequate beginning air) with a qualified dive partner, witnessed by the dive safety officer.*
- *Fire departments should ensure that incident commanders and group leaders maintain frequent and accurate air status and accountability on all divers. Additionally, no diver should be allowed to start a deep dive with inadequate air and adequate air reserves and resources at the dive site.*
- *Fire departments should ensure that public safety divers are properly trained to recognize and have the repetitive skills training to control out-of-air emergencies and be able to use their redundant air before anxiety leads to panic.*
- *Fire departments should provide annual training on dive hazards such as lung overexpansion injuries, out of air emergencies, emergency ascent procedures, including the dangers of breath holding, and emergency release of dive weights.*
- *Fire departments should ensure that a dive safety officer properly trained in technical rescue SCUBA diving is on-scene and integrated into the command structure.*

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Introduction

On June 6, 2016, a 28-year-old male, part-time, career fire captain (Diver 4) died while SCUBA[1] diving during an attempted recovery of a civilian drowning victim. The captain ran out of air while underwater and suffered an air embolism during a rapid ascent that resulted in his drowning.

On June 7, 2016, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research, Firefighter Fatality Investigation and Prevention Program of the incident. On June 20–28, 2016, three NIOSH investigators traveled to North Carolina to conduct an investigation. The NIOSH investigators met with the fire chief, assistant fire chief, members of the fire department dive team, members of the mutual aid dive team, and local law enforcement officials. The investigators reviewed the captain's dive log, training records, training requirements, fire department standard operating procedures, training records from the department, and audio radio transmissions from the incident. During the investigation, witness statements were reviewed and interviews were conducted with the firefighters and fire officers involved in the incident.

The local law enforcement agency sent the captain's dive equipment, including regulators and dive computer, to a professional dive shop for evaluation and air quality sampling. (*Note: The dive shop was not involved in the training of any of the local divers*). After the dive gear was inspected, it was returned to the local law enforcement agency and placed in a secure evidence facility. On June 21, 2016, NIOSH investigators inspected and photographed the SCUBA equipment, including the SCUBA gear the captain was using, and the captain's dive computer. NIOSH requested the local law enforcement agency to send the captain's dive computer to a dive rescue consultant. NIOSH contracted with a dive rescue consultant for further analysis and evaluation of the data contained on the dive computer, after which the dive computer was returned to the law enforcement agency with the results of the analysis.

Fire Department

The fire department involved in this incident is a combination department consisting of 15 full-time firefighters (3 shifts 24 hours on – 48 hours off), two paid administrative staff, one paid fire chief, one training captain, 13 part-time firefighters, and 15 volunteer firefighters. The department has 10

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[1] Self-contained underwater breathing apparatus (SCUBA) is an underwater breathing system where the inspired gas is delivered by a demand regulator and exhaled into the surrounding water (open circuit), and the gas supply is carried on the diver's back [NOAA 2001].

SCUBA divers. Four fire stations are located strategically throughout the city and serve a population of approximately 13,000 in a geographic area of approximately 47 square miles, responding to approximately 900 emergency incidents per year (of which approximately 600 are emergency medical calls). From June 2015 to June 2016, the department responded to two water-related incidents (one classified as surf rescue and the other a water rescue). The fire stations house five fire engines, one ladder truck, one heavy rescue truck, three tankers, one boat, one dive trailer, and one air compressor trailer. Air quality records for the breathing air compressor were on-site and provided to NIOSH. Records indicated that all samples met or exceeded the specification of NFPA 1989-2013 Grade E (latest record was 2/19/2016).

In 2009, the department re-established the 10-member dive team. The SCUBA equipment for the dive team was purchased in 2012, and SCUBA training was initiated in 2012. The department has a five-page Dive Operations Standard Operating Guidelines (SOG) (adopted in 2011 and revised 2013) for the dive team. The SOG provides dive team members with a list of basic items they must consider in the evaluation of tactical objectives on a dive call. The SOG details the steps needed to become a member of the dive team, including dive certification training, and requires all members of the dive team to maintain a minimum of eight dives per year to remain an active member of the dive team. The SOG requires all dive team members complete a swim test of no less than 200 meters with mask, fins, and snorkle, and tread water for 5 minutes. The SOG describes a mandatory skills assessment; a probationary period of 3 months is given for any dive team member who fails a skills assessment or doesn’t get the required number of annual dives. The SOG also describes response procedures for operating on a recovery dive, including a pre-dive assessment, safety procedures, assignments for personnel on shore, equipment checks and procedures, and water hazards assessment.

The SOG also describes minimum equipment all divers will wear, including a dry suit, full face mask and regulator, spare mask, dive knife, primary dive light and backup dive light, hood, gloves, boots, bouyancy compensating device (BCD), and redundant air supply system. The SOG states once the divers have completed the pre-dive checks of all equipment, the recovery operaton may begin.

The SOG states: “*If at any time a diver is not comfortable with the tasks or situation needing to be completed, the dive will be called off and the situation reviewed. There will be two divers in the water at all times conducting the recovery operation and a backup diver on the surface at 90% readiness for emergency situations. Two divers will submerge together for the recovery operation*.” The SOG also mentions decontamination of the dive gear prior to doffing.

The mutual aid dive team (FD 3) assisted with boat and sonar operations on day one and two of the incident, and eventually was called to assist with the recovery of Diver 4 on day two. They also recovered the civilian victim on day two. The mutual aid dive team has 90 members and responds to 24–36 dive incidents per year. Their dive team is stationed at three fire stations and consists of two heavy rescue companies, three boats, Haz Mat, and a technical rescue team. They are also supported with four law enforcement divers. Their department has 1150 career staff, 41 engines, 15 ladder trucks, six tenders, four hazmat vehicles, five brush trucks, one foam tanker, six aircraft rescue and firefighting (ARFF) vehicles at the international airport. They serve a city with a population of approximately 850,000. Dive team members are required to complete six dives per year to be on the technical rescue SCUBA team.

Training and Experience

The captain (Diver 4) had 12 years of combined experience as a volunteer firefighter and as a part-time career firefighter for the responding fire department. He was also a full-time career firefighter/captain for 9 years at a neighboring fire department and had the following fire certifications:

- Firefighter 1
- Firefighter 2
- Fire Officer 1
- Hazardous Materials, Awareness and Operations
- Fire Instructor 1
- Fire Instructor 2
- Fire and Life Safety Educator 1

Diver 4 was a member of the department's dive team and had a total of 2.5 years experience as a SCUBA diver with 2 years of experience as a rescue diver.

He had completed the department's required SCUBA training including the following certifications/levels at a local dive shop with a certified dive instructor:

- Professional Association of Diving Instructors (PADI), Open Water Dive Certification; April 26, 2013
- Night Dive and PADI Dry Suit; October 21, 2013
- Search and Recovery and Underwater Navigation Dive; October 22, 2013
- PADI Advanced Open Water; November 1, 2013
- PADI Rescue Diver Certification; July 16, 2014
- PADI Public Safety Dive Training; May 2015

The department's training records show Diver 4 completed practical dive training for 8 hours on June 8, 2015, 8 hours on June 9, 2015, 3 hours on April 14, 2016, and 4 hours May 5, 2016.

Diver 4's personal dive log book recorded a total of 18 dives, with one deep dive of 80 feet and one dive of 62 feet.

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The state of North Carolina has specific requirements and recommendations to become either a volunteer or a career firefighter. Candidates must be 18 years old with a high school diploma or GED and have a valid Class C or better North Carolina driver's license. Firefighters must complete training equivalent to the NFPA 1001 *Standard for Firefighter Professional Qualifications, Firefighter I and Firefighter II* [NFPA 2013a] and must be certified to Haz Mat (Hazardous Materials) Awareness and Haz Mat Operations. The state recommends a physical exam conducted by a qualified medical practitioner, according to the current edition of the National Fire Protection Association (NFPA) 1582 *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2013b].

At this department, dive team members are required to have the minimum training requirement met through a national certification agency in public safety dive training for their dive team.

In the department's SOG on dive operations, the requirements for SCUBA proficiency and to remain active on the dive team are a minimum of eight dives per year.

SCUBA Equipment and Dive Computer Data Log Information

Note: The SCUBA equipment information, the equipment orientation and information from the victim's dive computer data logger is extensive and detailed in this section. Contributing factors and recommendations related to the equipment orientation and recommendations based on the data logger information are discussed further in the investigation and recommendations sections.

The SCUBA equipment used in this incident was owned by the fire department dive team and not personally issued to Diver 4. A list of gear examined at the local police evidence room is noted below.

- 2 fins (2XL)
- Suit (Dry Suit)
  Manufacturer date: 2010
- 158 feet of 7/16th inch rope
- Body Bag Recovery System

  Main cylinder
  80 cubic feet of air
  3000 psi capacity (was found to be empty during examination) Manufacturer date: April 2010
- Alternate air cylinder with 19 cubic feet of air
  3000 psi capacity (was found to be full during examination) Serial #V030629
- Regulators
  #15068 DC2 Model
  #HF001531 (Serial#)
  #10577
  0088 dive computer

- Facepiece (Full)
  "One Size Fits All"
  #15088
  CE #0098EN250
  Serial #512904 with communication unit GSMQ[3]
- Buoyancy Control Device (BCD) Vest
  Size XL
  EN1809 Standard (1997)
  213 Newtons (48 lbs.)
  serial # 206274
  With half mask (spare dive mask) in pocket
- Weights
  2 lbs., 5 lbs., 6 lbs. (two of each). Total ditchable weights were **26 pounds.**
- *Note: The victim's ditchable weights were not jettisoned from the BCD and were still integrated into Diver 4's BCD after he was recovered. Photos were taken of Diver 4 by the mutual aid department and his equipment and gear profile. No weight belt was recovered. It is unlikely that Diver 4 had a separate weight belt although some boat members (non-divers) reported to NIOSH investigators that they thought he may have had a weight belt. Diver 4's written dive log showed a consistent use of 22 pounds on all of his dry suit dives with the exception of 26 pounds noted on one shallow dive. Other divers on the boat that day were using weight belts.*
- LED light
  #15086 (SFTFR)
- Gloves
  2XL
  AKNG
  PO #942966
  Dive Boots, size 14
- Full Face Hood
- Knife (and scissors)
  15104

Diver 4 was using an integrated dive computer. This dive computer logged a dive profile and a number of data events for this incident (see Figures 1 and 2). The dive computer also logged a number of previous dives but could not be attributed to this diver. After the incident, the SCUBA equipment was taken to the local sheriff's department and stored in the evidence room. The local police department had the SCUBA equipment and dive computer examined by an independent expert SCUBA diving facility in North Carolina that provided the sheriff's department a report. NIOSH investigators were provided a copy of this report along with the autopsy report by the sheriff's department.

NIOSH investigators had the dive computer examined by a second independent expert in Boca Raton, Florida. Information from both reports were used in this investigation. Additionally, the independent expert also examined a photo of Diver 4 that presented the SCUBA gear and equipment profile and his entanglement with the search rope when he was recovered from the lake (see Photos 1 and 2). They also provided information that showed Diver 4's BCD may have been unable to retain air, and therefore, he may not have been able to maintain positive buoyancy.

The orientation of Diver 4's redundant air regulator was routed under the air fill for the dry suit and under the high chest strap for the BCD. Although the final location of the mouthpiece would have been close to the diver's head, it would have been difficult to deploy (see Photo 3). NIOSH obtained a sketch of the SCUBA gear and equipment profile and orientation to better show the equipment issues that were associated with this incident (see Figure 3, image created for NIOSH by Pelton Designs, a NIOSH graphics contractor).

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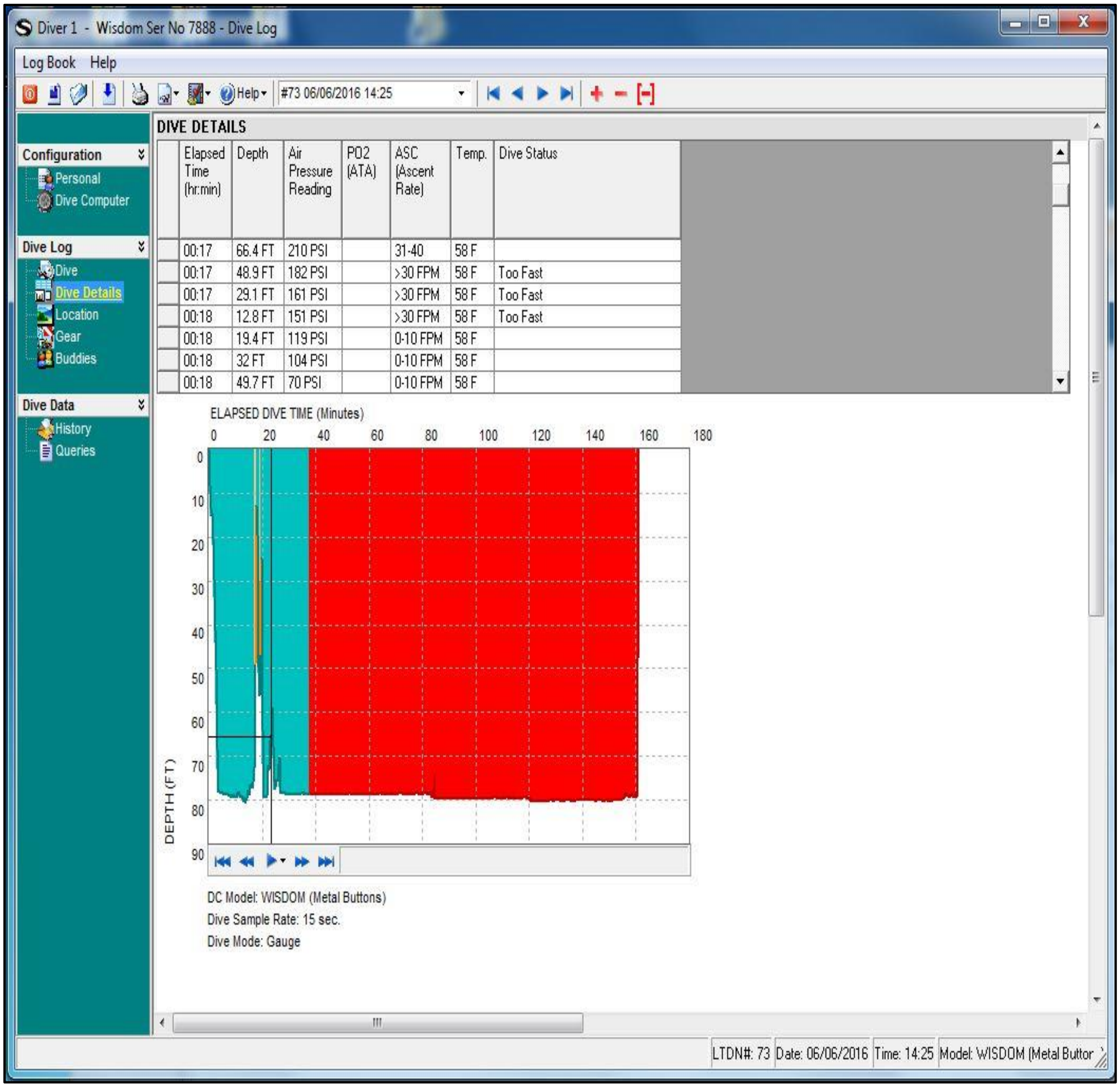

Figure 1. Screen shot of victim's dive profile ascent warning at the 17 minute mark coming through 66 feet up to 12.8 feet at minute 18 and low air remaining from his dive computer (the dive set typically will cease to provide air at 150 psi).
(*Courtesy of Craig S. Jenni, Dive & Marine Consultants International, Inc.*)

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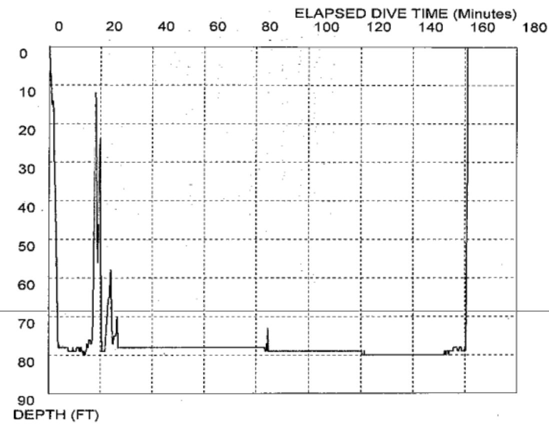

USER DEFINED SET POINTS

Time Settings

Time format:	24
Date format:	MM/DD/YYYY

Utilities Settings

Units of Measurement:	Imperial
Audible Alarm:	ON
Water Contact:	ON
FO2 Default:	ON
Deep Stop Set:	ON
Conservative Mode:	ON
Dive Sample Rate:	15 sec.
Safety Stop:	ON
Back Light Duration:	10 sec

Alarms Settings

Max. Depth:	100 FT
Elapsed Dive Time:	3:00
Dive Time Remaining:	5 Minutes
Max. NiBG:	0
Max. PO2 (ATA):	1.60
Turn Pressure:	1500 PSI
End Pressure:	800 PSI

DIVE DATA

Diver Name:	Diver 1 - Wisdom Ser No 7888
DC:	WISDOM (Metal Buttons), S/N: 7888
Life Time Dive No.:	73
Dive Date,Time:	06/06/2016, 14:25
DC Dive #:	1
Location:	
Dive Site:	
Elapsed Dive Time:	162 min.
Prior Surface Interval:	01:30
Max. Depth:	81 FT
Pressure Used:	2424 PSI
Min. Temperature:	57 F
Dive Sample Rate:	15 sec.
Max. NiBG:	8
Max. O2BG:	0
Breathing Gas:	Air
Cylinder:	
Cylinder Size:	
Working Pressure:	
Start Pressure:	2444 PSI
End Pressure:	20 PSI
Dive Time:	161. Minutes
Average Depth:	76.55 FT
SAC:	0. FT³/Min
Dive Mode:	Gauge
Dive Status:	Decompression, Violation
Dive Data Type:	DC

GEAR BAG

Name:	NONE
Weight Belt:	
Intergrated Weight:	
Other Weight:	
Regulator:	
Alt. Air Source:	
BC:	
Gauges:	
Suit:	
Boots:	
Gloves:	
Hood:	
Mask:	
Snorkel:	
Fins:	

Accessories:

SHERWOOD® Computer Interface - ©2003-2012 2002 Design, Inc. Page 1

Figure 2. Elapsed dive information page. Dive computer data logger shows the dive profile graph and beginning cylinder pressure at 2444 psi. Note the dive mode in gauge position and the decompression violation, also note alarm settings of 1500 psi turn pressure (similar to 50% alarm in SCBA), 800 psi end pressure (similar to EOSTI in SCBA) and dive time remaining alarm set at 5 minutes. This dive computer was used by Diver 4 and assigned to the dive truck.
(*Courtesy of Craig S. Jenni, Dive & Marine Consultants International, Inc.*)

Photo 1. Close up photo taken when the victim was recovered showed his shoulder dump valve was possibly pinned "open" by the body bag carabiner inside the D ring. This could have made maintaining positive bouncy difficult as any air pushed into the BCD may have escaped here.
(*Photo by mutual aid dive team. Analysis by Dive & Marine Consultants International, Inc.*)

Photo 2. A 158 foot, 7/16th inch search rope tangled up around the lift bag attached to the victim. The other end had a D-ring closure and was attached to the cage. A mutual aid diver cut the rope before recovering Diver 4.
(Photo courtesy of the mutual aid dive team, and cropped by NIOSH.)

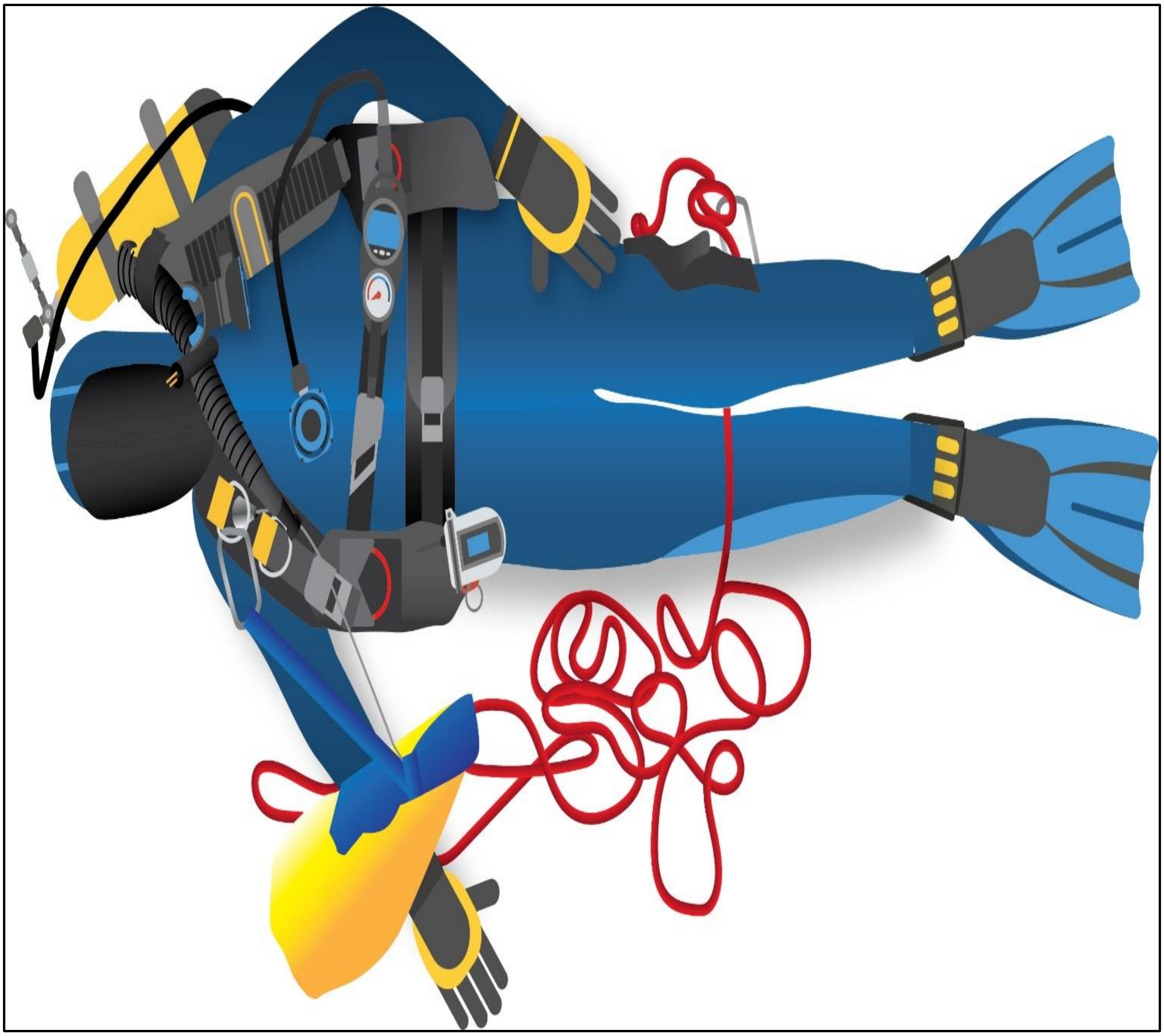

Figure 3. Sketch representing Diver 4 with body bag incorrectly attached to him and opened BCD dump valve. His ditchable weights are located in a difficult-to-release position due to incorrect sizing of buoyancy control (BC) vest. This sketch also showed the search rope he was entangled in. The redundant air regulator was profiled under his high chest strap and also under the dry suit air hose. Although it was close in proximity to his face, the fixed path orientation would have been difficult to back feed to provide more slack to orient in a useable position. A quick-release fastener may have been able to release without untangling.
(*Image created for NIOSH by Pelton Designs, a NIOSH graphics contractor*.)

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Photo 3. The photo shows the orientation of Diver 4's redundant air regulator is routed under the air fill for the dry suit and also under the high chest strap for the BCD. Although the final location of the mouthpiece would have been close to the diver's head, it would have been difficult to deploy. Diver 3 reported during interviews that Diver 4 was struggling with his redundant air regulator. Divers should always have easy access to the redundant and alternate air regulator. ***(Photo courtesy of the mutual aid dive team. The photograph was altered by NIOSH to obscure manufacturer's name.)***

Timeline

This timeline is provided to set out, to the extent possible, the sequence of events according to recorded radio transmissions and event times gathered from dive computers and interview statements. Times are approximate and were obtained from review of the dispatch records, dive computer event data loggers, witness interviews, and other available information. Some of the times have been rounded to the nearest minute. This timeline is not intended, nor should it be used, as a formal record of events. The times in this sequence are approximate times for day 1 and day 2 of the incident. Sonar operations by boat occurred on day 1, when crews were attempting to locate the civilian drowning victim; divers were present but did not dive because they were running out of daylight.

Incident Conditions	Time	Response Operations
	Day 1	
911 call center received a phone call reporting a civilian drowned while swimming from an unanchored boat.	**1530**	Multi-agency, multi-jurisdictional response with boats. The firefighter victim's department was dispatched to assist. Department 1 established command, initial sonar operations start with FD 2's boat and FD 5's boat. Department 2 was the victim's department boat with sonar and was on scene.
Department 3 was requested to respond Dive Boat 38 via mutual aid by Department 1 for the use of sonar only. (No divers were requested.)	**1632**	Department 3 dispatched a battalion chief, rescue truck and a dive boat with sonar. After arrival, they sent one FF over to FD 2's boat to assist getting their sonar working correctly
Department 3 was a large mutual aid department with a dive/sonar boat (Dive Boat 38) that was returning from a call upstate.		
Department 4's boat was a landing craft type bow from which FD 2 divers dove. (See Photo 4.)		
	2000	Dive Boat 38 and 6 FF divers arrived at approximately 2000 hours and searched with sonar 1- 2 hours until dark when all sonar operations stopped.

Incident Conditions	Time	Response Operations
	Day 2	
Five fire department boats operating on day 2 were FD 1 boat, used as security zone boat, FD 2 boat was also used as security zone boat, FD 3 providing Dive Boat 38 (career mutual aid dive boat, see Photo 5), FD 4 boat was used as a dive boat for divers from FD 2, and FD 5 boat which ran sonar.	**0900-1100**	Multiple fire department boats and multiple agencies return to the lake to start the boat and dive operations. Statewide mutual aid radio channel was not recorded so times are approximate.
	0908	Command had requested Dive Boat 38 boat for sonar operations only, Dive Boat 38 arrived on scene.
Dive Boat 38 operated their advanced sonar and located the civilian victim underwater.	**1100**	Dive Boat 38 marked the position and dropped the cage (see Photo 6). Once the cage was on bottom, Dive Boat 38 members positioned the cage closer to the civilian victim. They got the cage 18 feet from the civilian victim in 82 feet of water
FD 2's dive team began diving operations off of the FD 4 boat.	**1444**	Diver 1 and Diver 2 entered the water. Diver 1 had the 158' 7/16th inch search line, Diver 2 had the lift bag.
	1458-1459	Divers submerged.
	Approx 1500	
	1505	Divers had issues and had to come back up to the surface.
	1541	Diver 4 and Diver 3 were in the water.

Incident Conditions	Time	Response Operations
	1541	Diver 4 and Diver 3 were on the bottom and discussed how to locate the civilian victim.
The first air check was requested by the boat crew 14 minutes and 30 seconds into the dive.	**1555**	Diver 4 reported 400 psi and Diver 3 reported 600 psi. They were told by the dive leader on the boat to surface.
Both divers began to surface.		Both divers made it to the safety stop at 15-20 feet and Diver 4 said on the communications line- "Hurry, I am out of air." Diver 4 ran out of air and reportedly grabbed and dislodged Diver 3's facepiece.
Lieutenant on dive boat called a "Mayday" on the radio	**Appr 1601-1604**	Diver 3 surfaced and yelled "firefighter down, firefighter down." Diver 3 was reported to be approximately 40 yards from the surface buoy. He was picked up by a North Carolina fish and wildlife boat, transferred to another FD boat and taken to shore.
	Appr 1601-1604	A safety diver on the surface (Diver 5) entered the water, had trouble with water in his mask, cleared it and then went under to search. Shortly afterward he surfaced and said he had him but then couldn't get him. This rescue attempt was likely caught on Diver 4's dive computer data logger in Figure 5. Diver 5 was placed on another FD boat and taken to shore.
	Appr 1601-1604	The boat crew then pulled on Diver 4's communication line and it came apart.
BC from FD 3 requested ALS for dive boat.	**1604**	ALS was assigned.

Incident Conditions	Time	Response Operations
BC from FD 3 requested that his divers respond.	1604-1607	Assets from mutual aid station were dispatched.
	1640	FD 3 divers arrived.
	1640-1644	Dive Boat 38 went to shore to pick up FD 3 divers and equipment. Mutual aid BC from dive team was assigned "water operations."
Seven police boats and two fire boats established a water parameter control.	1640	Dive Boat 38 conducted a sonar search and located both targets. (See Figure 4.)
1st Rescue (FD 3) diver entered the water. Air checks were called for by communications box operator every 3 minutes.	1651	He made it to bottom/cage, did not find FD victim (Diver 4), but found the search rope and pulled slack out then ascended to safety stop.
1st Rescue (FD 3) diver was out of the water.	1702	
2nd Rescue (FD 3) diver entered the water. 2nd Rescue (FD 3) diver was out of the water.	1719-approx 1730	He found FD victim (Diver 4) and dragged him to cage on bottom then ascended to safety stop, then surfaced.
3rd Rescue (FD 3) diver entered the water.	1734	Located FD victim at the cage, cut the search line that was connected to the cage that the victim was tangled in and connected a rope to victim (Diver 4) then ascended to safety stop then the surface.
3rd Rescue (FD 3) diver was out of the water.	1755	
4th Rescue (FD 3) diver entered the water.	1815-1822	FD Victim (Diver 4) was brought to just below surface and placed in the recovery system then placed on Dive Boat 38.

Incident Conditions	Time	Response Operations
	1822-1830	FD Victim (Diver 4) pronounced deceased on Dive Boat 38.
Mutual aid dive operation phase 2-was underway for civilian victim.	1838	Recovery of civilian victim began off Dive Boat 38.
	1910	Dive Boat 38 adjusted the cage closer to the civilian victim. (See Figure 4.)
5th Rescue (FD 3) diver was in the water.	1927	
Civilian victim was located.	1939	
	1942	Civilian victim was brought to surface and transferred to a different fire boat and then to shore. All divers were taken out of the water.

Photo 4. Dive boat from fire department 4, from which Diver 4 was diving. It was not his department's boat. (*Photo courtesy of mutual aid fire department.)*

Photo 5. Dive Boat 38, a dive platform/vessel used by the mutual aid dive team. The team is a large municipal dive team that responds throughout NC. It has three dive stations, five dive companies and 92 dive personnel. (*NIOSH Photo.)*

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Photo 6. The "cage". It is used to anchor the ascent/descent rope to the bottom and is the point of reference for sonar and divers when performing searches. Its metal construction and form provide a distinguishable target for the sonar operators. Once positioned, it can be later moved by surface boats with sonar closer to the "target" to reduce blind diving. (*NIOSH Photo.)*

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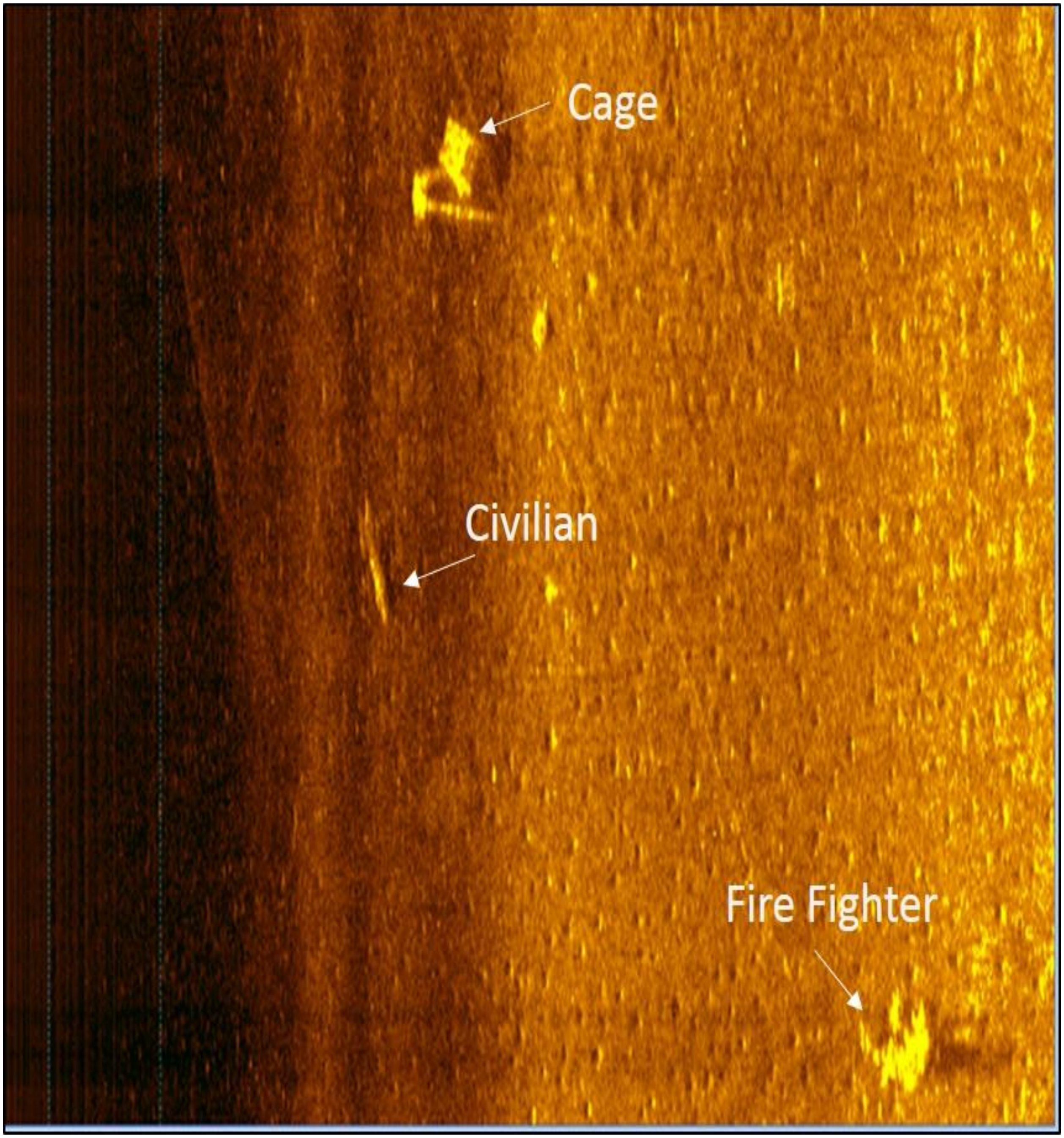

Figure 4. Sonar image showing the location of the cage (metal cage that the descent line is attached to), the civilian drowning victim's location, and the downed firefighter/diver. (*Courtesy of mutual aid dive team*.)

Weather and Water Conditions

At approximately 1610 hours on June 6, 2016, the weather in the immediate area was 68.9° F, with a dew point of 68.9° F. Wind conditions were 3.5 miles per hour from the south with scattered clouds at 1530 hours becoming clear at 1610 hours. Visibility was 10 miles [Weather Underground 2016].

The dive site was in a large, man-made lake created in 1963. The lake is the largest man-made lake in North Carolina and has 520 miles of shoreline, with a surface area of more than 32,475 acres (50 square miles) and covering four counties (See Photo 7). It has an average depth of 33 feet and a maximum depth of 110 feet and is 33.5 miles long by 9 miles wide [Wikipedia 2017].

During interviews with divers, the lake depth was reported to be 80–83 feet at the site where the civilian drowning victim was located, where the dive site was established, and where Diver 4 was located and recovered (see Figure 4). Divers reported surface light disappearing at a depth of 60 feet; further underwater visibility was reported to be dark and cloudy (by silt) at depth (approximately 80 feet) with zero visibility on the bottom.

The water temperature was not recorded but reported to be cold with thermoclines, an abrupt change in water temperature encountered at varying depths [NOAA 2001]. According to the data logger on Diver 4's dive computer, the maximum water depth on his dive was 81 feet and the dive computer logged the water temperature at 57° F.

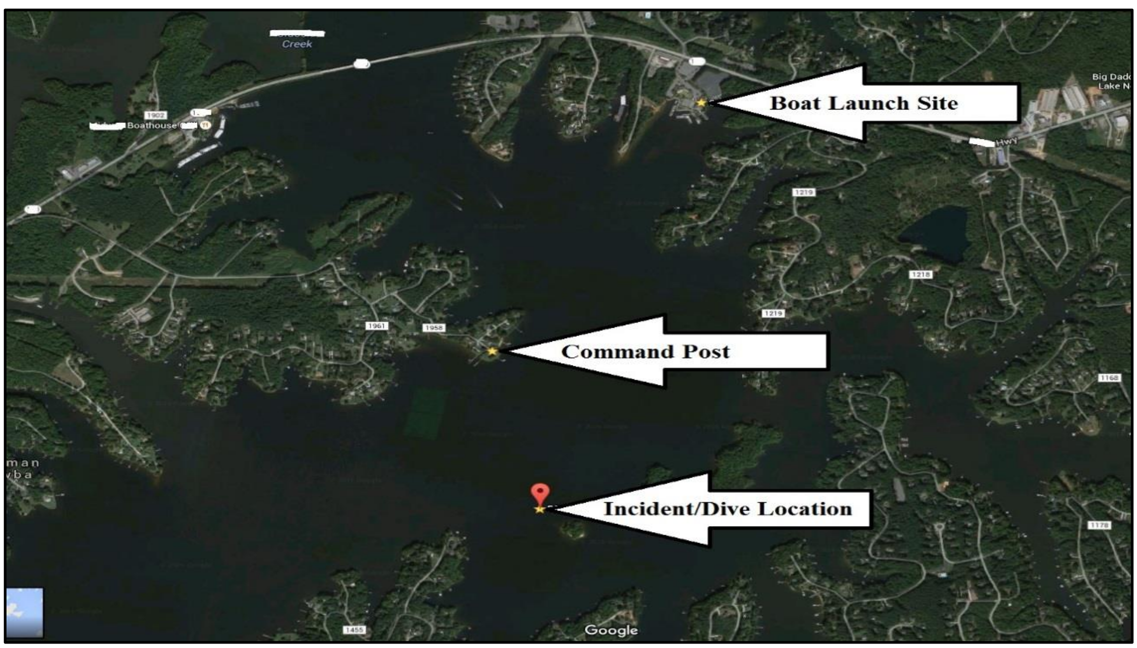

Photo 7. Location and site aerial view, *(courtesy of Google Earth)*.

Investigation

On June 5, 2016, at approximately 1530 hours, the local fire department was dispatched to the lake for a report of a civilian drowning. The first due Fire Department (FD 1) responded and established command and asked for assistance from Fire Department 2 (FD 2). FD 2 assistant chief assisted FD 1 at the command post and FD 2 boat responded to assist. Once on scene the FD 2 boat ran sonar operations in a grid pattern and did not find anything on the first pass. On the second pass they located a mark (probable civilian drowning victim) in 55 feet of water, however they experienced a technical problem on the third pass and the mark had moved off of an underwater shelf and was then located in 70 feet of water. The boat then dropped a cage but had issues stabilizing it and eventually retrieved it. The mark was continuing to move down the shelf into deeper water.

Fire Department 3 (FD 3 mutual aid department), was dispatched at 1630 to the lake to assist with sonar operations. Battalion 3, Rescue from FD 3 and the Dive unit from FD 3 responded. On arrival, Battalion 3 went to command and Rescue from FD 3 and Dive unit from FD 3 went to launch the boat. There were equipment issues with sonar on FD 2's boat. FD 3's team lead offered one of his firefighters to assist in trouble shooting the sonar on FD 2's boat. Eventually the firefighter was able to assist with the sonar and get it operational. At approximately 2030 hours FD 3's large boat (Dive Boat 38) arrived with two sonar fish and the stationary high-definition sonar system.

Fire Department 4's boat had four divers from the victim's department (FD 2) in the area where the sonar search was being conducted.

Operations to locate and retrieve the civilian drowning victim were suspended at 2200 hours.

On June 6, 2016, at approximately 0800 hours, search operations commenced. An initial briefing was held at Command. The FD 2 deputy chief was running the dive operation. Battalion 3 from FD 3 called command and asked if they needed to respond. They were told to respond with Dive Boat 38 with a battalion chief and the officer from the Rescue Truck from FD 3.

The search boats began a search with sonar. Fire Department 1 returned to the scene with their boat, a 22-foot boat with a recreational fish finder sonar. Dive Boat 38, FD 3 Battalion Chief and Rescue from FD 3 arrived on the scene and then launched at approximately 1000 hours. They interviewed the civilian's family members to try and get a better understanding of the location where the civilian victim jumped into the water the previous day.

Dive Boat 38 asked command to search a grid with their sonar for 1 hour, and the other agency boats established a perimeter. Dive Boat 38 located a target, marked it in approximately 80 feet of depth, dropped their cage and then returned to shore and asked the dive section leader for EMS to standby on scene. The crews had lunch and then returned to reposition the cage on the target. Dive Boat 38 moved the cage within 18 feet of the target (civilian victim) at a bearing of 105 degrees from the cage in 80 feet of water.

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Although FD 3 had divers on the scene, they were not asked to assist in the dive and but asked to run sonar only. Dive Boat 38 located the target, refined the target and moved the cage closer to the target. The FD 4 fire boat motored to the boat launch site and picked up the FD 2 divers and took them out to the dive site. The FD 4 fire boat arrived at the dive site (marked by Dive Boat 38's buoy) but had to wait for another mask and hood to be brought from shore. The Captain on Dive Boat 38 boat told the FD 2 divers that the civilian victim was on the bottom at 80 feet, 18 feet from the cage at a bearing of 105 degrees. This was derived from the sonar that Dive Boat 38 was using. Dive Boat 38 personnel then observed the divers from FD 2 on FD 4's boat (See cover photo in the Executive Summary). Then FD 2 divers started their dive.

At approximately 1444 hours the first set of divers were reported in the water. Diver 1 had a 158-foot, 7/16th inch search rope and the body bag and Diver 2 had the lift bag. They surface swam over to the descent buoy and started descending underwater at 1458. They were only down for 3-5 minutes when as they were descending, Diver 1 had trouble equalizing at 25 feet; he stopped and tried to equalize, surfaced and then descended back down to 40 feet. He continued to have trouble equalizing so Diver 1 and Diver 2 surfaced together. At 1505 hours, both divers were back on the surface. Diver 3 was the safety diver on this dive and on the surface.

The boat crew called for two additional SCUBA cylinders and a hood from shore. The victim (Diver 4) geared up to get in the dive rotation. The boat crew reported that they helped him get ready and that he checked his equipment before getting into the water. During interviews, the boat crew told NIOSH investigators that Diver 4 had a full tank of air.

Note: It was later discovered by NIOSH investigators that Diver 4's starting air underwater was recorded as 2,444 psi by his dive computer. This recording is a "wet start" meaning an automatic activation of the dive computer at 5-6 feet underwater. NIOSH investigators received information from the dive computer dealer and manufacturer confirming that that model dive computer "only records underwater and not on the surface. The computer will start recording at 5-6 foot of depth." If Diver 4 checked his air pressure on the boat prior to the dive, it would not be recorded in the data log. There is a possibility that Diver 4 could have checked his air pressure and then had a large loss air event on the surface and that loss would not be recorded in the data logger. However, during interviews, no one reported hearing a large air loss event and no one reported that they heard an air loss over the communications line to the surface. If Diver 4 used his tank air (instead of his atmosphere switch) for an extended surface swim to get from the boat to the descent buoy, this could account for the low starting volume recorded on the data logger at 5-6 feet.

The second set of divers in the water were Diver 3 and Diver 4 (the victim), and the safety diver, now Diver 5. Diver 3 and Diver 4 swim on the surface to the descent buoy. Diver 3 reported during interviews that he had 2900 psi of air and Diver 4 had 2850 psi air in their cylinders before they submerged. They both submerged and stopped at about 30-40 feet to equalize. Diver 4's data logger showed a brief interruption in descent at 15 foot then a descent to the bottom. Diver 3 was to be the search diver and was carrying a 100 foot, 7/16th inch search rope with a carabiner and Diver 4 was to be the anchor diver staying at the cage and was carrying the body recovery system and lift bag which he was supposed to leave at the cage.

Diver 3 reported during interviews that he searched out approximately 9 feet in 3 feet of silt and reported having trouble maintaining neutral buoyancy; and he asked Diver 4 to switch, which they did. He reported that Diver 4 searched out approximately 9 feet on the search rope (one end of the search rope was secured to the cage). *Note: Photo 2 shows that the search rope was also tangled around Diver 4's lift bag. Rescue divers from FD 3 who later recovered Diver 4 reported that they cut the search rope from the cage.*

At approximately 1545 hours Diver 4 and Diver 3 were on the bottom, discussing how to locate the civilian victim when an air check was called by the tender on the dive boat. The non-recorded communications line was connected between the dive leader on the boat and Diver 3 and Diver 4. The safety diver (Diver 5) was not connected and could not hear the communications. Diver 4 answered 450 psi and Diver 3 answered 630 psi. The dive leader on the boat ordered them to surface. Diver 3 reported that he left the cage and went to meet Diver 4 in the middle (of the search line) and after meeting, they started their ascent. Diver 3 reported that they ascended to a 20-30 foot safety stop together. (Diver 4's data logger shows he ascended to 12.8 feet, see Figure 5).

After both divers made it to the safety stop, Diver 4 said on the communications line, "Hurry, I am out of air." Diver 3 reported that both of them had started to descend back down to approximately 40 feet when he felt something hit his chest and saw Diver 4 trying to get to his pony (redundant air cylinder) regulator. Diver 3 reported that Diver 4 was in a panic and then saw him pull his facepiece off and then Diver 4 attempted to pull off Diver 3's facepiece, dislodging it. Diver 3 then kicked away from Diver 4 and surfaced (without his facepiece on). Diver 4's data logger and graph show this ascent, descent and rapid ascent in Figure 5.

Diver 3 reported during interviews that he did not drop his weight belt before surfacing. Diver 3 surfaced and yelled, "Firefighter down, firefighter down." He was reported to be approximately 40 yards from the surface buoy. Diver 3 was picked up by a North Carolina fish and wildlife boat, transferred to a FD boat, and taken to shore then by ambulance to the hospital. The lieutenant on dive boat called a "Mayday" on the radio.

The FD 4 boat (dive boat) was not anchored when they saw Diver 3 break the surface and yell. The dive boat captain told Diver 5 that Diver 4 was out of air. Diver 5 had trouble with water in his mask and tried to purge it but was unsuccessful. One of the other divers on the boat helped him adjust his facepiece and Diver 5 entered the water and found the communication cable (connected from the surface boat to Diver 4) and followed it down to search for Diver 4.

Diver 5 reported following the communication line down and lost visibility at 25 feet and continued down to approximately 75 feet and found Diver 4. He reported finding Diver 4 on the bottom on his knees leaning to his side. This event is likely captured on the data log profile, approximately dive minute 21 through 23 in Figure 5.

Diver 5 tried to inflate Diver 4's BCD but it had no air. He then tried to release Diver 4's weights (see Photo 8) and tried to inflate Diver 4's dry suit with no success. Diver 5 was able to inflate his own BCD but knocked his facepiece loose trying to inflate Diver 4's dry suit. Diver 5 then had to ascend and during the ascent, he heard his ascent alarm sounding. He tried to release air from his BCD but was on the surface before he could release enough air to slow his ascent. A North Carolina fish and wildlife boat was the first to reach Diver 5 on the surface and pulled him into their boat. After Diver 5 was picked up by the fish and wildlife boat, he was transferred to a FD boat, and taken to shore then to a hospital by ambulance.

The recovery of Diver 4. *It is important to note that the divers listed below are divers from the mutual aid fire department dive team (FD 3). They are listed in the report as Divers 1-5 with recovery roles involving the fire department victim (Diver 4) and the civilian drowning victim. They are not the same Divers 1-5 as listed in this report above.*

After the Mayday, Command asked BC 3 from the mutual aid department to send their dive team to assist. They were dispatched and arrived in 30 minutes. Since Dive Boat 38 was already on scene and anchored in a non-diving role, they immediately assisted.

Upon the declaration of a Mayday, Dive Boat 38 started a search for Diver 4 and quickly located him with the side scan sonar (See Figure 4). Additional mutual aid divers arrived on scene, and Dive Boat 38 returned to shore to pick up the divers.

Dive operations began off of Dive Boat 38 (now returned and anchored) to recover Diver 4. The first diver (Diver 1) entered the water at 1651 hours and made it to the bottom and the cage. He was on a communication line with the surface and told them he did not find the Diver 4 (victim) but did find Diver 4's search rope. He pulled all the slack out. Diver 1 was then told to ascent to the safety stop and then surface. Air checks were performed every 2-3 minutes. Diver 1 was out of the water at 1702 hours. Diver 2 entered the water at 1719 and descended. He reported during interviews that it was dark passing through 40-50 of depth. He got to the bottom and found the cage and the search rope and pulled it tight and followed it out. His flashlight revealed something yellow and he saw Diver 4 on his back with his face mask off and palms up.

Diver 2 grabbed Diver 4 (victim) by the BCD strap and pulled him along the search line back to the cage. He told the tender on the boat (via the underwater communications line) that he had brought the victim back to the cage. Diver 2 was told to ascend to the safety stop and then surface.

Diver 3 entered the water at 1734 hours and descended. He carried a rope to tie off to the victim and bring the other end back to the surface. Once Diver 3 reached the bottom he found the victim at the cage and connected the rope to the victim. He then cut the 7/16th inch search line that attached to the cage on one end and was wrapped around the victim. Air checks continued every 2-3 minutes by the surface tender. Diver 3 was told to ascend to the safety stop and then surface. Diver 3 was out of the water at 1755 hours.

The mutual aid dive team had a fourth diver enter the water at 1815 to assist when the crews on Dive Boat 38 brought Diver 4 (the victim) to Dive Boat 38, but just under the surface. Diver 4 (victim) was placed in a recovery system just under the water surface and then brought on board Dive Boat 38. The fourth diver from the mutual aid dive team was out of the water at 1822 hours.

Diver 4 (victim) was pronounced dead on Dive Boat 38. Dive Boat 38 then took Diver 4 to shore where he was transported by ambulance from the scene.

Dive Boat 38 then assisted with dive operations to locate and retrieve the civilian drowning victim. At 1927 hours Diver 5 from the mutual aid department located and recovered the civilian drowning victim. At 1942 hours the civilian victim was brought to the surface and all divers were reported out of the water.

Additional investigative information. *The following information from Diver 4's dive computer data logger analysis assistance was provided by an expert contracted by NIOSH. The dive profile was expanded by a NIOSH statistician, and likely points plotted by the NIOSH investigator.*

Diver 4 used a dive computer that logged data during his dive. It detailed a descent to 78–79 feet for approximately 17 minutes. During this time, Diver 4 had a rapid air usage (breathing rate). At the 10-minute mark, Diver 4 had only 50% of the air supply left. According to the data logger, he reached the bottom in approximately 3 minutes and was using his breathing air at a high rate. His dive computer has a factory "turn pressure" setting of 1500 psi which should have alarmed and alerted him that he had 50% gas volume left 7 minutes into the dive. Additionally, the dive computer had a setting of 800 psi for "end time" which should have alarmed and alerted him at 14-15 minutes into the dive. It is not known if Diver 4 acknowledged the alarms, however nothing was reported through his communications to the surface crew concerning alarms.

Figure 5 is the graphic of Diver 4's dive profile produced by the NIOSH statistician. A likely synopsis is that Diver 4 started with 2,444 psi (size of tank not entered into dive computer). He had a gradual descent to 78-79 feet where he remained for approximately 17 min. At that time his cylinder pressure dropped below 250psi and he commenced a rapid ascent (> 30 feet/minute). Given the computer was set at a 15-second sampling period, it is impossible to determine whether Diver 4 actually made it to the surface (according to witness statements, it is likely that 12.8 feet was as shallow as he was able to ascend). The computer registered him as shallow as 12.8 feet at the start of minute 18 with a cylinder pressure of 151 psi (which is not sufficient to provide breathable air from the cylinder). Thereafter, Diver 4 started a second descent at approximately minute 18:15. Diver 4 descended to 56.3 feet and then started a second ascent at minute 19:15, despite having only 56 psi of air.

The second ascent registered 24.6 feet as the closest Diver 4 came to the surface before beginning a third descent at minute 19:45. Diver 4's third descent ended at 79.2 feet, at minute 20:45 with 30 psi remaining in the cylinder. There was a fourth ascent to a shallowest depth of 58.9 feet at minute 24, but by minute 24:45 Diver 4 was back at 77.6 feet. This ascent may represent the rescue attempt by Diver 5. At minute 26:30 Diver 4 had another brief ascent to a shallowest depth of 70.2 feet (unknown cause but could have resulted from the attempt to raise him by the communications line by the surface crew), followed by a final descent to approximately 78.6 feet until Diver 4 was brought to the surface at hour 2:40 (from the start of the dive).

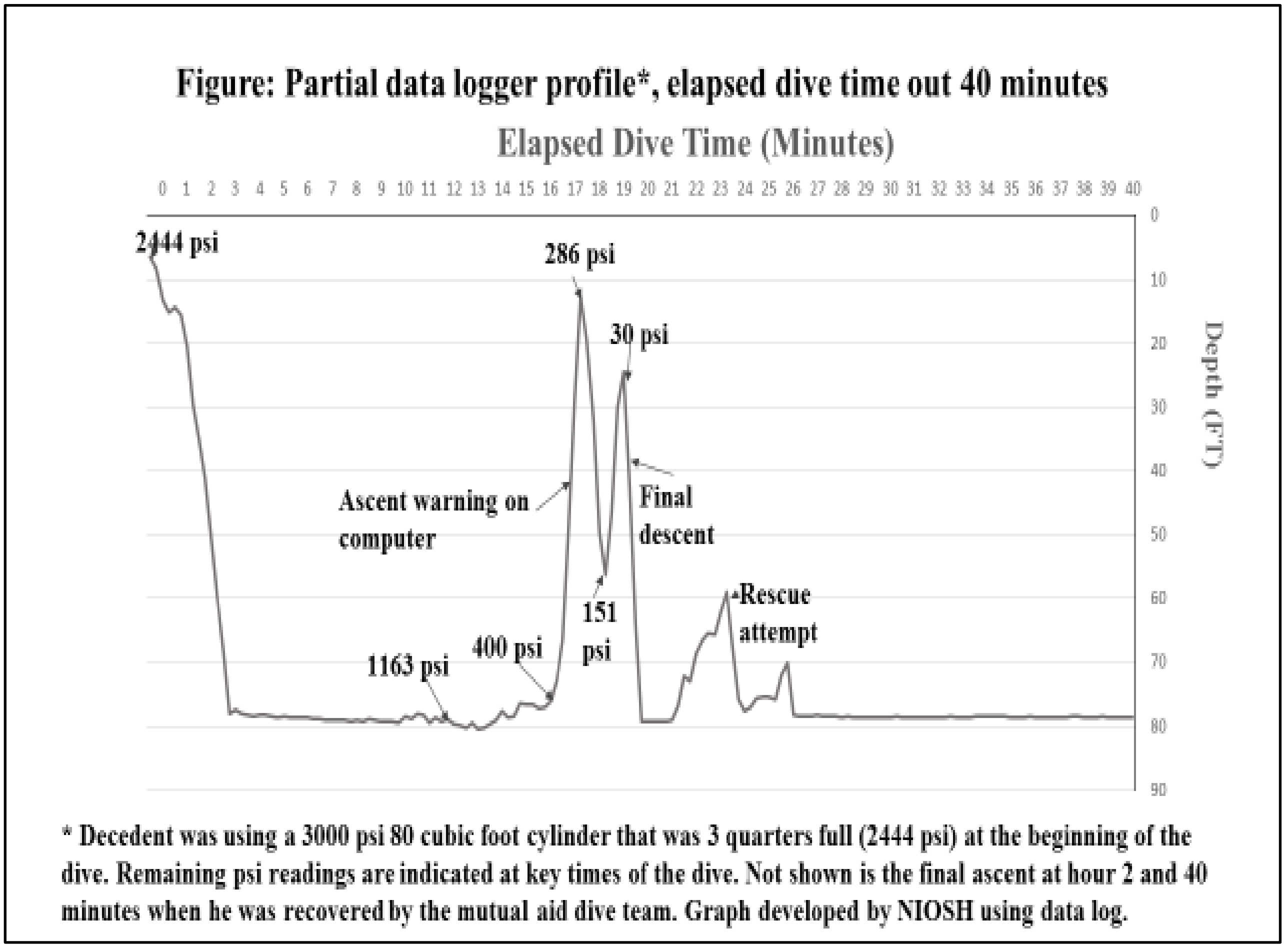

Figure 5. Partial data logger profile expanded to show dive profile of Diver 4. This profile shows the beginning air pressure and rapid usage at depth and during his descent and his ascent. The data log shows that Diver 4 made it up to a depth of 12.8 feet just prior to the out of air event. Also shown is the rescue attempt by Diver 5. Note that this data only covers 40 minutes of the 2 hours and 41 minutes of data. ***(Graphic and likely plots by NIOSH.)***

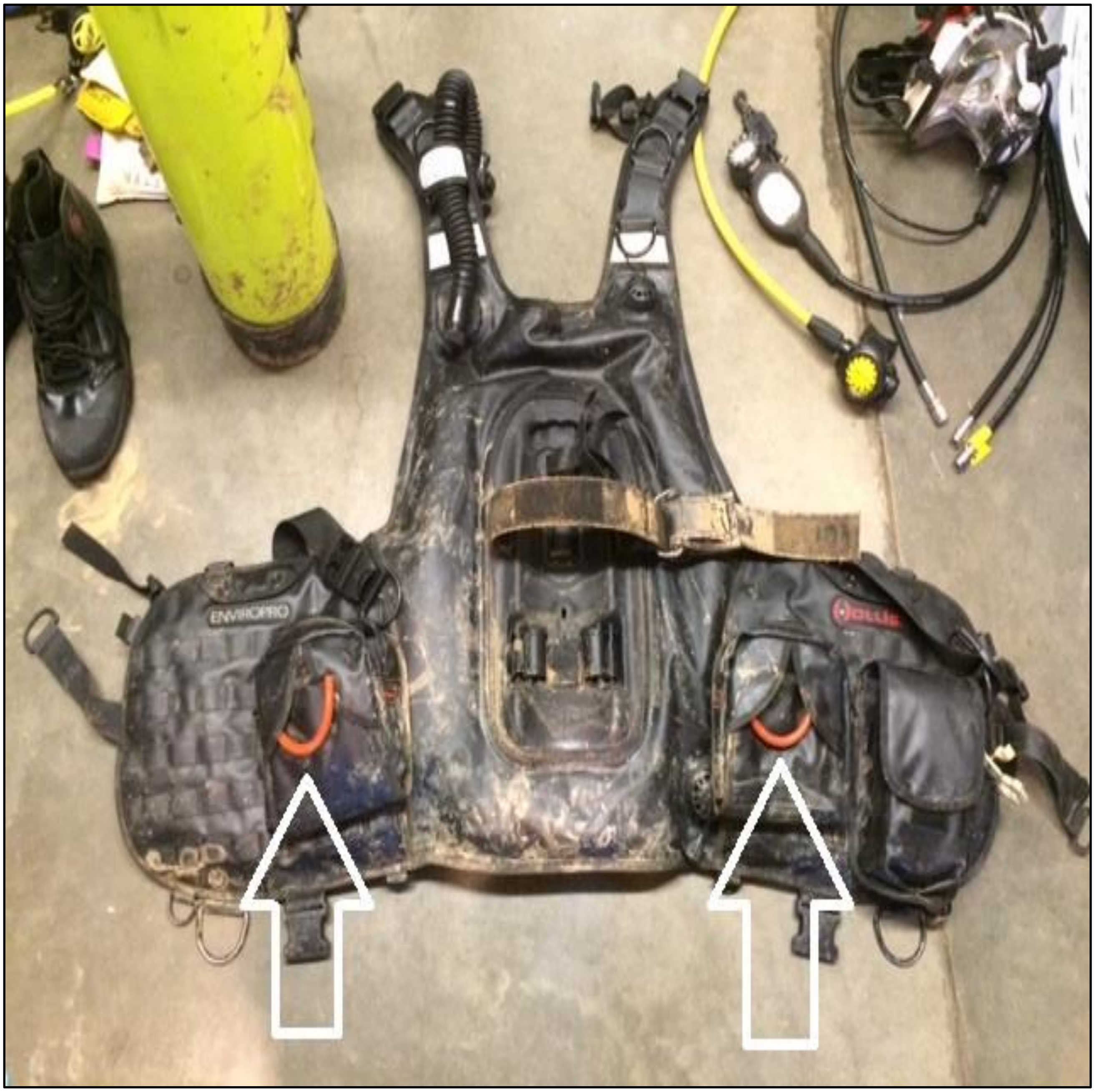

Photo 8. Photo of Diver 4's buoyancy control device (BCD) vest showing ditchable weight release pull handles.
(*Photo by NIOSH*.)

Contributing Factors

Occupational injuries and fatalities are often the result of one or more contributing factors or key events in a larger sequence of events that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatality:

- Pre-dive safety check
- Air management
- Uncontrolled out-of-air emergency (not being able to use redundant air supply)
- Panic/rapid uncontrolled ascent while holding breath
- Training and experience
- SCUBA equipment issues affecting buoyancy control
- Lack of a safety officer trained in technical rescue SCUBA diving during the event.

Cause of Death

According to the autopsy report, the cause of death was drowning due to arterial gas embolism while SCUBA diving. An arterial gas embolism is due to gas being directly introduced into the arterial circulation, most likely from breath holding on ascent and subsequent rupture of alveoli. The autopsy report listed the victim's weight as 300 pounds and body length of 73.5 inches with a body mass index (BMI) of 39.

Recommendations

Recommendation #1: Fire departments should ensure that public safety divers complete a pre-dive safety check (including adequate beginning air) with a qualified dive partner, witnessed by the dive safety officer.

Discussion: A pre-dive safety check with a checklist sheet for each diver should be required. This checklist sheet should include a personal check by the diver and his/her partner (only divers should check another diver) and witnessed by the dive safety officer. This checklist sheet should include (but not limited to):

- Main cylinder beginning gas pressure
- Primary regulator function (facepiece check on full face)
- Alternate or secondary regulator (octopus) check
- Redundant cylinder gas pressure

- Redundant cylinder main valve on and second stage in correct orientation or valve in correct position and function check (important to ensure valve is in correct position for start of dive)
- Dive computer check
- BCD function check
- Dry suit check
- Communications equipment check
- SCUBA equipment check including mask, fins, cutting tools, lights, and backup lights.

This pre-dive safety check is required for each diver and should be witnessed by the dive partner (or diver assistant) and the dive safety officer and this check should never be hurried. Inattention to any of these items can result in a malfunction that can be difficult to overcome underwater.

This pre-dive safety check should be recorded on a formal checklist for each diver, noting every step with a checkmark and providing the actual recording of information for beginning air pressure for main and redundant air cylinders (pony cylinder). An example of a pre-dive checklist sheet is provided in Figure 6.

Dive Checklist/Operations Worksheet

Primary Diver	Safety Diver	90% Diver
____________	____________	____________
Tender ____________	Tender ____________	Tender ____________
Diver ____________	Diver ____________	Diver ____________

Primary Diver	Safety Diver	90% Diver
____ Hood	____ Hood	____ Hood
____ Mask	____ Mask	____ Mask
____ Full face mask	____ Full face mask	____ Full face mask
____ Wet/dry suit	____ Wet/dry suit	____ Wet/dry suit
____ Harness/carabiner locked	____ Harness/carabiner locked	____ Harness/carabiner locked
____ Quick release snap shackle	____ Quick release snap shackle	____ Quick release snap shackle
____ Buoyancy control device	____ Buoyancy control device	____ Buoyancy control device
____ Regulator	____ Regulator	____ Regulator
____ Depth gauge/pressure gauge	____ Depth gauge/pressure gauge	____ Depth gauge/pressure gauge
____ Octopus/alternate air source	____ Octopus/alternate air source	____ Octopus/alternate air source
____ Compass	____ Compass	____ Compass
____ Gloves	____ Gloves	____ Gloves
____ 2 cutting tools	____ 2 cutting tools	____ 2 cutting tools
____ Weight belt ____ lb	____ Weight belt ____ lb	____ Weight belt ____ lb
____ Ankle weights	____ Ankle weights	____ Ankle weights
____ Fins	____ Fins	____ Fins
____ Review objective	____ Review objective	____ Review objective
____ Establish initial overlap in pattern	____ Establish initial overlap in pattern	____ Establish initial overlap in pattern
____ Review found object protocol	____ Review found object protocol	____ Review found object protocol
____ Comm check/review line signals	____ Comm check/review line signals	____ Comm check/review line signals
____ Review diver in distress protocol	____ Review diver in distress protocol	____ Review diver in distress protocol
____ Review emergency procedures	____ Review emergency procedures	____ Review emergency procedures
Start tank pressure ______ psi	Start tank pressure ______ psi	Start tank pressure ______ psi
Start dive time: ______	Start dive time: ______	Start dive time: ______

MAX. DEPTH FOR DIVE: ______	MAX. DEPTH FOR DIVE: ______	MAX. DEPTH FOR DIVE: ______
Tank pressure ______ psi 5 minutes	Tank pressure ______ psi 5 minutes	Tank pressure ______ psi 5 minutes
Tank pressure ______ psi ____ minutes	Tank pressure ______ psi ____ minutes	Tank pressure ______ psi ____ minutes
Tank pressure ______ psi ____ minutes	Tank pressure ______ psi ____ minutes	Tank pressure ______ psi ____ minutes
Ending tank pressure ______ psi	Ending tank pressure ______ psi	Ending tank pressure ______ psi
END DIVE TIME: ______	END DIVE TIME: ______	END DIVE TIME: ______
MAX. DEPTH: ______	MAX. DEPTH: ______	MAX. DEPTH: ______
Feet/total bottom time: ______ minutes	Feet/total bottom time: ______ minutes	Feet/total bottom time: ______ minutes
RAPID FIELD NEURO Exam results: POSITIVE/NEGATIVE	RAPID FIELD NEURO Exam results: POSITIVE/NEGATIVE	RAPID FIELD NEURO Exam results: POSITIVE/NEGATIVE
(Attach copy of check sheet to this form)	(Attach copy of check sheet to this form)	(Attach copy of check sheet to this form)
TENDER SIGNATURE	TENDER SIGNATURE	TENDER SIGNATURE
DIVE SUPERVISOR SIGNATURE	DIVE SUPERVISOR SIGNATURE	DIVE SUPERVISOR SIGNATURE

Figure 6. An example of a pre-dive checklist. ***(Courtesy of Dive Rescue International.)***

In this incident, other divers on the boat indicated that they performed checks on themselves and the boat crew members indicated during interviews that they assisted. According to Diver 4's dive computer data logger, the dive computer began recording when Diver 4 was underwater, passing through the 6-foot mark (see Figures 7 and 8). If Diver 4 had turned on the dive computer on the surface to check his beginning air pressure, the computer would not have recorded that event before the automatic activation at 6 feet of depth shown in the first row on Figure 4. According to the dive computer manufacturer, the dive computer does not log any information until 5-6 foot of depth.

Based on the dive computer evaluation provided by the local sheriff's office dive expert, Diver 4's dive computer was in gauge mode and not in air mode (factory default setting is air mode). This mode means that only air pressure, time, depth, and temperature are available to the diver. Decompression planning, tissue loading and other topics are not calculated. This may have been an inadvertent mode change but was a deviation from all 72 of the previous dives logged on this particular computer. The dive computer mode setting is an item on the pre-dive checklist.

Public safety divers should never assume that an unchecked cylinder is full. Many divers/dive boat operations mark a full cylinder with a plastic boot over the valve body and indicate a used cylinder by leaving the plastic guard off. If a diver wants to replace a cylinder, this gives the diver a visual indication of which cylinders to choose from, but divers should always check with a gauge to ensure the cylinder is full. Divers should always check their own gas pressure before any dive; they should not rely on someone saying a cylinder is full or a visual cue such as the plastic valve cover.

Dive Details

Diver Name:	Diver 1 - Wisdom Ser No 7888	Breathing Gas:	
DC:	WISDOM (Metal Buttons), S/N: 7888	Cylinder:	
Life Time Dive No.:	73	Cylinder Size:	
Dive Date,Time:	06/06/2016, 14:25	Working Pressure:	
DC Dive #:	1	Start Pressure:	
Elapsed Dive Time:	162 Minutes	End Pressure:	
Prior Surface Interval:	01:30	SAC:	
Max. Depth:	81 FT		
Average Depth:	76.55 FT		
Min. Temperature:	57 F		
Dive Sample Rate:	15 sec.		
Dive Mode:	Gauge Dive		
Dive Status:	Decompression, Violation		
Dive Data Type:	DC		
Location:			
Dive Site:			

Elapsed Dive Time (hr:min)	Depth	Ascent Rate	Pressure Reading	Dive Time Remaining (hr:min)	Stop Depth	Temperature	Dive Status
00:00	6.4 FT	0-10 FPM	2444 PSI	00:48	09:59	82 F	
00:00	8.3 FT	0-10 FPM	2414 PSI	00:45	09:59	82 F	
00:00	13.4 FT	0-10 FPM	2383 PSI	00:39	09:59	82 F	
00:01	15.2 FT	16-20 FPM	2356 PSI	00:36	09:59	82 F	
00:01	14.3 FT	16-20 FPM	2335 PSI	00:11	09:59	82 F	
00:01	15.6 FT	0-10 FPM	2318 PSI	00:11	09:59	82 F	
00:01	20.4 FT	0-10 FPM	2295 PSI	00:13	09:59	82 F	
00:02	29.6 FT	0-10 FPM	2272 PSI	00:13	05:10	82 F	
00:02	35.1 FT	0-10 FPM	2244 PSI	00:14	03:15	82 F	
00:02	41.2 FT	0-10 FPM	2194 PSI	00:10	02:16	82 F	
00:02	50.3 FT	0-10 FPM	2162 PSI	00:07	01:23	82 F	
00:03	59.3 FT	0-10 FPM	2120 PSI	00:05	00:59	82 F	
00:03	68.4 FT	0-20 FPM	2060 PSI	00:04	00:41	82 F	
00:03	78. FT	0-20 FPM	2014 PSI	00:03	00:31	82 F	
00:03	77.4 FT	0-20 FPM	1965 PSI	00:03	00:31	81 F	
00:04	78. FT	0-20 FPM	1900 PSI	00:03	00:30	80 F	
00:04	78.3 FT	0-20 FPM	1860 PSI	00:02	00:30	80 F	
00:04	78.4 FT	0-20 FPM	1818 PSI	00:03	00:29	79 F	
00:04	78.3 FT	0-20 FPM	1783 PSI	00:03	00:29	78 F	
00:05	78.3 FT	0-20 FPM	1736 PSI	00:04	00:29	78 F	
00:05	78.4 FT	0-20 FPM	1711 PSI	00:04	00:29	77 F	
00:05	78.6 FT	0-20 FPM	1678 PSI	00:04	00:28	76 F	
00:05	78.4 FT	0-20 FPM	1644 PSI	00:04	00:28	75 F	
00:06	78.6 FT	0-20 FPM	1604 PSI	00:04	00:28	74 F	
00:06	78.6 FT	0-20 FPM	1591 PSI	00:04	00:28	73 F	
00:06	78.6 FT	0-20 FPM	1577 PSI	00:04	00:27	73 F	
00:06	78.8 FT	0-20 FPM	1548 PSI	00:05	00:27	72 F	
00:07	78.8 FT	0-20 FPM	1527 PSI	00:05	00:27	71 F	
00:07	78.8 FT	0-20 FPM	1506 PSI	00:07	00:27	70 F	
00:07	79. FT	0-20 FPM	1472 PSI	00:06	00:26	70 F	
00:07	79. FT	0-20 FPM	1441 PSI	00:04	00:25	69 F	
00:08	79. FT	0-20 FPM	1412 PSI	00:03	00:25	69 F	
00:08	79. FT	0-20 FPM	1403 PSI	00:03	00:25	68 F	
00:08	79.2 FT	0-20 FPM	1372 PSI	00:03	00:25	68 F	
00:08	79. FT	0-20 FPM	1359 PSI	00:04	00:24	67 F	
00:09	79.2 FT	0-20 FPM	1343 PSI	00:04	00:24	66 F	
00:09	78.8 FT	0-20 FPM	1324 PSI	00:05	00:25	66 F	
00:09	79. FT	0-20 FPM	1295 PSI	00:04	00:24	66 F	
00:09	79.2 FT	0-20 FPM	1274 PSI	00:03	00:23	65 F	
00:10	79.3 FT	0-20 FPM	1243 PSI	00:03	00:23	65 F	
00:10	79.3 FT	0-20 FPM	1215 PSI	00:01	00:23	64 F	
00:10	79.4 FT	0-20 FPM	1188 PSI	00:01	00:23	64 F	
00:10	78.4 FT	0-20 FPM	1163 PSI	00:01	00:23	64 F	
00:11	78.8 FT	0-20 FPM	1132 PSI	00:00	00:23	63 F	
00:11	78. FT	0-20 FPM	1096 PSI	00:00	00:23	63 F	
00:11	78.3 FT	0-20 FPM	1059 PSI	00:00	00:22	63 F	
00:11	79.4 FT	0-20 FPM	1031 PSI	00:00	00:21	62 F	

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Figure 7. Page 1 of Diver 4's data logger showing the dive computer automatically turned on when he descended through the 6-foot mark. Note the logged air pressure at 2444 psi as his beginning air pressure.

Career Captain Drowns After Running Out Of Air During Technical Rescue SCUBA Dive—North Carolina

Dive Details

Elapsed Dive Time (hr:min)	Depth	Ascent Rate	Pressure Reading	Dive Time Remaining (hr:min)	Stop Depth	Temperature	Dive Status
00:12	78.6 FT	0-20 FPM	996 PSI	00:00	00:22	62 F	
00:12	79.3 FT	0-20 FPM	965 PSI	00:00	00:21	62 F	
00:12	78.9 FT	0-20 FPM	929 PSI	00:00	00:21	61 F	
00:12	79.6 FT	0-20 FPM	883 PSI	00:00	00:20	61 F	
00:13	79.9 FT	0-20 FPM	837 PSI	00:00	00:20	61 F	
00:13	80.3 FT	0-20 FPM	804 PSI	00:00	00:19	61 F	
00:13	79.4 FT	0-20 FPM	764 PSI	00:00	00:20	61 F	
00:13	80.4 FT	0-20 FPM	726 PSI	00:00	00:19	60 F	
00:14	80.2 FT	0-20 FPM	687 PSI	00:00	00:19	60 F	
00:14	79.6 FT	0-20 FPM	645 PSI	00:00	00:19	60 F	
00:14	79. FT	0-20 FPM	616 PSI	00:00	00:19	60 F	
00:14	77.7 FT	0-20 FPM	572 PSI	00:00	00:19	60 F	
00:15	78.6 FT	0-20 FPM	529 PSI	00:00	00:19	60 F	
00:15	78.4 FT	0-20 FPM	495 PSI	00:00	00:18	60 F	
00:15	76.4 FT	21-30 FPM	470 PSI	00:00	00:19	59 F	
00:15	76.6 FT	0-20 FPM	434 PSI	00:00	00:19	59 F	
00:16	76.7 FT	0-20 FPM	402 PSI	00:00	00:19	59 F	
00:16	77.3 FT	0-20 FPM	368 PSI	00:00	00:18	59 F	
00:16	77. FT	0-20 FPM	326 PSI	00:00	00:18	59 F	
00:16	76. FT	0-20 FPM	286 PSI	00:00	00:18	59 F	
00:17	72.8 FT	0-20 FPM	248 PSI	00:00	00:21	59 F	
00:17	66.4 FT	31-40 FPM	210 PSI	00:00	00:28	58 F	
00:17	48.9 FT	>30 FPM	182 PSI	00:00	00:54	[illegible]	
00:17	29.1 FT	>30 FPM	161 PSI	00:00	[illegible]	58 F	
00:18	12.8 FT	>30 FPM	151 PSI	[illegible]	09:59	58 F	
00:18	19.4 FT	0-10 FPM	119 PSI	00:00	[illegible]	[illegible]	
00:18	32. FT	0-10 FPM	104 PSI	00:00	03:37	58 F	
00:18	49.7 FT	0-10 FPM	70 PSI	00:00	01:00	58 F	
00:19	56.3 FT	0-10 FPM	56 PSI	00:00	00:39	58 F	
00:19	46.8 FT	>30 FPM	36 PSI	00:00	01:04	58 F	
00:19	30.1 FT	>30 FPM	30 PSI	00:00	03:35	58 F	
00:19	24.6 FT	0-10 FPM	30 PSI	00:00	06:36	58 F	
00:20	42.3 FT	0-10 FPM	30 PSI	00:00	01:43	59 F	
00:20	63.9 FT	0-20 FPM	30 PSI	00:00	00:32	59 F	
00:20	79.2 FT	0-20 FPM	30 PSI	00:00	00:15	60 F	
00:20	79.3 FT	0-20 FPM	30 PSI	00:00	00:15	60 F	
00:21	79.3 FT	0-20 FPM	30 PSI	00:00	00:15	61 F	
00:21	79.3 FT	0-20 FPM	30 PSI	00:00	00:15	61 F	
00:21	79.3 FT	0-20 FPM	30 PSI	00:00	00:14	61 F	
00:21	79. FT	0-20 FPM	30 PSI	00:00	00:14	61 F	
00:22	76.8 FT	0-20 FPM	30 PSI	00:00	00:15	61 F	
00:22	72.1 FT	21-30 FPM	30 PSI	00:00	00:18	61 F	
00:22	72.9 FT	0-20 FPM	30 PSI	00:00	00:17	61 F	
00:22	68.6 FT	0-20 FPM	30 PSI	00:00	00:19	61 F	
00:23	66.6 FT	0-20 FPM	30 PSI	00:00	00:22	61 F	
00:23	65.4 FT	0-20 FPM	30 PSI	00:00	00:23	61 F	
00:23	65.7 FT	0-20 FPM	30 PSI	00:00	00:23	61 F	
00:23	61.9 FT	31-40 FPM	30 PSI	00:00	00:27	61 F	
00:24	58.9 FT	0-10 FPM	28 PSI	00:00	00:32	61 F	
00:24	67.7 FT	0-20 FPM	28 PSI	00:00	00:21	61 F	
00:24	75.7 FT	0-20 FPM	28 PSI	00:00	00:14	61 F	
00:24	77.6 FT	0-20 FPM	28 PSI	00:00	00:13	61 F	
00:25	77.1 FT	0-20 FPM	28 PSI	00:00	00:12	61 F	
00:25	75.6 FT	0-20 FPM	26 PSI	00:00	00:13	61 F	
00:25	75.3 FT	0-20 FPM	26 PSI	00:00	00:13	61 F	
00:25	75.4 FT	0-20 FPM	26 PSI	00:00	00:13	61 F	
00:26	75.7 FT	0-20 FPM	26 PSI	00:00	00:12	61 F	
00:26	71.9 FT	31-40 FPM	26 PSI	00:00	00:14	61 F	
00:26	70.2 FT	0-20 FPM	26 PSI	00:00	00:16	61 F	
00:26	78.3 FT	0-20 FPM	26 PSI	00:00	00:11	60 F	
00:27	78.4 FT	0-20 FPM	26 PSI	00:00	00:10	60 F	
00:27	78.4 FT	0-20 FPM	26 PSI	00:00	00:10	60 F	

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Figure 8. Page 2 of Diver 4's data logger showing Diver 4 made it to the safety stop at minute 18 (12.8 feet) however his gas was depleted to 151 psi and likely not able to draw any more air and started descending back down to 56 feet before his final ascent back up to 24 feet at minute 19. He then began his final descent.

Recommendation #2: Fire departments should ensure that incident commanders and group leaders maintain frequent and accurate air status and accountability on all divers. Additionally, no diver should be allowed to start a deep dive with inadequate air and adequate air reserves and resources at the dive site.

Discussion: Poor air management has resulted in firefighter and public safety diver deaths [NIOSH 2005, 2009, 2012]. Public safety divers must manage their air effectively and must return to the surface with their reserve air intact. Reserve air is defined as emergency reserve air for the diver to use to escape in case of unforeseen occurrences or underwater emergencies. Public safety divers must manage their air so that they have adequate air to return to the ascent line, to make a controlled ascent, for a safety decompression stop, and to still have their reserve air intact (1,000 psi) when they reach the surface. In recreational diving, 500 psi is a general reserve; however, many agencies and public safety courses recommend 1,000 psi as an adequate reserve.

Public safety divers and tactical and command officers need to recognize and communicate their air status and use air management on the incident scene. Air management happens at the diver (task) level, the crew (tactical) level, and at the command (strategic) level. Fire departments should ensure that air management is practiced at the task level (firefighters, divers), tactical level (unit or dive leaders), and the command level (command post, accountability or dive group leader).

At the task level, public safety divers need to ensure their air supply is adequate (full cylinder) at the start of the dive and need to control and monitor their air usage during a dive. They need to ensure that their backup air cylinder is full and in the on position and the regulator is accessible. They must be able to see and recognize the dive computer, pressure gauge, and pre-set air warnings and then communicate that information to their crew members. Fire department dive teams should use a pre-dive safety checklist and the dive safety officer should witness the diver equipment checks. Figure 6 provides an example of a pre-dive checklist. The safety checks for surface supplied-air systems with bailout bottles are different from the safety checks for self-contained underwater systems with redundant (pony) systems. Valve position(s) during air checks are important, especially when reading the correct cylinder or air status. The diver’s tender needs to be a diver and understand the system he/she is assisting the diver with. Additionally, the dive safety officer needs to be familiar with the system and witness the pre-dive safety check.

At the tactical level, crew or team leaders need to plan accordingly for the safe air management of all dive team members. They need to recognize when a diver is using excess air by frequent air status checks and by monitoring communications if using open communication systems. Surface support teams need to record the beginning air status and continuously monitor air status throughout the dive. If a diver misses an air status when a benchmark has been met (i.e., diver made the bottom, diver has found the target and is returning, or diver is ascending), the surface support team should prompt a response from the diver. The tactical level crew leader (dive leader) ensures that the dive plan is being followed and requests additional resources based on anticipated needs. All divers need to practice air management and return to the surface with their reserve air intact. Many public safety dive authorities recommend twice the remaining air in reserve as the recreational dive industry (i.e., 1,000-psi reserve vs 500-psi reserve in a 3,000-psi, 80-cubic-foot cylinder). Escape, redundant, or backup cylinders and systems always need to be checked and in the correct status prior to diving (e.g., in-line valve in correct orientation and first-stage valve in correct position), and the diver needs to ensure that the backup air system regulator or secondary valve is in an accessible location.

Dive team leaders should be responsible for planning the dive using proper air management techniques and dive protocols for the particular dive and depth and then plan the dive accordingly. The technical rescue dive safety officer should review and agree with the dive plan. Air management is a constant and multi-level responsibility. It can be easy for divers to become distracted with the difficulty of the assignment, environmental conditions, and civilian body recovery issues and lose track of their air supply. The multi-level air management system for public safety SCUBA diving has constant checks and balances as there is less room for error underwater.

Finally, air management at the strategic level ensures that the proper number of divers match the capabilities and competencies of the teams. In most public safety dive events, time is on your side to ensure capability, capacity, and competency of the resources [Orusa 2007]. Once the incident is classified as a recovery mission, there are no urgency events and incident commanders, group leaders, safety officers, dive team leaders, and dive team members need to carefully plan, coordinate, and execute the mission with all of the focus on the safety of the dive team members in completing, terminating, postponing, transferring, sharing, or rejecting the mission. When rescue considerations are no longer viable and the mission is recovery, all of the emphasis is on the dive team member’s safety.

At the strategic level, Command needs to understand air management at the command level. This means that someone at the command post is monitoring or ensuring that air status is being monitored and recorded. Additionally, with the assistance of the safety officer, Command needs to monitor accountability of the crews. Command needs to estimate additional resource needs based on crew performance and how long they have been working (estimating air supply usage) and check on air status with the tactical-level crew leader. Command needs to ensure that the technical rescue team has all of the resources that are capable and competent to achieve its mission. This includes multi-agency, multi-jurisdiction cooperation and integration when appropriate. Command needs to ensure that all air management and accountability needs of the technical rescue dive team are met through the incident safety officer (ISO) and take action to halt any mission when any of the team’s needs are not met. Since most dive events are recoveries, time is typically on the technical rescue dive team’s side. Since technical rescue SCUBA diving is considered a high-risk/low-frequency mission, it is easier to error on the side of diver safety and halt an operation when all aspects of the mission are not ready.

Public Safety divers need to understand and communicate their air supply status to their surface support team. Surface support teams need to monitor and record the beginning air and continuous air status throughout the dive. If a diver misses an air status update when a benchmark has been met (i.e., diver made the bottom or diver has found the target and returning, or diver is ascending) the surface support team should prompt a response.

Career Captain Drowns After Running Out Of Air During Technical Rescue SCUBA Dive—North Carolina

In some instances, public safety divers may not pay attention to their air usage and remaining air until they get a prompt by the dive team crew or, in the case of zero visibility, they hear an audible warning from the computer. This may be due to a number of reasons, including lack of familiarity with a new SCUBA gear setup (full-face vs half-face) or a lack of training. In modern firefighting SCBA, firefighters have heads-up display (HUD). Lights inside the facepiece indicate air management milestones such as full, three-quarters, 50% flash, and 33% end-of-service-time indicator (EOSTI).

Recommendation #3: SCUBA manufacturers and standard-setting organizations for public safety divers should consider including HUD in all full-face SCUBA apparatus due to the frequent zero-visibility conditions and silt-out in low-light conditions.

Discussion: It is extremely challenging for a diver without an HUD to give regular air status updates in low-light or zero-visibility conditions. In a low-light or zero-visibility condition at the bottom, even grabbing your dive computer with one hand and shining a light on it with your other hand can cause you to slightly drift down in a layer of silt while you are following a search rope. Silt-out conditions then may obscure the light source.

A diver (just like a firefighter) should never have to guess how much air they have. Once the remaining air drops below milestone indicators, two sensory stimulations should activate (e.g., sound, light, and/or vibration). This ensures that the diver will not unknowingly pass through the remaining air milestones. Finally, the surface crew with wired communications needs to ensure air checks through the communication line and all divers in the water should be on that communication line.

With the addition of HUD, public safety divers will have the ability to know their approximate air supply status by reading the milestone light(s) in their facepiece. Fire departments and public safety dive organizations should consider manufacturers that provide HUD for full facepiece for their purchasing whenever possible.

Recommendation #4: Fire departments should ensure that public safety divers are properly trained to recognize and have the repetitive skills training to control out-of-air emergencies and be able to use their redundant air before anxiety leads to panic. Additionally, when dive teams mix full-facepiece regulators with stand-alone regulators from a pony system, the divers must be well-trained to accomplish the difficult removal and switch task.

Discussion: The ability of firefighters and divers to understand and control an out-of-air emergency is heavily reliant on repetitive-skill and, muscle-memory training in addition to didactic training.

It is critical that firefighters/divers understand how to avoid and how to react and control an out of air emergency. Over familiarization and practice with their equipment is one of the most effective ways to build repetitive-skill, muscle-memory capabilities.

When a relatively minor situation such as initially missing an air status change or check (i.e., milestone lights in HUD or audible alarm from dive computer), redundant safety measures such as air status prompts from a trained safety/accountability crew can help interrupt a complication before the situation escalates into an urgent response need. Once the initial situation goes beyond a simple adjustment or reaction, the public safety diver must react with over learned skill sets on their redundant or back up breathing air system, communicate and then exit the danger.

Many recreational SCUBA diving scenarios have adequate visibility to read a depth and pressure gauge. Unfortunately, many if not most public safety SCUBA dive incidents occur in little- to no-visibility conditions. Therefore, reading a depth and pressure gauge is difficult using an underwater light source. This can be especially difficult if the diver is using his/her hands to maneuver equipment, hold on to a descent line, manage a search rope, or even use the auto inflate/deflator to achieve neutral or desired buoyancy. Modern dive computers have audible alert signals that can be programed to meet the needs of the diver (e.g., audible alarm can be made to sound at 50% air and maximum desired depth in addition to automatic built-in protocol alarms for mandatory decompression stops). Only having one sensory stimulation in SCUBA diving (sound vs. sight) places the public safety SCUBA diver at a much greater risk of missing milestone signals. Public safety SCUBA divers should have a minimum of a full-face diving mask with an HUD. Unlike recreational diving, visibility is often poor, and the audible sensory stimulation alone may not be sufficient.

Anxiety can lead to an increased heart rate, breathing rate, and large breathing air consumption rates. Over-familiarization with equipment can reduce anxiety before the anxiety develops into panic. Fight or flight responses to panic underwater have led to distressed divers in a panic attempting to dislodge a partner’s mask or regulator (as happened in this incident) and other public safety diver incidents as well [NIOSH 2003, 2012].

Repetitive skills training with SCUBA is vital for the safety of all divers and can help to overcome anxiety should emergency situations be encountered. It is even more important for public safety SCUBA divers who don’t have the same mission and dive conditions that recreational divers have. Extreme climate and water conditions, limited or no visibility, extraordinary entanglement hazards, water pollution, challenging physical and mental conditions, heavy and cumbersome equipment, and a lack of repetitive skill opportunities are challenges that all public safety divers face.

Basic SCUBA skills training with the equipment divers will be using is an ongoing process that should be performed regularly to ensure that firefighters "know their SCUBA equipment just like firefighters must know their SCBA." Some benefits of repetitive dive skills training with a SCUBA include the following:

- an increased comfort and competency level
- decreased anxiety
- automatic muscle memory response for the vital function controls, such as pulls for the ditchable weights or release handle/buckle for weight belts

- lower air consumption
- increased awareness of the user's air level (noticing and using the HUD when equipped)
- automatic muscle memory response for other vital function controls, such as dive computer and air pressure function keys, the auto-inflate/deflate for the BCD, inflate/deflate controls for the dry suit, purge button for the facepiece to rid mask of water or knowing how to evacuate water from a flooded half facepiece.

The public safety diver needs to have these primary control functions as a second nature response for normal diving operations. When any anxiety or panic begins, the only way that these functions will be second nature is for the diver to have over-trained on their use. Repetitive skills training also provides the user with an increased ability to operate these functions and controls in a high-anxiety moment or an emergency. Many times, using these skills will be necessary with gloved hands, limited vision, and reduced ability to hear commands from others (especially if the full-face communications unit has been removed). These skill sets have to be second nature at all depths. If a public safety diver becomes too focused on a task or distracted, they can descend (or ascend) unknowingly into a more dangerous situation.

In most fire-fighting training scenarios, these skills can be performed in a non-immediately dangerous to life and health (IDLH) atmosphere. However, public safety SCUBA divers don't have that luxury and the need for repetitive skills training is just as great. The training necessary to master these skills is expensive and requires a commitment and a discipline from all levels of the agency(s) responsible for the team's operation. Performed in conditions that are more controllable, such as pools, repetitive skills training helps build firefighter/divers' muscle memory so their hands will be able to activate the controls with gloves on and the operation will have a better chance to be a conditioned or second-nature response in case of an emergency [NIOSH 2011, 2012].

The first step in overcoming a SCUBA (and SCBA) out-of-air emergency is complete over-familiarization with your specific equipment and your breathing air requirements and usage. Firefighters/divers need to understand that many out-of-air emergencies are caused by firefighters/divers not recognizing the remaining air supply relative to their depth and mission and then another event occurs, such as difficulty or being unable to maintain buoyancy control (positive, negative, or neutral).

There are other events that can challenge a public safety diver's ability to overcome an out-of-air emergency, such as using a full facepiece and having to switch to a standard regulator for your back-up air. Removing the full facepiece causes a loss of visibility and/or cold shock to the face all while trying to get the spare air regulator in your mouth. Then you have to find your half mask in your BCD pocket and put it on and flush the water out of it (clear it with air from your nose) so you can see. All of this without losing buoyancy and drifting down deeper or popping to the surface uncontrolled while doing this. This mask and regulator switch out is a learned skill that must be practiced. There are engineered solutions that allow the divers' spare cylinder to be valved into the primary air system. This would allow the diver to just adjust a valve position instead of removing the full facepiece mask; however, the redundant cylinder is no longer totally separate and independent. A disadvantage of this type of system could be starting the dive with the valve in the incorrect position and all of the air from both cylinders is used at the same rate and in the event of a diver needing the pony cylinder air, it would be empty. While there are advantages and disadvantages with both systems, the key take away is over-familiarization with the system your department or team uses.

Another challenge to a public safety diver's ability to overcome an out-of-air emergency is using weight equipment they may not be overly familiar with. If a diver has always used a quick release weight belt and is less trained in ditchable and non-ditchable weights that are integrated into the BCD, they may not be able to locate and activate the release mechanisms and return to concentrating on the original out-of-air complication. Public safety divers have died from not being able to release the weights or being over-weighted (in non-ditchable pockets) [NIOSH 2005, 2013].

A public safety diver's ability to overcome these events is directly related to their practical training and repetitive muscle memory skill. Many uncontrolled out-of-air emergencies can be overcome by repetitive skills training. NIOSH investigators have identified air management as a contributing factor on many investigations of firefighter and firefighter SCUBA diver line-of-duty deaths. Fire departments need to ensure that training on air management occurs at all levels of the command structure [NIOSH 2011, 2012].

Recommendation #5: Fire departments should ensure technical rescue SCUBA dive teams have a Dive Safety Officer on site who is trained in technical rescue SCUBA diving before commencing a dive.

Discussion: A trained technical rescue SCUBA Dive Safety Officer should be on scene and part of the command structure and tactical planning for the dive. The Dive Safety Officer should be located at the dive site and available to the command post but not be in the planned dive rotation.

NFPA 1670, Chapter 4.5.2, states that "at technical search and rescue training exercises and in actual operations, the incident commander shall assign a safety officer with the specific knowledge and responsibility for the identification, evaluation, and where possible, correction of hazardous conditions and unsafe practices [NFPA 2014]. The assigned safety officer should meet the requirements specified in NFPA 1521 *Standard for Fire Department Safety Officer* [NFPA 2015].

Safety officers assigned to special operations incidents, such as technical rescue SCUBA diving incidents, need to have the expertise in the specific technical rescue field to effectively evaluate hazards and provide direction with respect to the safety of all personnel. The dive safety officer can help provide an additional level of safety review for the dive operation including, mission (risk vs. gain), personnel (are the public safety divers mentally prepared for the high risk/low frequency dive and is the skill required beyond the team members training and competencies?), available resources and equipment, back up divers or Rapid Intervention Crew (RIC) for the primary dive team, Advanced Life Support (ALS) medical group for the divers.

A qualified fireground safety officer may not possess the necessary expertise in water rescue and, therefore, might not recognize or understand capabilities of the team members, limitations and hazards to rescue workers, the need for specialized equipment appropriate for water rescue operations problems with equipment, or performance issues of personnel. NFPA 1521 notes, “in cases where the designated incident safety officer does not possess the technician-level training, appointing a technician-level trained assistant or technical specialist with the necessary training will help satisfy the safety needs of the technician-level members.”

The dive safety officer has the critical advisory role to the ISO and the incident commander on the risk vs. benefit at the strategic and tactical level. A dive safety officer properly trained in the technical rescue field being performed can also help prevent a public safety diver from attempting a skill beyond their level of training. The diving safety officer and incident safety officer should be integrated into the incident command structure [NFPA 2015].

A specifically trained and qualified dive safety officer can monitor the incident action/dive plan (primary decisions regarding rescue/recovery, team capabilities, outside resources), dive conditions, dive plan activities such as water depth, dive plan complications, and operations to determine whether they fall within the criteria as defined by the fire department dive team’s risk management plan. The diving safety officer should also witness the diver(s) pre-dive safety checks as well as monitor the health and well-being of the divers pre- and post-dive.

NFPA 1561 *Standard on Emergency Services Incident Management System and Command Safety* states in Paragraph 5.3.1 that "the incident commander shall have overall authority for management of the incident". NFPA 1561 Paragraph 5.3.2 states, "The Incident Commander shall ensure that adequate safety measures are in place" [NFPA 2013c]. However, technical rescue incidents require that the incident commander have a safety officer who is trained in the discipline (SCUBA, Water Rescue, Confined Space Rescue, High Angle Rescue, Hazmat, and Trench Rescue) and dedicated to the specific operation. A safety officer for a Technical Rescue SCUBA incident should also be located where the dive operation is taking place. They can monitor the operation, evaluate resource status, ensure accountability and pre-dive safety and equipment/air checks, continuously evaluate member abilities and capabilities, and ensure that all operational function positions are staffed, and qualified backup rescue personnel are in place to aid in the event of complications.

Based upon the size and complexity of an incident, Incident Commanders should delegate responsibilities that include a safety officer for the incident scene a safety officer for the technical discipline being performed (in this case, a Dive Safety Officer). The incident command system can be expanded to include functions necessary to effectively command and control an incident. Upon confirmation, the dive safety officer should obtain the following information:

- Meet with the incident commander, command staff (including the Incident Safety Officer) and dive team leader and discuss the needs and advise on the risk vs. benefit analysis at the strategic level and the tactical level. Does the benefit of the operation justify the risks to the personnel to achieve it?

- Overall situation status and resource status, resource capabilities
- Strategy and incident action plan (dive plan)
- Known hazards and concerns (water depth, degree of difficulty, water and environmental complications, weather)
- Status of dive crews, crew leaders, crew capabilities, crew competencies, equipment, and personnel accountability
- Ensuring the dive crews are following the dive plan and accurate event monitoring and recording are taking place
- Back-up dive team assets
- ALS standby for medical care for divers
- Establishment of the rehabilitation group
- Confirmation of established radio communication channels (command channel, tactical channels)
- In summary, plan the dive, and dive the plan

The Dive Safety Officer should don the personal protective equipment appropriate for the potential hazards that he/she will be exposed to (e.g., auto-inflating or standard personal floatation device (PFD) for protection around the water and/or float coat for colder weather). Also, the Dive Safety Officer should be identified by a vest or helmet.

The Dive Safety Officer should meet with the Technical Rescue Group Leader, Incident Safety Officer, Incident Commander and develop a communication plan and coordinate their activities. The Incident Safety Officer is responsible for overall safety of the incident scene and reports to the incident commander. The Dive Safety Officer reports to the Technical Rescue Group Leader, however coordination and communication between the safety officers can be advantageous on large complex missions.

NFPA 1521 *Standard for Fire Department Safety Officer Professional Qualifications* defines the role of the Incident Safety Officer (ISO) at an incident scene and identifies duties such as recon of the incident scene and reporting pertinent information back to the Incident Commander; ensuring the department's accountability system is in place and operational; monitoring radio transmissions and identifying barriers to effective communications; and ensuring established safety zones and other designated hazard areas are communicated to all members on scene [NFPA 2015].

The Incident Safety Officer and technical rescue group Dive Safety Officer add a higher level of training, attention, and expertise to help the Incident Commander. The Incident Safety Officer and technical rescue group Dive Safety Officer must have particular expertise in analyzing safety hazards and must know the particular uses and limitations of protective equipment. For example, while the

Dive Safety Officer may be focused on the safety of the divers, the incident safety officer can help ensure the safety of the boat teams and land support firefighters [Dodson 2007; Dunn 2000; NIOSH 2009, 2010].

Experience in the technical rescue discipline being performed is an extremely valuable resource. The technical rescue group Dive Safety Officer has a different area of responsibility than the Incident Safety Officer. He/she has the specific knowledge, skills, qualifications, and experience to oversee the safety of the members of the technical rescue group and the mission they are performing. They must have that level of experience to recognize realistic mission goals, team and resource capabilities, team member capabilities, and team member limitations and have the discipline and authority to add, change, modify, intervene or stop an unsafe operation. This is especially important in technical rescue SCUBA operations where the largest portion of all operations is in a recovery vs a rescue mode and time is on the team's side. The Incident Safety Officer working together with a trained and experienced the technical rescue group Dive Safety Officer can provide a fire department with a higher level of expertise to perform the necessary incident scene functions and assist the Incident Commander with incident scene safety.

In this incident, the assistant Chief of FD 2 was the Incident Commander and monitored and kept record as he received communication updates from operations (Dive Group Supervisor). The Dive Group Supervisor as a lieutenant from FD 2 on the dive boat and the communications officer was also from FD 2. They did have a safety diver on the surface during the dives however the role of Dive Safety Officer was not included at the dive site.

Recommendation #6: Fire departments should provide annual training on dive hazards such as lung overexpansion injuries, out of air emergencies, emergency ascent procedures, including the dangers of breath holding, and emergency release of dive weights.

Discussion: Fire department dive teams need to provide annual refresher training on dive hazards such as lung overexpansion injuries, including arterial gas embolism, pneumothorax, mediastinal emphysema, and subcutaneous emphysema and their prevention. Diving hazards can include deadly medical conditions associated with lung overexpansion injuries. Public safety SCUBA divers need to have annual refresher training on these and other SCUBA diving hazards. While diving maladies and other hazards may be taught in formal basic SCUBA and other advanced SCUBA classes, the knowledge gained in class needs to be re-enforced through annual refresher training.

Lung overexpansion injuries include arterial gas embolism, pneumothorax, mediastinal emphysema and subcutaneous emphysema. What they all have in common is that each of these type of injuries can be induced by holding your breath for any reason during an ascent while on SCUBA or surface-supplied air [Hendrick et al. 2000].

Understanding basic properties of gas when subjected to pressure is key to understanding dive hazards associated with lung overexpansion. According to Boyle's Law, the volume of a parcel of gas varies inversely with the pressure exerted on it. If the pressure increases twofold, the volume of the gas will be half its original volume, and its density will be twice as great [Hendrick et al. 2000]. If a person on the surface has 5 liters of air in his/her lungs and holds their breath and dives underwater, the pressure increases and the 5 liters of air are still there, but occupying a smaller space. If they descend down to 99 feet (where the pressure is 4 times what it is at sea level) the 5 liters will only occupy 1/4 the volume space in the lungs. Then as they return to the surface—if they don't inhale or exhale—the air will return to its normal volume and density once they are on the surface [Hendrick et al. 2000]. An example would be free diving from the surface while holding one's breath. Breathing compressed gas underwater changes that dynamic significantly. When SCUBA divers inhale underwater, their lungs are filled with compressed air to keep their lungs the same size they were on the surface, which means that they are breathing increasingly denser air as they descend. To maintain 5 liters of air lung volume, a SCUBA diver needs to inhale the surface equivalent of 10 liters of compressed air at 33 feet, 15 liters of compressed air at 66 feet, and 20 liters of compressed air at 99 feet. This is accomplished through the functions of a diving regulator to deliver air to the diver at ambient pressure according to the depth [Hendrick et al. 2000].

If SCUBA divers hold their breath while ascending, the denser air that they inhaled at depth will expand the lungs beyond their normal elastic capability, causing tissue damage [Hendrick et al. 2000]. These injuries can be life-threatening and result in catastrophic incapacitation and death.

In basic SCUBA diving education, divers are taught to always breathe continuously and normally, **never hold their breath and to exhale on ascent**. However, there are instances where divers may be distracted and unintentionally ascend while holding their breath. Divers need to have refresher training on common conditions that could cause a distraction as ascent while holding their breath. Here are a few examples:

- Panic moment or uncontrolled anxiety
- Uncontrolled out-of-air emergency or low-air event
- Over-weighted (with dive weights or not being able to jettison weights as in this incident)
- Accidental loss of a weight belt
- Preoccupation with an equipment issue, such as the mask
- Managing buoyancy (failure to release necessary air in their BCD to maintain a controlled ascent; remember that any air you autofill into your BCD at depth will also expand as you ascend)
- Inability to maintain positive buoyancy (BCD shoulder dump valve accidently jammed open by carabiner for body bag)
- Exertion during a difficult task
- Coughing, sneezing, or vomiting
- Breathing heavy in response to finding the target [Hendrick et al. 2000].

Because public safety diving is more dangerous than sport or recreational diving, public safety divers need to use every margin of safety available [Hendrick et al. 2000]. Ascending from depths needs to be a planned and trained-for evolution to keep from having serious medical complications associated with gas expansion.

Many factors can lead to an underwater emergency and planning to avoid the events that lead to the emergency is the first step. Dive emergencies can arise from a number of causes including exhaustion, embolism, decompression sickness, nitrogen narcosis, heart attacks and other medical conditions, strong currents, entanglements, equipment failure, out of air emergencies and panic [NOAA 2001]. Divers need to be familiar with procedures to overcome these events.

Divers should train to use task-level air management (diver always aware of their air remaining), tactical air management (dive team surface monitoring and recording) and strategic level air management (command and division level support through proper resources and personel) to avoid low air events that lead to out of air events.

The first step in evaluating an out-of-air emergency is to confirm that the apparent air loss is real. For example, a tank valve not fully open can present as a difficulty to draw air, but is easily corrected if recognized. The diver needs to stop, think and attempt to breath and if it is possible to do so, proceed with a normal ascent [NOAA 2001]. If a diver determines that their air supply is depleted, the NOAA diving manual suggest the following order for managing air loss:

- Normal ascent
- Alternate [or redundant] air source ascent (alternate air is a second air line from the main tank, a redundant air source is a second "pony" cylinder with its own second stage regulator)
- Controlled emergency swimming ascent
- Buddy breathing ascent
- Emergency buoyant ascent (putting air in the BCD and dropping weights) [NOAA 2001].

A redundant air cylinder can provide emergency breathing air and is independent of the primary air supply. For example, these "pony" cylinders range in size from 1.7-15 cubic feet. A 4 cubic foot cylinder can provide 14-16 breaths at a depth of 100 feet and can provide 80 breaths in shallow water. There are also redundant air cylinders that can be manifolded into the diver's primary air system, so they don't have to remove the full facepiece dive mask and insert a regulator and then switch to a half mask.

During annual refresher training divers should be reminded of the hazards of an uncontrolled ascent as well as how to release their weight belts or integrated ditchable and non-ditchable weights in an emergency ascent. However, **an emergency buoyant ascent is difficult and hazardous and should**

only be used as a last resort to resolve an emergency and the diver must be venting air continuously (exhaling all the way to the surface). A diver having difficulty ascending should release his/her weight belt and divers experiencing stress at the water's surface should drop the weight belt immediately to ensure that they will float [NOAA 2001]. If a diver has traditionally used a weight belt and transitions over to integrated (ditchable) weights, they need to relearn the muscle memory to release. The first place they may reach for is the belt release if they haven't relearned how to release the ditchable or integrated weights.

Recommendation #7: Fire departments should recognize public safety SCUBA diving as high risk/low frequency events and ensure public safety divers are properly trained, equipped, and supported to perform public safety diving responsibilities and integrate the training and SOPs with regional dive and water rescue team(s) with whom they regularly respond.

Discussion**:** Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Fire departments should recognize public safety SCUBA diving as a high risk/low frequency event (Figure 9) and use a risk assessment program to determine the level of involvement in which they wish to participate. During this assessment, departments can decide if they want to accept the risk (fully committed to equipping and training their own team), share the risk (integrate with other teams in a mutual aid or regional team) or decline the risk (using a program risk analysis to transfer SCUBA duties to other agencies).

There is no standard scale to measure and evaluate frequency and severity of risk for the fire service. NFPA 1500 (Standard on fire department occupational safety and health program), provides guidance on risk assessment [NFPA 2018]. It is important that a fire department develop a risk management program that is based upon the process of identifying, evaluating, prioritizing, and controlling risk. The risk management plan incorporates a full range of control measures that may be used to limit, reduce, or eliminate the probability that an undesirable outcome will occur.

An important factor is that fire departments should prepare and maintain a written statement or policy that establishes the existence of the fire department, the services the fire department is authorized and expected to perform, and the basic organizational structure. This will be the basis for the development of the risk management program. The frequency and severity of risk starts with a thorough community risk assessment [NFPA 2018].

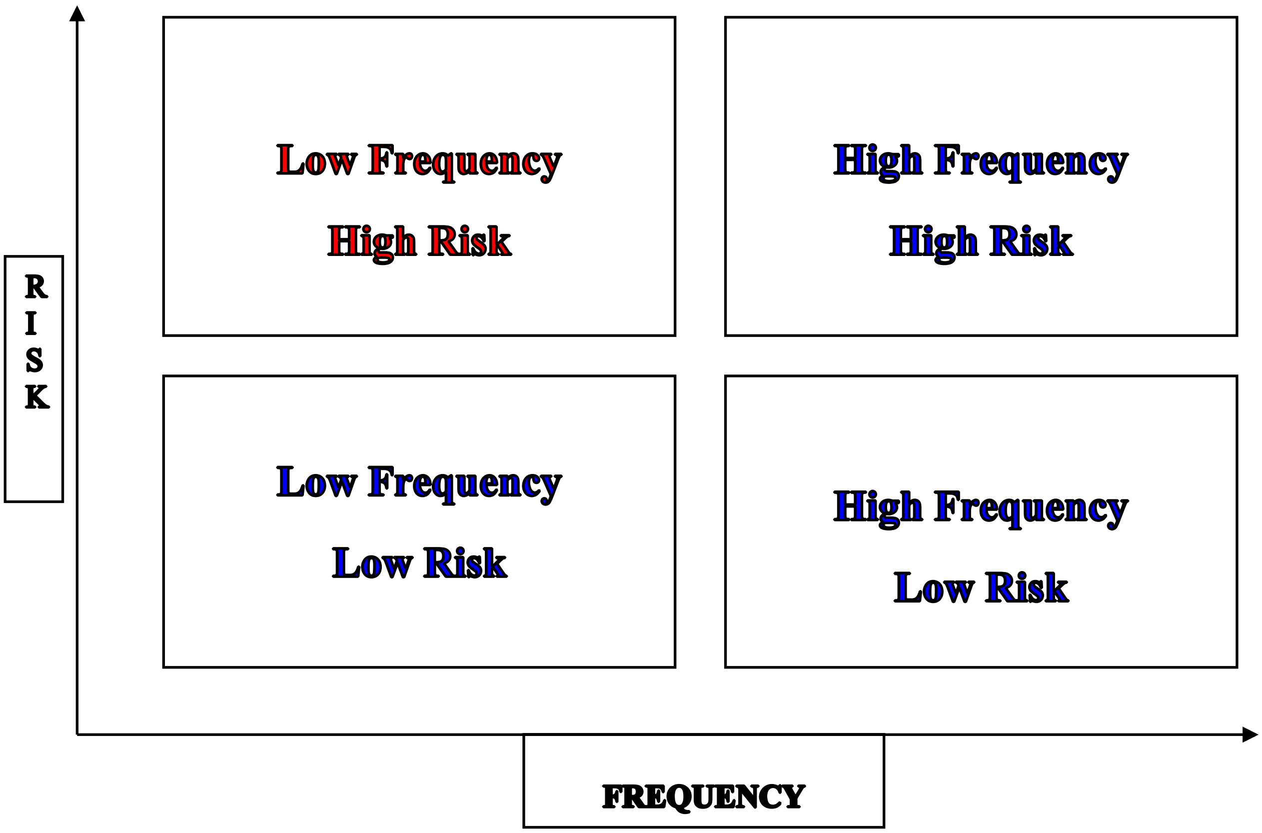

Figure 9. Risk vs. frequency scale. [NFPA 2018]

Fire departments should prepare and maintain written policies and standard operating procedures that document the organizational structure, membership, roles and responsibilities, expected functions, and training requirements, including the following:

- The types of standard evolutions that are expected to be performed and the evolutions that must be performed simultaneously or in sequence for different types of situations
- The minimum number of members who are required to perform each function or evolution and the manner in which the function is to be performed
- The number and types of apparatus and the number of personnel that will be dispatched to different types of incidents

- The procedures that will be employed to initiate and manage operations at the scene of an emergency incident [NFPA 2018].

Fire departments that decide they want to accept the risk and perform technical rescue water operations, including SCUBA diving and water rescue, need to ensure that personnel receive the proper initial training, advanced training, repetitive skills training and interagency training with mutual aid or regional dive teams that they regularly respond with. Fire departments must also understand that the commitment will involve a continuing commitment to advanced and recurrent training and also equipment and marine apparatus purchasing and maintenance.

Managing risk includes mandatory continuing education and skills documentation programs. Steve Orusa, Fire Chief of Fishers Indiana Fire Department and nationally renowned expert and author of *Dive Rescue Specialist, Operational Training for Public Safety Divers* [Orusa 2007] notes, a lack of basic diving skills has been statistically identified as one of the leading causes of public safety diving fatalities. With 86% of the fatalities occurring in training and recovery modes (as was this incident), managing the components of rescue and recovery mode and the risk/benefit analysis in water rescue operations and training are critical.

In his book Chief Orusa notes: "Inadequate SCUBA skills may be the leading cause of public safety diver accidents. In many cases, a problem developed that the diver was unable to solve due to a basic skill level. In most cases, divers had received either insufficient or nonexistent SCUBA skills refresher training after initial certification." Public safety divers should have training and experience in a variety of environments likely to be encountered in rescue operations, such as deep-water complex dives, limited visibility, cold water diving, ice, current, contamination and hazardous materials, dry suit, and lifting operations.

Annual confirmation of these skills should be performed to ensure continued competency. Dive team(s) need to stay current on training and annual skills evaluation. An example of an evaluation form to assess skills of public safety divers is provided in Figure 10.

The level of knowledge, skills, ability, equipment and support required for a public safety SCUBA diver are outlined in NFPA 1006 [NFPA 2017] and NFPA 1670 *Standard on Operations and Training for Technical Search and Rescue Incidents* [NFPA 2014]. Throughout NFPA 1006 and 1670, hazard analysis and risk assessment are addressed. One of the most hazardous events a diver can encounter is not being able to solve problems or make decisions underwater. The typical chain of events in a public safety diving accident is as follows:

- The public safety diver becomes cold and/or tired
- Their stress level, which is already high under such circumstances, increases
- The public safety diver encounters a problem or makes a mistake they cannot solve

- Panic ensues
- Death or serious injury results [Orusa 2017].

Public safety diving requires emergency response teams with specific knowledge, skills, ability, equipment and continued support beyond basic firefighter or emergency responder requirements to resolve unique or complex rescue situations. Additionally, when the team is faced with complex, deep, highly technical recovery dives, it is important to realize the team's limitations and when the team needs assistance and call additional resources (mutual aid). Some jurisdictions utilize regional teams to meet the goals of risk management for a specific risk (shared risk).

A key part of an overall rescue strategy should be mutual aid. The use of formal or informal mutual aid can help share the risk by providing additional experience, equipment, personnel and other resources to a public safety diving event. Other benefits include, greater levels of coverage and redundancy, building trust between organizations and leadership benefits that can ultimately make for a safer dive environment. Additionally, it can remove destructive competitiveness and rivalries between departments and/or agencies.

Since the resource requirements and commitments are very high, a shared risk approach may work for some jurisdictions. Regional or mutual aid teams need to train together (if they are going to work together) so they can recognize and work together and have a level of coverage and/or redundancy that they may not have otherwise. If regional teams are going to work and train together, they should consider integrating their standard operating procedures (SOPs) and standard operating guidelines (SOGs). The difference between SOPs and SOGs is the difference between a procedure, which must be followed, and a guideline, which is more flexible and allows the responder to tailor his/her actions to fit the situation. A set of SOPs would include any rules that should be inviolable. For example, a public safety diver should always end his/her dive with 1,000 psi remaining for emergency reserve air (3,000 psi per 80-cubic-foot cylinder). The 1,000-psi rule should not be broken and is a good example of an SOP [Hendrick et al. 2000].

Fire department SCUBA dive teams need to stay current on new equipment available such as "in mask" air supply status or heads up display (HUD), communications and protective gear such as dry suits and redundant air supply options. Also, new high-definition sonar systems are available that can reduce a dive teams' exposure to blind diving, by working to locate and isolate a dive target to within several feet. Blind underwater searches using search ropes and gridding-off areas are very task-oriented and time-consuming (underwater time) and therefore could require a significantly greater resource commitment for a significantly longer period of time. Reducing your exposure to the hazard is a recognized risk management principal. Dive teams should consider reducing the risk by reducing the exposure to the hazard (underwater) by spending more time and resources when they can on surface operations and technology to locate and mark targets with extreme accuracy.

Continued support for the team is an important component of the leadership of technical rescue teams. Once a team is properly trained and equipped, the organization must continue to provide support to maintain the technical rescue team's operational readiness through continued training and review of program goals and needs. Inadequately trained divers should not be allowed to participate in technical rescue SCUBA diving incidents beyond their level of training.

I.A.D.R.S. Annual Basic Scuba Skills Evaluation

Diver's Name: ____________________ Department: ____________________

Air Consumption: Start ________psi / Finish ________psi Time: Start _______ / Finish ________ / Total ________

Water Depth: __________Pool / Open Water (circle one) Examiner: ____________________

Task grading: S = Satisfactory N = Needs Improvement (specify) N/A = Not Applicable (use for equipment only)

Equipment Handling and Set-Up

__________- properly assembles equipment (basic gear / specialty gear)
__________- shows familiarity and comfort with equipment
__________- properly protects equipment (i.e. tank valve / regulator)
__________- review (line & hand signals / air consumption rates / buddy awareness / emergencies / diver log)

Watermanship Skills

__________- 500 yard continuous forward stroke swim - no swim aids for time (refer to grading criteria)
__________- 15 minute tread / last 2 minutes with hands out of water (refer to grading criteria)
__________- 800 yard snorkel swim (refer to grading criteria)
__________- 100 yard inert diver rescue tow (refer to grading criteria)

Skin Diving Skills

__________- mask clearing
__________- snorkel clearing (popping & expansion)
__________- snorkel without mask (led by partner, 1 lap)
__________- fin kicks (flutter / dolphin) one length each, using mask and snorkel
__________- in water surface dives (head first / feet first)

SCUBA Diving Skills

__________- entries (giant stride / seated or controlled entry)
__________- neutral buoyancy control (oral / power) inflation
__________- dry suit buoyancy control and emergency procedures (i.e. hose disconnect or flooding)
__________- regulator clearing (blowing / purging) and retrieval
__________- regulator without mask (led by partner, 1 lap)
__________- full face mask (removal / switch to regulator / clearing full face mask / replace full face mask)
__________- descent procedures (signal / check time & air / raise inflator hose / feet first descent / clear ears)
__________- ascent procedures (signal / check time & depth / + buoyancy / raise inflator hose / ascend @ 20ft/min)
__________- air sharing at depth and during ascent
__________- buddy breathing at depth and during ascent
__________- emergency swimming ascent procedures (simulate out of air / signals / ascends / continuous exhaling / surfaces / inflates BC orally using bobbing technique)
__________- emergency buoyant ascent procedures (simulate out of air / signals / drops weights / ascends / continuous exhaling / surfaces / inflates BC orally using bobbing technique)
__________- weight belt (removal / replacement) on surface and bottom
__________- buoyancy control device (removal / replacement) on surface and bottom
__________- OPTIONS: Blackout Mask / Night Dive / Navigation / Confidence Obstacle Course

Performance Comments: ____________________

Equipment Care and Storage

__________- properly disassembles equipment
__________- cleans and restores equipment properly

Additional copies available at no charge via the International Association of Dive Rescue Specialists webpage. Visit www.IADRS.org

Figure 10. Annual Basic SCUBA Skills Evaluation.
(*Courtesy of International Association of Dive Rescue Specialists.)*

Recommendation #8: Fire departments and other public safety dive teams should consider advanced level training courses/agencies that closely match the public safety dive team needs.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Public safety dive hazards are extreme and unforgiving. Public safety dive teams have to operate (or consider operating) in many extreme conditions such as ice-covered lakes, very cold diving conditions, limited or no visibility, a myriad of entanglement hazards, marine traffic, ship intakes and outflows, marine life hazards, biohazards and chemical pollutants, and technical deep water wreck penetration diving. As stated before, public safety SCUBA diving is a very high risk and low frequency discipline, therefore having personnel with high degree of experience in any one of the above-mentioned hazards is not always possible or available.

Fire departments that incorporate public safety dive teams as part of their community risk assessment and have decided to provide a level of public safety SCUBA diving need to identify all of the possible dive possibilities and ensure that they select a training agency or organization that will match the dive training needs and discipline to the local dive response requirements.

For example, a public safety dive team that regularly dives in ice covered lakes should not select a training course/agency that specializes in warm water recreational diving for their advanced training.

When a department or dive team selects a training course/agency, some things they should consider are:

- Public safety diving specific training standards. Does the organization or agency have clearly defined standards that address the specific needs of public safety diving (benchmarks for instruction, equipment, safety, documentation, skill maintenance and conduct can help teams to judge the quality of a program).

- Public safety diving specific curriculum that provides clearly defined objectives for each classroom, pool and open water training session that is developed through experience in public safety diving and observations and tailored to help solve dive challenges in their respective water environments.

- Operational experience in their instructional staff. The instructor should be an experienced member of a public safety dive team and experienced in the specific discipline that the department has identified. In the public safety dive industry, experience must breed caution not complacency [Orusa 2017].

- The instructional staff should be able to provide a list of references. The agency should be able to provide other types of dive team training that they have provided. This established the credibility of the agency as well as the instructors that will be training your divers.

- Departments should consider if the training agency will be a resource for dive team SOPs and templates from other safe and effective dive teams. The training agency or organization can also have in place programs that identify requirements for basic SCUBA rescue/recovery teams or highly technical SCUBA rescue/recovery teams.

- The agency should have a certification program that ensures continuing education and skills maintenance. Chief Orusa notes: "being a good public safety diver two years ago doesn't mean you will function safely and effectively today. Skill levels, if not reinforced, deteriorate over time and public safety divers don't have the luxury to be 99% efficient underwater. They have to be 100% effective and mandatory skills checks for efficiency are the answer."

- Departments should do their homework and research successful teams throughout the country and use them as a resource to identify advanced training agencies [Orusa 2017].

Recommendation #9: Fire department dive teams should ensure vessels are properly equipped when used for supporting dive operations or consider other options.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Vessels/boats used to support diving operations should be staffed and equipped to support public safety dive operations. For example, vessels/boats should include emergency resuscitation gear (ideally ALS gear and ALS personnel if the dive site is a distance away from land units), communications equipment, anchoring gear, prop guards on propulsion motors, and adequate deck space for all divers and equipment. Protection from the sun and the elements, sanitary facilities, and rehydration liquids are also important.

Additionally, vessels used for dive platforms should be capable of remaining stationary and close to the dive site without causing danger to the divers. This keeps the distance from the dive boat to the descent buoy at a minimum and causes less fatigue to the divers from extended surface swims (see cover photo in the Executive Summary). A drifting dive or support boat with unguarded propellers that are constantly engaging and maneuvering to stay close to the dive buoy is a danger to divers. The safest dive vessel is an anchored dive boat with the motors shut down. There may be occasions where currents may necessitate a dive boat that is drifting at the same rate as the divers and there is no descent buoy. In these instances, the dive boats should have prop guards or water jet propulsion and consider shutting engine(s) down while placing divers in the water or recovering divers (see Photos 9 and 10 for examples of prop guards and Photo 11 for an example of a jet drive on an outboard engine).

An unanchored dive boat can be more difficult to maintain a close distance to the descent buoy, and a drifting dive boat may force divers to swim greater distances than necessary on the surface before submerging (see Photo 12). This surface swim can be exhausting when fighting any wind or current. Additionally, with the surface communication line tethered to the divers from the unanchored dive boat, the communication umbilical system could be put under a strain by wind or current effects on the surface vessel. This could cause a separation of the communications line or even an unneeded distraction or complication to the public safety diver.

The same challenging conditions (locating the dive boat and swimming over to it; the dive boat motoring into the dive area with unguarded props) may also be present after the returning divers follow the ascent line up. Another advantage of having the dive boat anchored is the ability to mark the safety stop on the descent/ascent line with emergency cylinders/regulators at the safety stop. If a diver has gotten close to their emergency reserve air, there should be a breathable air source at the safety stop.

Boat support personnel should be familiar with dive operations to assist dive crews when needed. However, only divers should perform a pre-dive check of another diver’s equipment. A non-diver can easily miss important equipment checks. Only divers should buddy check another diver.

Photo 9. An example of a propeller guard for a small and medium sized outboard engine. There are also jet drive propulsion options for outboard engines *(Photo by NIOSH.)*

Photo 10. Example of propeller guards on larger twin outboards (*Photo courtesy of Bing Images/Holtonmarine.)*

Photo 11.Example of a large horsepower outboard jet drive engine ***(Photo courtesy of Bing images.)***

Career Captain Drowns After Running Out Of Air During Technical Rescue SCUBA Dive—North Carolina

Photo 12. Aerial photo of lake with the location of the dive site marked. Dive sites can often be in open areas and remote from the Command Post and boat launch site.
(Courtesy of Google Earth.)

Recommendation #10: Standards-setting organizations should consider adopting a national consensus standard for public safety SCUBA divers that includes minimum initial and refresher training and a SCUBA equipment standard that includes minimum respirator performance.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Currently, there is no national consensus standard for public safety SCUBA divers. A national standard could include minimum training requirements as well as quarterly training and annual skills review and refresher training. Public safety SCUBA diving is different than other public safety disciplines in that the training environment is just as dangerous as the work environment. Firefighter/divers have died during training and the level of training varies throughout the country in different jurisdictions.

Proper training, equipment and continued administrative support (for program funding) are equally important and would benefit from a national standard. For example, a high-quality commercial grade heads-up display and a full-facepiece, dry suit and communications equipment should be a minimum requirement for public safety SCUBA divers. Although the equipment can be more expensive than recreational equipment, the benefits far outweigh the cost savings for departments that have to use recreational equipment (see Photo 13).

Recommendation #11: Fire departments should consider implementing a body recovery procedure to reduce the time dive teams spend at depth recovering a victim.

Discussion: Fire department should consider implementing a body recovery procedure that limits the hazards to divers. This procedure involves raising the victim up to a shallow depth while keeping divers clear of entanglement hazards before deploying the body recovery packaging system. The victim can then be packaged closer to the surface (an example could be bringing the body up to the recovery boat, but just below the surface) as a safer practice for divers and the assisting boat crew members verses carrying a body retrieval bag (see Photo 14) to the bottom and packaging on the bottom. There may be advantages to the recovery divers by not introducing additional entanglement hazards at greater depth with limited visibility and other hazards.

Having a procedure for body recovery in place that minimizes diver exposure and is a good safety practice As Chief Orusa notes: “Very often it is a unique chain of events that leads to a water rescue line of duty death. Breaking one link in that chain sometimes can prevent a tragedy from occurring.” Minimizing diver exposure to the hazards should be a goal for all dive teams and having a procedure for body recovery closer to the surface reduces a number of hazards.

Career Captain Drowns After Running Out Of Air During Technical Rescue SCUBA Dive—North Carolina

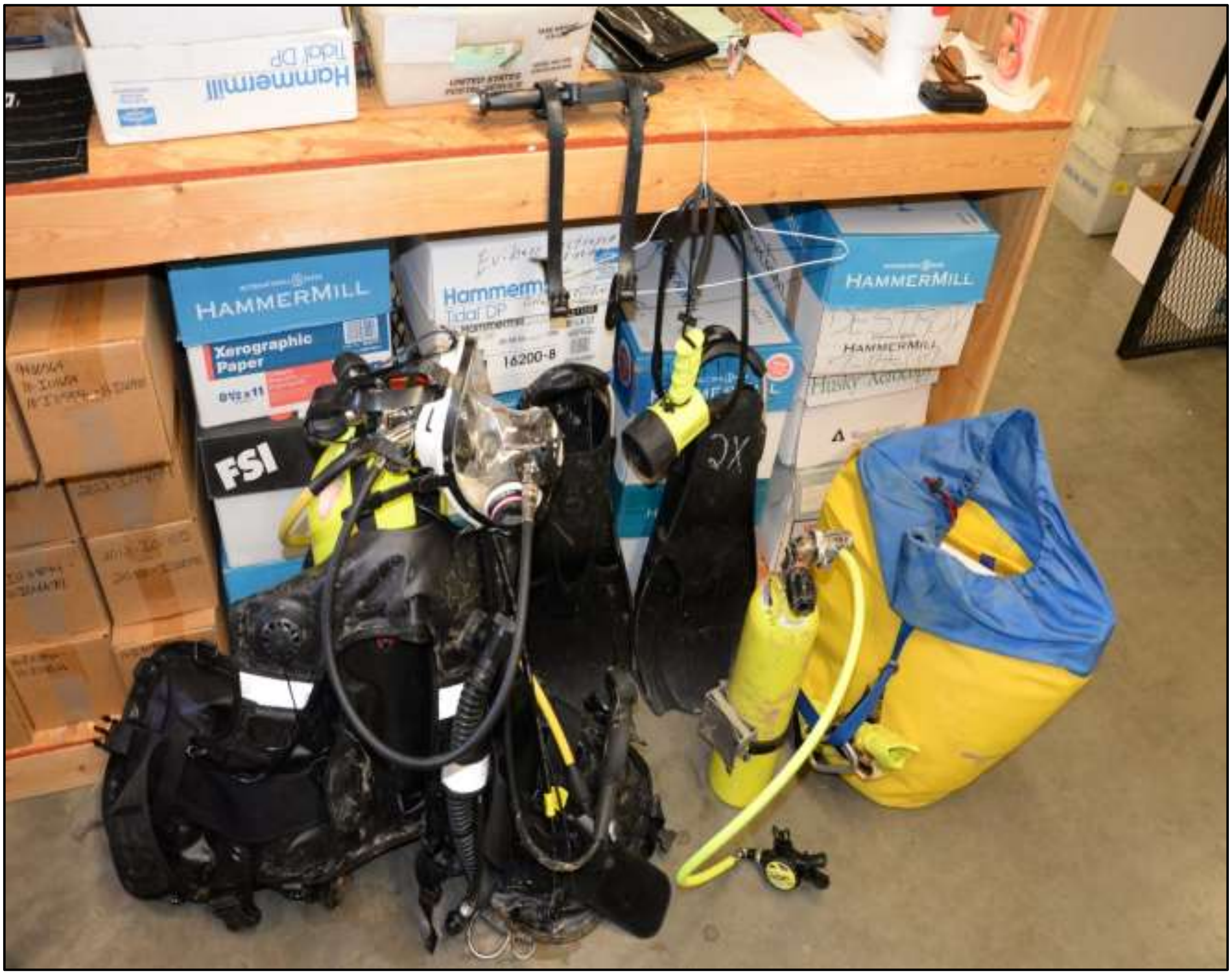

Photo 13. Victim's SCUBA gear and recovery bag he was carrying.
(Photo by NIOSH.)

Photo 14. Example photo of the same type recovery bag expanded that Diver 4 was carrying clipped to his BCD.
(NIOSH Photo.)

Since this incident, the department was able to move forward by researching and obtaining a Remote Operations Vehicle (ROV) for underwater recovery operations. The ROV was first of its kind in the department's region. It was equipped with sonar and video capabilities and can work up to a depth of 1000 feet. Since acquiring this equipment, the department has assisted many agencies in and out of the state in making recoveries. The ROV along with other surface water technology equipment obtained by the department drastically reduces the need for members to have to get into the water. Should divers be required, the ROV can work in conjunction with the divers to enhance their safety as well as make recoveries, reducing the need for divers to take those unnecessary risks.

References

Dodson D [2007]. Fire department incident safety officer. 2nd ed. New York: Thomson Delmar Learning.

Dunn V [2000]. Command and control of fires and emergencies. Saddle Brook, NJ: Fire Engineering Book and Videos.

Hendrick W, Zaferes A, Nelson C [2000]. Public safety diving. Saddle Brook, NJ: PennWell.

NFPA [2013a]. NFPA 1001 Standard for firefighter professional qualifications, Firefighter I and Firefighter II. Quincy, MA: National Fire Protection Association.

NFPA [2013b]. NFPA 1582 Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association.

NFPA [2013c]. NFPA 1561 Standard on emergency services incident management system and command safety. Quincy, MA: National Fire Protection Association.

NFPA [2014]. NFPA 1670 Standard on operations and training for technical search and rescue incidents. Quincy, MA: National Fire Protection Association.

NFPA [2015]. NFPA 1521 Standard for fire department safety officer professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2017]. NFPA 1006 Standard for technical rescuer professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2018]. NFPA 1500 Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association.

NIOSH [2003]. Career firefighter drowns during final dive of training course—Indiana. By Tarley J, Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2002-15.

NIOSH [2005]. Career firefighter drowns while conducting training dive—New Hampshire. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2004-36.

NIOSH [2009]. Career firefighter dies while diving for a civilian drowning victim—Rhode Island. By Miles S.T., Tarley J, Baldwin T. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2008-32.

NIOSH [2010]. Career lieutenant dies following floor collapse into basement fire and a career firefighter dies attempting to rescue the career lieutenant—New York. By Wertman S, Bowyer M. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2009-23.

NIOSH [2011]. Career firefighter dies while conducting a search in a residential house fire—Kansas. Revised. By Bowyer M, Miles S.T. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2010-13.

NIOSH [2012]. A career captain dies and 9 firefighters injured in a multistory medical building fire—North Carolina. Revised. By Bowyer M, Miles S.T., Loflin M. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2011-18.

NIOSH [2013]. Volunteer captain dies while participating in advanced dive training at quarry—Ohio. By Tarley J, Bowyer M. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2012-25.

NOAA [2001]. NOAA diving manual. 4th ed. Flagstaff, AZ: Best Publishing Company.

Orusa S [2007]. Dive rescue specialist, operational training for public safety divers. 3rd ed. Fort Collins, CO: Dive Rescue International.

Orusa S [2017]. LODD Review report. June 2017

Weather Underground [2016]. Weather history for KSVH, June 6, 2016. Atlanta, GA: The Weather Channel Interactive, Inc.

Wikipedia [2017]. Lake Norman. San Francisco, CA: Wikepedia Founaiton, Inc.

Career Captain Drowns After Running Out Of Air During Technical Rescue SCUBA Dive—North Carolina

Investigator Information

This incident was investigated by Stephen T. Miles, Investigator/Safety and Occupational Health Specialist, Matt Bowyer, Investigator/General Engineer and Murrey Loflin, Investigator/Safety and Occupational Health Specialist with the NIOSH Firefighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, located in Morgantown, West Virginia. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

An expert technical review was provided by Chief Steven Orusa, Fire Chief for the Fishers Fire and Emergency Services, Fishers, Indiana. Chief Orusa is also the author of *Dive Rescue Specialist, Operational Training for Public Safety Divers*. He has served over 33 years in law enforcement and fire service positions. He is past director of the International Association of Dive Rescue Specialists Response Team and has served on public safety and military dive operations worldwide. A second expert technical review was provided by Deputy Chief Ron Dorneker, Deputy District Chief, Marine & Dive Operations with the Chicago Fire Department. Chief Dorneker is certified as a Public Safety Diving Instructor by Emergency Response Diving International (ERDI). He is also certified by SCUBA Diving International (SDI), and Professional Association of Diving instructors (PADI).

An expert dive computer evaluation was performed for NIOSH investigators by Craig Jenni with Dive & Marine Consultants International, Inc., Boca Raton, Florida. An examination of dive equipment and analysis of dive computer information were also performed by Air Hogs SCUBA for the local sheriff's department and made available to NIOSH investigators courtesy of the local sheriff's department. Information from both of these evaluations were incorporated into this report. Additional assistance was received from Pelton Designs, a NIOSH graphics contractor, to produce an illustration from a photo. Additional assistance was received from Mr. Blades Robinson and Dr. Richard Sadler with Dive Rescue International.

This report was authored by Stephen T. Miles.

Additional Information

Additional information on Public Safety Diver Stress and helping with mental preparedness is available in the FireRescue magazine November, 2017 article, Staying Sharp Underwater by Lt. Scott Huff with the Indianapolis Fire Department Dive Team.

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