Career Firefighter/SCUBA Diver Drowns While Searching for Civilian in an Industrialized River—Illinois

Executive Summary

On May 28, 2018, a 46-year-old career firefighter/SCUBA diver drowned while searching for a civilian who fell off of a boat into an industrialized river. At 1951 hours, SCUBA Team 687, Fast Boat 688, Ambulance 66, and Helicopter 682 were dispatched. Two divers (Diver 1 served as a stationary underwater line tender, while Diver 2 searched in a circular pattern) deployed from the fire department helicopter, which hovered about 5 feet above the river. After jumping in, the two divers swam on the surface to a civilian boat to get a last-seen point from the missing civilian's party. The two divers then descended to the bottom and commenced a search.

Helicopter makes approach to deploy the divers.
(Courtesy of the fire department.)

The dive supervisor arrived at 2005 hours on the south shoreline, then contacted the divers via a underwater radio and directed them to surface to reposition them. During the second dive, the dive supervisor requested an air check, and Diver 1 reported 1400 pounds per square inch (psi) and Diver 2 (the victim) reported 1200 psi. They were instructed to complete their search pattern and surface. The fire department's fast boat arrived on scene with relief divers. The dive supervisor instructed the fast boat to pick up the helicopter divers and deploy their divers. A police boat that was on scene prior to the fast boat was near the divers when they surfaced, but the fast boat informed the police boat that it would pick up the divers. After the two divers surfaced and came together, Diver 1 was assisting Diver 2 because it appeared that Diver 2 was having difficulty maintaining positive buoyancy. The police boat threw a life ring toward the divers. The fire department's fast boat instructed the divers to come to its boat and drove the boat toward the divers, causing the police boat to relocate away from the divers.

The divers then started to drift in a circular pattern toward the bow of the fast boat. Diver 1's hands were on the hull, and Diver 2 simultaneously pulled Diver 1's mask off. While Diver 1 inflated his buoyancy compensating device, Diver 2 disappeared under the water. Two divers from the fast boat and police divers were deployed. The fire department's rapid intervention team divers on the shoreline also were deployed via a rapid deployment craft. Approximately 8 minutes later, Diver 2 was located by the police boat diver. Diver 2 was brought on board the police boat and was transferred to paramedics onshore. Advanced life support measures were performed, and Diver 2 was transported to a local hospital, where Diver 2 was pronounced dead. The civilian drowning victim was recovered the next day farther down the river by the police marine unit.

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Contributing Factors

- *Air management*
- *Fundamental SCUBA skills*
- *Buoyancy control (inability to maintain positive buoyancy)*
- *Members unaware of distress*
- *Multiple agency integration and cooperation.*

Key Recommendations

- *Fire departments and public safety dive agencies should ensure regular training on fundamental dive skills, such as air management, buoyancy control, redundant air and out-of-air procedures*
- *Fire departments and public safety dive agencies should ensure that incident commanders, dive group leaders, and members maintain situational awareness, accountability, and frequent and accurate air status on all divers*
- *Fire departments and public safety dive agencies should ensure all public safety divers use dive computers*
- *Fire departments, standard-setting organizations, public safety dive agencies, and SCUBA manufacturers should consider adding heads-up displays in all full face mask SCUBA because of frequent zero-visibility/silt-out conditions.*
- *Fire departments and public safety dive agencies should ensure that a properly trained dive safety officer is on scene and integrated into the command structure*
- *Fire departments and public safety dive agencies should recognize public safety SCUBA diving as a high-risk/low-frequency event and ensure that public safety divers are properly trained, equipped, and supported to perform dives; training and standard operating procedures/standard operating guidelines (SOPs/SOGs) should include the regional dive and water rescue team(s) who regularly respond with interagency cooperation*
- *Fire departments and public safety dive agencies should ensure that the helicopter SOPs/SOGs address diver in distress situations when divers are deployed prior to the arrival of shore and/or marine units*
- *Fire departments and public safety dive agencies should ensure that communications equipment is reliable and has interoperability*
- *Standards-setting organizations should consider developing and adopting national consensus standards for Public Safety Diver (PSD) and equipment that address initial and refresher training and respirator performance.*

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Introduction

On May 28, 2018, a 46-year-old male, career firefighter/SCUBA diver drowned after searching for a civilian in an industrial river.

On May 29, 2018, the United States 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 7–13, 2018, and June 24–30, 2018, two NIOSH investigators traveled to Illinois to conduct an investigation. The NIOSH investigators met with the district chief/director of safety, deputy fire commissioner, deputy district chief/marine and dive operations, members of the fire department dive team, members of the marine police dive team, and an attorney representing the local police union. The investigators reviewed training records, training requirements, and standard operating procedures (SOPs) used by the fire department. A complete record of the radio transmissions also was reviewed. During the investigation, NIOSH investigators conducted interviews with the firefighters/fire officers and marine police involved in the incident.

On June 24, 2018, NIOSH investigators inspected and photographed the SCUBA equipment used during the incident. NIOSH asked the fire department to send the firefighter's SCUBA gear to a dive rescue consultant for further analysis and evaluation of the data contained in the equipment. *Note: This department does not use dive computers.* This was done at NIOSH's expense, after which the dive equipment was returned to the fire department. The dive equipment evaluation is included in the Appendix.

Fire Department

The fire department involved in this incident is a career department. At the time of the incident it had 5,143 full-time employees. The fire department is led by the fire commissioner and is assisted by a first deputy commissioner. The first deputy commissioner oversees the four bureaus—Operations, Fire Prevention, Administrative Services, and Logistics. The fire department has 5 divisions, 25 batallions occupying 98 stations (including a fire boat station as well as police boats). The fire department has 96 engines, 61 trucks, 4 squads, 80 advanced life support (ALS) ambulances, 2 hazardous materials (hazmat) units, 2 urban search and rescue units, 10 airport crash apparatus, 2 helicopters, and 2 fire boats. The operations bureau is the largest in the fire department, consisting of four divisions—fire suppression and rescue, emergency medical services, special operations, and the office of fire investigation. The operations bureau is comprised of more than 4,500 firefighters and paramedics, which are commanded by the deputy fire commissioner.

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The fire department has a Special Operations Division which is commanded by an assistant deputy fire commissioner and is subdivided into Hazmat and Air-Sea Rescue. Hazmat, Air Operations, and SCUBA Operations are each commanded by a deputy district chief. An on-duty special operations battalion chief reports to the assistant deputy commissioner of the division, as well as the three special operations deputy district chiefs. The special operations battalion handles all specialized units and companies. Currently, four special operations squad companies respond to special operation calls and working fires. The squads are housed at four different stations. Each squad has an officer and three divers.

The Special Operations Division is responsible for 37 miles of lakefront, 80 square miles of Lake Michigan, 28 miles of two major river systems, and various ponds and lagoons. During the past 3 years, the division has responded to 700 water rescue incidents and recovered/rescued more than 200 individuals from the water.

The fire department also has an Air Operations Station, with two Bell 412 EP helicopters, staffed with two pilots and two divers per shift. The Air Sea Rescue Unit for this fire department was established in 1965. The busy lakefront presents the Air Sea Rescue Unit unique emergency challenges, including providing assistance to boats in distress, performing water rescues, and conducting air search missions. Divers assigned to the Air Sea Rescue Unit are trained under public safety rescue diver guidelines specific to the fire department's needs and particular environment. The air pilots are trained in helicopter search and rescue and hoist rescue techniques patterned after nationally recognized standards. The Air Sea Rescue Unit uses the two Bell 412 EP helicopters to aid in its efforts. This equipment is used for multi-mission roles, which are primarily search-and-rescue flights, but also include administrative and law enforcement roles.

The Fireboat Station houses a dive truck; a fast boat with three 300 horsepower outboard engines, 1200 gallons per minute (gpm) fire suppression pump, GPS, radar, thermal imaging, and two rafts; and a fire boat engine (capable of breaking 12-inch thick ice) that is 90 feet long and weighs 228 tons, has 15,000 gpm pump capacity with three monitors on the bow, a monitor on a 30-foot elevated platform toward the rear, a 1,000-gallon tank of foam; and several 30-foot by 12-foot rafts.

Standard operating procedures (SOPs) exist for water rescue incidents and Emergency Response Diver International (ERDI) standards are followed. General dive equipment consists of thermal undergarments, a dry suit, a full face mask, redundant air supplies, and cutting tools. All divers are tender directed and on tether lines at all times.

Note: A tender is a diver that is stationary and serves as the anchor for the tethered line to the search diver. The search diver reels out several feet of tethered line then conducts a search pattern looking for the missing victim. This is repeated until the victim is found or has time to resurface. In this case, Diver 1 was the tender and Diver 2 was the search diver.

Training and Experience

In 2015, the Illinois Office of the State Fire Marshal implemented new minimum certification standards for all firefighters in the state, and these standards meet or exceed the requirements of National Fire Protection Association (NFPA) 1001 *Standard on Firefighter Professional Qualifications* for Firefighter I and Firefighter II [NFPA 2019].

As of December 2015, the Illinois Firefighter Requirements for Basic Operations included:

- 180 course hours with written and practical exams
- Fire Service Vehicle Operator Course
- Hazmat Awareness
- Hazmat Operations
- Technical Rescue Awareness
- Cardiopulmonary resuscitation (CPR)/Basic First Aid
- National Incident Management System (NIMS) 100 and 700
- National Fallen Firefighters Foundation Courage to Be Safe Course.

This career fire department enacted requirements that exceed the state's requirements. The fire department hires candidates through the city career civil service process. The fire department gives recruitment tests for both single-role paramedics and firefighter positions. Candidates that pass the exam are placed on an eligibility list and that list is sorted in lottery order. The lottery order is then referred to the department as vacancies become available. Candidates must pass a background check. Once a candidate is selected by the city, the candidate is sent to the fire department for a candidate physical ability test.

Firefighter recruits must complete a probationary period, which is considered 9 months of continuous employment from the date of initial hire. The fire department operates its own recruit training academy, which recruits attend for at least 6 months, exceeding the state requirement. In addition to completing Basic Operations Firefighter certification requirements referred to above, recruits receive approximately 150 additional hours of firefighting training at the academy. Each recruit also must complete instruction in emergency medical services and receive emergency medical technician (EMT) certification as a state of Illinois EMT-Basic. After completing the recruit training, candidates are further reviewed during the candidate field evaluation period, which is a period of 12 months of post-fire academy assignment on a company (engine or truck).

Firefighters are required to participate in 2 hours of training per work shift, which is documented by the company officer. All firefighters complete a 30-minute mask drill (self-contained breathing apparatus [SCBA]) at the beginning of each work shift, which includes monitoring the air pressure in their SCBA cylinder. During the mask drill, firefighters add their personal accountability system identification tag to the personal accountability report apparatus collection ring located on the apparatus they are assigned to.

All pump operators on the fire department hold the career service rank of fire engineer, which requires them to pass competitive written and practical examinations. Engineers also complete a 5-week class at the fire academy. Ladder/truck apparatus do not have pumps. Ladder/truck operators are referred to as a driver. The fire department's engineer and driver training requirements exceed the requirements of NFPA 1002 *Standard for Fire Apparatus Driver/Operator Professional Qualifications* [NFPA 2017a].

Promotion to the lieutenant rank involves a written test and an oral interview process. *Note: Seniority is 30% of the promotion criteria for those competing for Lieutenant and Captain.* Newly promoted lieutenants go through a 5-week training program at the fire academy, which covers fire officer, fire dynamics, water rescue, high-rise operations, medical form documentation, and employee-assistance program classes. The training program includes 3 days of live fire burns, including flashover simulation. The 5-week class covers the entire curriculum of the NFPA 1021 *Standard on Fire Officer Professional Qualifications* [NFPA 2020a].

Promotion to the captain rank involves both a written examination and oral interview process. Selected officers attend a 2-week training program that covers incident safety officer (ISO) training, fire dynamics, motor vehicle accidents, personal protective equipment (PPE), the employee-assistance program, and Fire Officer 1.

The battalion chief position is the highest tested rank. The 4-week training program for battalion chief officers includes incident safety officer, Fire Instructor 1, Fire Officer 1, and employee assistance programs.

All officer training classes involve tactical, hands-on training with simulators and tactical boards. Officers at the deputy district chief rank and above are appointed by the fire commissioner.
In compliance with the NIMS training requirement, the fire department requires all firefighters to complete NIMS training commensurate with their rank. The fire department's NIMS training requirements for firefighters, fire engineers, and battalion chiefs are greater than the federally mandated minimum requirements. Company officers are provided with opportunities to complete advanced NIMS training (Incident Command Systems [ICS] 300, ICS 400, All-Hazards Incident Management Team Training) that exceeds the federal minimum requirements for their rank.

Special operations battalion chiefs must have the following minimum qualifications for training and experience: career service rank of battalion chief; battalion chief-EMT or battalion chief-paramedic in this fire department. Minimum Certified Open Water Diver, as recognized by United States-Recreational SCUBA Training Council, which currently is the National Association of Underwater Instructors, Professional Association of Diving Instructors (PADI), Professional Diving Instructors Corporation, SCUBA Diving International, SCUBA Schools International, and SCUBA and Nitrox Safety International; Department of Homeland Security/Federal Emergency Management Agency ICS 100, 200, 300, 400, 700, 703, and 800; and the Fire Department Incident Safety Officer Course. Candidates must pass a physical/medical examination (Chicago Fire Department [CFD] Special Teams Medical Examination) as required and must possess the following license and Illinois Office of the

State Fire Marshal certifications: Instructor I, Confined Spaces, Structural Collapse Operations, Firefighter III, Hazardous Material Tech A or B, Rope Rescue Operations, and Trench Operations.

Note: It is not clear that the special operations battalion chief who responded to this incident had a recognized open water diver certification.

To become a diver you must have 5 years of service in a fire department and apply with a Public Safety Diver (PSD) Open Water Certification. Diver training and operations are conducted under current PSD Standards. An interview and vetting process is completed with all applicants. The application consists of work experience, ERDI skills, and a 40-hour diver endorsement program.

The endorsement program consists of the following:

- ***Equipment handling and set up***
  - Properly assemble equipment
  - Demonstrate familiarity and comfort with equipment
  - Properly protect equipment (tank valve, regulator, AGA mask, dry suit)
  - Properly don the Viking™ dry suit
  - Properly don all PSD SCUBA gear (according to CFD procedures)
  - Properly set up the communications system (communications box, headset, and communications lines)
  - Understand hand signals
  - Demonstrate familiarity and comfort with rapid intervention team (RIT) bottle and contingency plans
- ***Watermanship skills***
  - Swim 500 meters or equivalent (no backstroke)
  - Tread 5 minutes in water
  - Swim 35 feet underwater
  - Perform a surface dive to a depth of 10 feet and recover a 10-pound object
- ***SCUBA diving skills***
  - Entries (giant stride, seated or controlled entry)
  - Buoyancy control (inflator hose malfunction)
  - Proper use of AGA mask
  - AGA mask clearing
  - AGA removal, switch to pony and normal swimming ascent
  - Dry suit emergency procedures (inflator hose malfunction, flooding)
  - Descent procedures (feet first)
  - Ascent procedures with victim (secure victim with right hand, normal ascent to surface, left hand for buoyancy compensator inflation, roll on back, position communications line, support victim's head above water)
  - Proper handling of victim during removal from water
  - Emergency swimming ascent procedures (simulate out of air in primary tank)
  - Weight belt removal and replacement on the surface and bottom

- Removal and replacement of buoyancy control device on surface and bottom
- Proper use of cutting tools
- Rapid intervention techniques and contingency plans

- ***Equipment care and storage***
  - Properly disassemble equipment
  - Restore all equipment so it is ready to use
  - Properly store the Viking dry suit (zipper waxed, latex parts powdered, suit rolled).

The Deputy District Chief of Safety, in-charge of dive operations, holds all possible ERDI certifications and certifies all divers. A dedicated swimming pool is used for training members.

The divers complete the PSD training and are issued internationally recognized certifications. This training and certifications assure that the fire department is compliant, so it can continue standardized dive operations with other fire departments in the county and throughout Illinois. Public safety diving is different from recreational diving in many aspects. PSDs are trained to understand a large variety of specialized equipment, including harnesses, quick release pony bottles, line handling, underwater extrication tools, cutting tools, full face masks, and contingency lines. These divers also are trained to implement tender and profiler protocols. Public safety diving is undertaken 24 hours a day under all weather conditions and includes night diving and ice diving. Divers encounter potential contamination problems, high-risk entanglement, entrapment environments, and black water.

Standards are in place regarding how, what, and where to instruct public safety diving, including standards for equipment and mandates for recurrent training. The standards help to ensure the safety of divers, as well as successful rescue operations. Current national standards recommend that departments certify their divers in the skills below.

Emergency Response Diving 1 and 2
In this training, divers learn the fundamentals of dive operations from scene evaluation through incident debriefing. It also prepares PSDs and surface-support personnel to respond effectively to a water-incident scene.

Topics include:

- Overview of public safety drowning accidents
- Selecting, training, and equipping dive teams
- Family media and other agency relations
- Search pattern fundamentals
- Victim retrieval tactics
- Responding to vehicle accidents
- Accident scene documentation
- An introduction to specialized equipment and RIT operations.

Ice Diver
This training focuses on planning and implementing an ice diving operation. Techniques of diving beneath the ice for operations in rescue and recovery modes are introduced.

Topics include:
- Ice diving protocols
- Multiple subsurface ice dives
- RIT operations during subsurface operations.

Full Face Mask Diver
The full face mask training provides the skills and knowledge for the diver to utilize full face masks for emergency response diving. Basic full face mask topics and skills are presented.

Other topics and skills include:
- Encapsulation, communications with a full face mask
- Selecting proper masks for emergency response diving
- Decontamination procedures
- RIT operations.

Dry Suit Diver
Dry suit diving training addresses the proper precautions required when diving in potentially hazardous conditions.

Dry suit diving topics include:
- Suit types
- Accessories
- Sizing, custom adjustments
- Emergency procedures
- Repairs
- Maintenance
- RIT operations.

Surface Ice Rescue
This training focuses on planning and implementing a surface ice rescue operation. Techniques of how to approach several types of victims in varying environments as a primary tender, primary rescuer, backup rescuer, and backup tender are introduced.

Contaminated Water Diver
In this training divers demonstrate proficiency of all contaminated water skills and techniques, dive assessment and parameters, and a high level of awareness. Training dives incorporate hazard

recognition and handling, use of specialized equipment, and decontamination of equipment, and learn about environmental risk assessment, resulting in short- and long-term health benefits.

Underwater Vehicle Search and Rescue

This training focuses on planning and implementing an underwater vehicle search-and-rescue operation and introduces the techniques of diving in rescue and recovery modes.

Topics include diving protocols, which deal with:
- Entanglement
- Confined space
- Contaminated water
- RIT operations
- Contingency planning for safe and effective operations.

Diver 2 Training and Certifications

Diver 2 had 15 years of service as career firefighter and had the following fire certifications:
- Firefighter 1
- Firefighter 2
- Firefighter 3
- Emergency Medical Technician
- Hazardous Materials, First Responder Operations
- Hazardous Materials, Technician A.

Diver 2 was a member the department’s dive team for 5.5 years.

Diver 2’s activity log was up to date with the last entry on May 4, 2018. Diver 2 attended company school and open water dive training with SCUBA Team 687 for witness interviewing techniques, scene set up, searching the box area, and safety guidelines for divers, and also attended search patterns for divers using communications systems, dealing with entanglement hazards and limited visibility, locating a submerged victim, making a proper ascent, and putting the victim in the handcuff knot for removal from the water. During this dive training, team members were properly removed from the water using the diver dress down as prescribed. In addition, divers received confined water training for fitness and endurance and performed lifeguarding evolutions for surface rescue.

Incident Commander Training

The deputy district chief of the Marine and Dive Operations served as the incident commander for the incident described in this report. The deputy district chief has led the Marine and Dive Operations since 2001 and is responsible for maintaining the daily functioning of the fire department marine operations, including dive team training and safety operations for more than 160 personnel. The deputy district chief responds to incidents and executes coordinated rescues and recoveries, certifies all divers, and holds all of the ERDI certifications previously described.

SCUBA Equipment

The SCUBA equipment used in this incident was owned by the fire department dive team and is personally issued to each diver. A list of the gear examined by the NIOSH investigators at the fire department with local police present includes:

- One dry suit
- One harness
- One buoyancy compensating device
- One pony attachment
- One 80-cubic foot bottle
- One 19-cubic foot pony bottle (redundant cylinder)
- One EMT scissors with sheath
- One Shortie knife
- One Frameless mask with manually operated ambient breathing valve
- One underwater light
- One retractor (*The retractor was missing except for approximately 15 feet of rope and NIOSH could not confirm if the retractor had been entangled in the M2 Police boat prop*)
- Two regulators (one for primary and the second for the redundant)
- One stand-alone analog pressure gauge
- One full face mask
- One ambient breathing valve for full face mask
- One through water communications device (wireless)
- Two SCUBA fins w/springs
- One pair of 5-milliliter gloves
- One 2-inch stainless steel cam buckle
- One 2-inch webbing (for weight belt)
- Two 10-pound lead weights (*The diver's weight belt was not jettisoned.*)
- Two 4-pound lead weights.

Note: The diver was not using an integrated dive computer.

The fire department had a local dive shop evaluate the SCUBA gear as part of its investigation. NIOSH was informed that the results of that evaluation concluded that the SCUBA was functional. NIOSH investigators had a second independent expert in Boca Raton, Florida, evaluate the SCUBA gear. The expert concluded that the SCUBA equipment functioned as designed. The full report is provided in the Appendix. The SCUBA equipment used in this incident was owned by the fire department dive team and is issued personally to each diver (see Photo 1).

Photo 1: Example of a suited up diver.
(Courtesy of the fire department.)

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 interview statements. Times are approximate and were obtained from review of the dispatch records, witness interviews, and other available information. Some of the times were rounded to the nearest minute. This timeline is not intended for use as a formal record of events.

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Incident Conditions	Time	Response Operations
The 911 Call Center receives a phone call reporting that a civilian fell off the back of a boat while traveling upriver.	**1945**	Dispatch asks caller for the location of the boat.
Location of the boat is determined.	**1950**	Engine 39, Ladder 5, Squad 1, Ambulance 19, Unit 515, and Battalion Chief (BC) 15 are dispatched.
Engine 39, Ladder 5, Squad 1, Ambulance 19, Unit 515, and BC15 are en route.	**1951**	Unit 682 (helicopter with two divers), Ambulance 66, SCUBA team 687, and Fast Boat 688 are dispatched.
	1952	Engine 2 is dispatched. Police marine boats, Police Boat M2 and Police Boat M4, are dispatched to assist.
Engine 39 and BC15 arrive on scene.	**1953**	
Ladder 5 arrives on scene. BC15 makes cell phone contact with the civilian boat.	**1954**	
	1956	Dive Team Supervisor 686 is dispatched.
Ambulance 19 arrives on scene.	**1957**	
Ambulance 66 arrives on scene.	**1958**	
Unit 515 arrives on scene.	**2000**	
Squad 1 arrives on scene; watches Helicopter 682 deploy divers.	**2001**	Helicopter 682 deploys two divers 10 feet off the water and 20 feet west of the boat. Divers swim over to the civilian boat to get to the last-seen point.
	2003	Tender (Diver 1) and Diver 2 make their first descent. Diver 2 gets hung up a few times but gets clear. Four search patterns, each of 2-foot increments, are conducted.

Incident Conditions	Time	Response Operations
SCUBA Team 687 arrives on scene and sets up land-to-underwater communications. The dive group supervisor (Unit 686) arrives on scene and takes command.	2005	SCUBA Team 687 establishes wireless voice communications with Diver 1. The dive group supervisor instructs the civilian boat to come to the south shore to verify the last-seen point, then relocates the dive team 20 feet north for the second dive.
	2008	Ambulance 65 is dispatched.
	2019	Engine 28 is dispatched.
Engine 28 arrives on scene.	2026	
Ambulance 65 arrives on scene.	2030	
Engine 2 arrives on scene.	2035	
	2036	Ambulance 8 and DDC1 is dispatched.
	2037	Ambulance 34 is dispatched.
Ambulance 8 arrives on scene.	2039	Squad 5 is dispatched.
Deputy District Chief (DDC) 4 arrives on scene.	2040	DDC4 is dispatched.
DDC1 arrives on scene.	2041	
	2046	Diver 2 is missing.
Ambulance 34 arrives on scene.	2048	
Police diver finds Diver 2.	2054	
Squad 5 arrives on scene.	2055	
	2110	Diver 2 is loaded into Ambulance 8.
	2129	Diver 2 is in critical condition.
	2143	Ambulance 68 is dispatched.
Ambulance 68 arrives on scene.	2148	
Diver 2 is pronounced at hospital.	2202	

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Weather and Water Conditions

At approximately 1945 hours, the weather in the immediate area was 81° degrees Fahrenheit (81° F), the dew point was 63° F, and the relative humidity was 29%. Wind conditions were 15 miles per hour from the south. Visibility was 10 miles and partly cloudy [Weather Underground 2018].

The dive site was on the south branch of an 156-mile industrialized river. This area of the river passes railroad yards and an industrial area. It has an a maximum depth of 16 feet and is an average of 300 feet wide.

Interviewed divers reported that this part of the river was dark with zero visibility and consisted of entanglement hazards from illegal dumping and metal structures. The water temperature was not recorded but was reported as cold.

Investigation

On May 28, 2018, a 46-year-old career firefighter/SCUBA diver drowned, while searching for a civilian in an industrialized river. At approximately 1945 hours, a cell phone call came in from a boat on the river stating that a male occupant had fallen off the back of the boat while traveling up the river. After approximately 5 minutes of communication to determine the boat's location, Engine 39, Ladder 5, Squad 1, Ambulance 19, Batallion 15, and Unit 515 were dispatched.

SCUBA Team 687, Fast Boat 688, Ambulance 66, and Helicopter 682 with two divers were dispatched. At approximately 1952 hours, Engine 2 and police marine boats (Police Boat M2 and Police Boat M4) were dispatched. At 1953 hours, Engine 39 and BC15 arrived on scene looking for access to the south side of the river, which provided visual contact with the civilian boat. BC15 observed two individuals in the boat and requested cell phone contact from Dispatch. At 1956 hours, Dive Group Supervisor 686 (deputy district chief of Marine and Dive Operations) was dispatched. During the next several minutes, Ambulance 19, Ambulance 66, and Unit 515 arrived on scene.

Photo 2: Helicopter 682 makes approach to deploy the divers.
(Courtesy of the fire department.)

At 2001 hours, Squad 1 arrived on scene just as Helicopter 682 deployed two divers while hovering about 10 feet over the river and 20 feet south of the boat (see Photo 2). Diver 1 deployed first. Tapping the top of the head, Diver 1 indicated an okay status and moved to the west so Diver 2 could deploy. While enroute, the two divers had determined that Diver 1 would serve as a stationary underwater line tender, while Diver 2 would search in a circular pattern tethered to Diver 1.

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Both divers swam to the civilian boat to obtain the last-seen point from the missing civilian's party. *Note: Sixteen minutes after initial 911 call, Helicopter 682 headed to the local airfield to refuel, leaving two divers from the helicopter in the river with no support vessels close by to block the river and ensure the safety of the divers from potential boat/barge traffic that could have endangered the divers.*

The civilians directed the divers to about 20 feet east of the boat. Diver 1 clipped the trident reel to Diver 2 and descended to the bottom. On the bottom, Diver 1 hit the push-to-talk button and told Diver 2 to start a search pattern to the left. Diver 1 let out 2 feet of rope per circular pass. On the fourth pass Diver 2 was hung up on bottom debris and could not free himself. Diver 1 told Diver 2 to follow the line back, which was succesful. Diver 2 made it back to Diver 1 and indicated "I got you."

At 2005 hours, SCUBA Team 687 and supervisor for Dive Group 686 arrived on scene. SCUBA Team 687 set up wireless communications. The team established contact with Diver 1 and Diver 2 and instructed them to come topside for communications. Diver 1 acknowledged on the underwater radio twice that they were coming to the surface. The dive group supervisor waved the civilian boat over to the south side of the shore, so the supervisor could interview the civilians and get a better look at where the civilian had fallen off the boat. The dive group supervisor experienced difficulty communicating because the civilians only spoke Spanish. A bilingual police officer served as a translator. A civilian on the boat pointed out a blue boat tie-off as a reference for the last-seen point. When the dive team surfaced, the dive group supervisor asked if they could see the him and they both signaled "yes" by putting their hands on top their heads. The dive group supervisor then instructed Diver 1 and Diver 2 to move 20 feet north and conduct a second search based on the last-seen point provided by the civilian.

During the second dive, the dive group supervisor requested an air check. Diver 2 communicated 1200 psi and Diver 1 had 1400 psi. This was repeated twice. The divers were instructed to complete their pattern and surface. The fire department Fast Boat 688 arrived on scene with relief divers. The dive group supervisor instructed the fast boat to pick up the helicopter divers and deploy its divers. The dive group supervisor terminated the dive by the helicopter divers and told them to surface. The dive group supervisor indicated that Diver 1 responded "surfacing."

Police Boat M2 was on scene prior to Fast Boat 688 and was near the divers when they surfaced.

Note: Police Boat M2 was contacted to provide support by the fire department's dive group supervisor via ship-to-shore radio, which was the only means of communication between fire and marine police at the time of this incident.

The dive group supervisor reported seeing Diver 2 surface first, and Diver 1 surfaced about 3 seconds later. Diver 1 had to reel up the tethered line on the reeling spool while surfacing near Diver 2. One of the police officers attempted to deploy a life ring to the surfaced divers several times (see Photo 3). *Note: Deploying the life ring to assist divers to the boat is a best practice used by the Police Marine Unit. NIOSH investigators were told the police officer believed Diver 2 was in distress.*

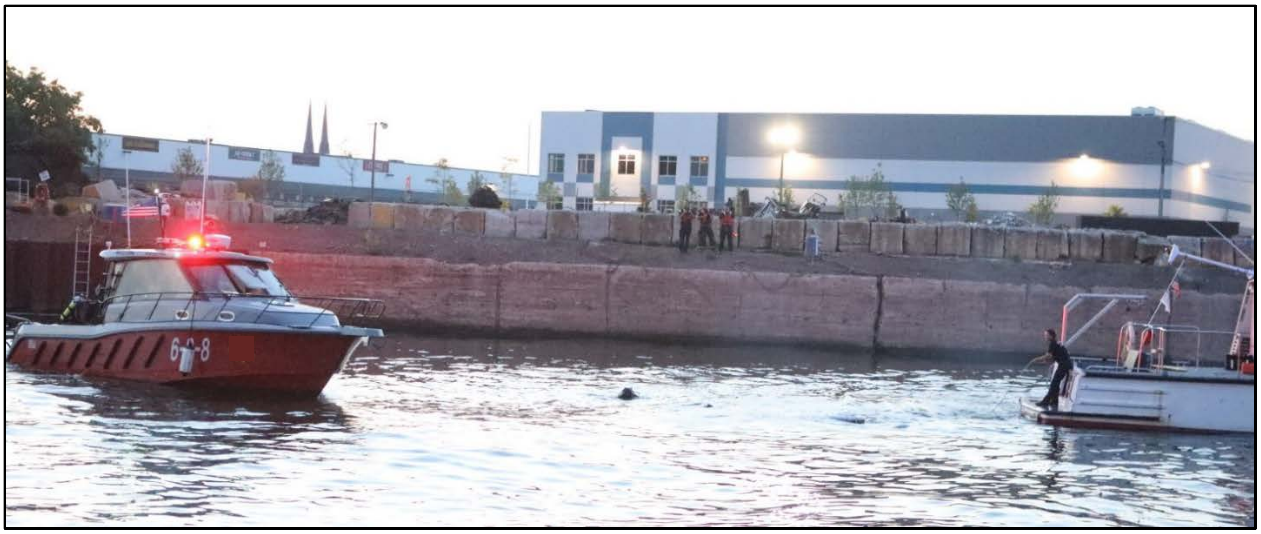

Photo 3: Officer on Police Boat M2 throws life ring to Diver 2.
(Courtesy of the fire department.)

Diver 2 and Diver 1 came together, and Diver 1's left hand was on Diver 2's right shoulder strap (see Figure 1). Diver 2 appeared to have difficulty maintaining positive buoyancy. Fast Boat 688 approached the area by doing a 180-degree turn to face south and perpendicular to the river. The lieutenant of Fast Boat 688 told Police Boat M2 that it would pick up their divers. Police Boat M2, which was facing east on the river, briefly engaged its engines to avoid getting too close while Fast Boat 688 was trying to get the two divers to come toward them. The lieutenant on Fast Boat 688 yelled to both divers to come to the boarding door of the fast boat. The two divers then started to drift in a circular pattern toward the bow of the Fireboat 688. This was possible because of the positioning and movement of both Fast Boat 688 and Police Boat M2. Diver 1 was able to put a hand on the hull of Fast Boat 688. Diver 2 grabbed the Diver 1's mask and pulled it off of Diver 1's face. Diver 2 also pulled the line reel out of Diver 1's right hand. Diver 1 inflated the buoyancy compensating device (BCD) and stayed on the surface. Diver 2 disappeared beneath the surface of the water.

Career Firefighter/SCUBA Diver Drowns While Searching for Civilian in an Industrialized River—Illinois

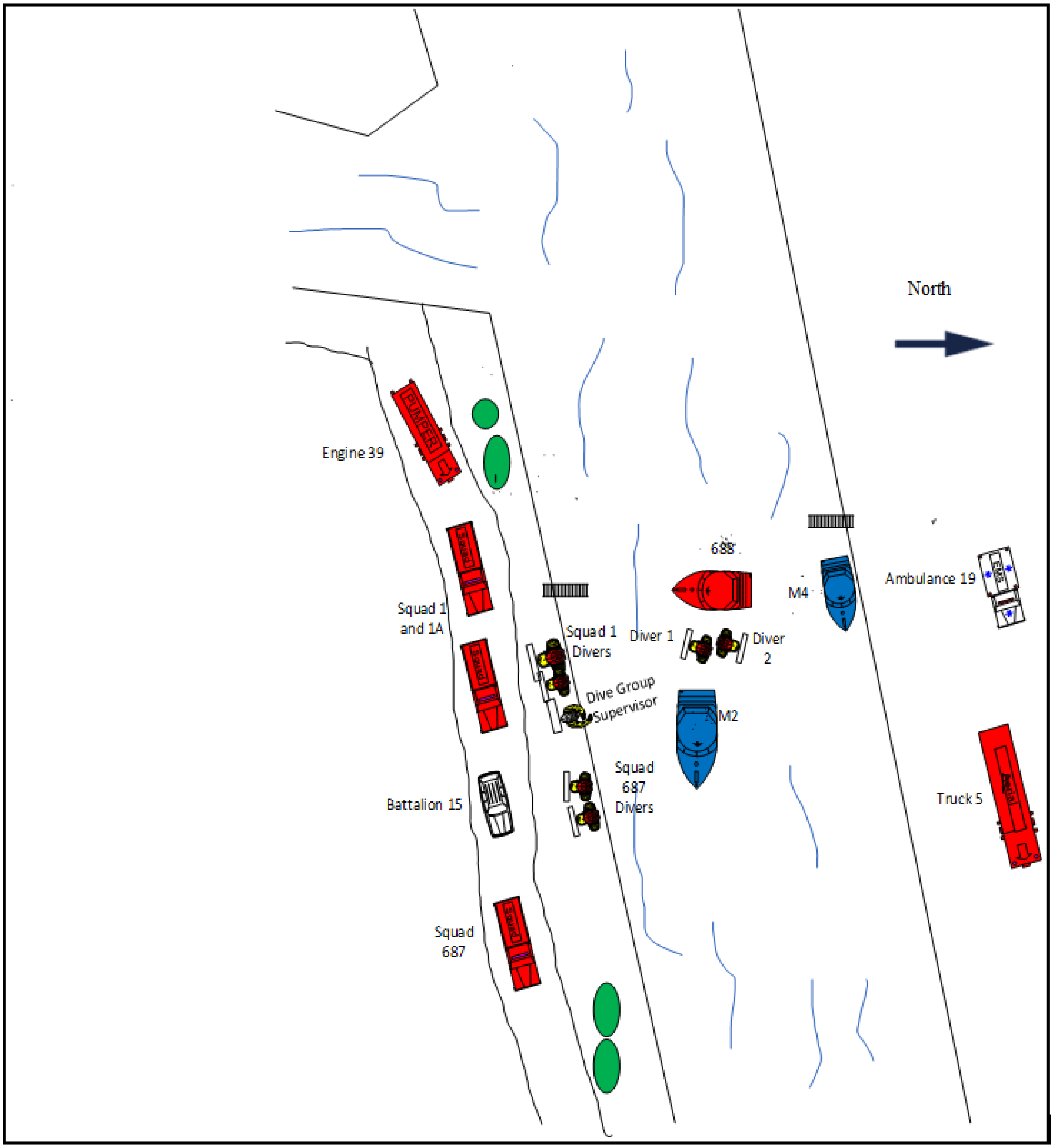

Figure 1: Apparatus and crew placement when helicopter drivers surfaced.

Diver 1 last saw Diver 2 lying flat on his back near the water's surface. Diver 2 was about 12 feet away from Diver 1 and drifting southwest of Fast Boat 688. Police Boat M2 radioed the dive group supervisor and asked if the dive group was missing a diver. No response was received. The lieutenant on Fast Boat 688 threw a retrieval line to assist Diver 1 in getting onto the boat. After getting on the boat, it was reported that Diver 1 had lost Diver 2. The fast boat lieutenant radioed the dive group supervisor to report that contact was lost with Diver 2. The dive group supervisor advised everyone to look for the diver and advised Fast Boat 688 and Police Boat M2 to establish a last-seen point. The dive group supervisor then advised the deputy district chief that a search had begun for Diver 2.

Fast Boat 688 was directed to do a subsurface search, and Police Boat M2 was asked to go to the shore and pick up the dive group supervisor. Police Boat M4 with divers was tied up to a barge on the north shore. Police Boat M2 moored to the shoreline, while the dive group supervisor talked to the ambulance and truck crews to see if they had seen anything. The view from the ambulance and truck crews was obstructed. Ambulance 65 and Ambulance 8 were on the north shore of the river, Ambulance 65 was dispatched for the missing civilian, and Ambulance 8 was the assigned RIT ambulance for the divers. Shortly after arrival, Ambulance 8 learned that a firefighter was missing, so it expedited removal of its equipment.

The dive group supervisor radioed the deputy district chief to deploy SCUBA Team 687 RIT divers on the shoreline via a rapid depoyment craft to cross the river. Police Boat M4 transferred its divers to Police Boat M2, and it maneuvered to approximately 10 feet from the last-seen point. Police Boat M4 then tied up next to Police Boat M2 and deployed a diver off the back of the boat.

At approximately 2054 hours, Diver 2 was located by a Police Boat M4 diver, who was deployed from the north side of the river just west of Fireboat 688. Diver 2 was brought on board Police Boat M2, where police divers removed Diver 2’s mask but left the other equipment on, including the weight belt.

Note: According to the National Oceanic and Atmospheric Administration, a diver who is having bouyancy issues should jettison the weight belt [NOAA 2001].

The police divers noted that Diver 1’s main tank was empty but the auxiliary (pony bottle) tank was full. The fire department dive group supervisor, who had come on board Police Boat M2, assisted in removing the SCUBA gear and cutting off his dry suit. CPR was started on Diver 2. A stokes basket was lowered down the river bank approximately 30 feet to Police Boat M2 and Diver 2 was put in a stokes basket.

Divers, firefighters, and paramedics formed a chain to lift and pull the stokes basket with Diver 2 to Ambulance 8’s awaiting stretcher. At approximately 2110 hours, Diver 2 was in Ambulance 8. Two paramedics and two firefighter/paramedics began ALS care in the rear of the ambulance while enroute to the hospital. The ambulance crew continued CPR and ventilation until they were relieved by the emergency room doctor. Diver 2 was pronounced dead at the hospital. The civilian victim was recovered the next day down river by the marine police unit.

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. NIOSH investigators identified the following items as key contributing factors in this incident, which ultimately led to the fatality:

- Air management
- Fundamental SCUBA skills
- Buoyancy control (inability to maintain positive buoyancy)
- Members unaware of distress
- Multiple agency integration and cooperation.

Cause of Death

According to the autopsy report, the cause of death was drowning.

Recommendations

Recommendation #1: Fire departments and public safety dive agencies should ensure regular training on fundamental dive skills, such as air management, buoyancy control, and redundant air and out-of-air procedures.

Discussion: Public safety dive teams should regularly train on air management to ensure that PSDs know how to have enough breathing air to complete their primary mission and allow enough reserve air to return to the surface or escape an unforeseen emergency. Divers should train to use task-level air management (always aware of their remaining air), 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 may lead to out-of-air events.

The first step in overcoming a SCUBA (and SCBA) out-of-air emergency is complete familiarization with the specific equipment and breathing air requirements and usage. When another event occurs simultaneously, firefighters/divers need to understand that many out-of-air emergencies occur when they do not maintain a sufficient air supply relative to their depth and mission, such as the inability to maintain buoyancy control (positive, negative, or neutral).

During an out-of-air emergency, it is important to confirm that the apparent air loss is real. For example, a tank valve that is not fully open can make it difficult to draw air, but it is easily corrected if recognized. Divers need to stop, think, and attempt to breathe. If it is possible to do so, divers should proceed with a normal ascent [National Oceanic and Atmospheric Administration [NOAA] 2001].

If divers determine that their air supply is depleted, the *NOAA Diving Manual* prioritizes the following ascent approaches 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 or pony cylinder can provide emergency breathing air and is independent of the primary air supply. These pony cylinders range in size from 1.7 to 15 cubic feet. A 4-cubic-foot cylinder can provide 14 to 16 breaths at a depth of 100 feet and 80 breaths in shallow water. It is possible to manifold some redundant air cylinders into the diver's primary air system. This allows divers to continue to wear the full face piece dive mask and insert a regulator before switching to a half mask.

Other conditions can challenge a PSD's ability to overcome an out-of-air emergency, such as removing a full face piece to switch to a standard regulator to access the backup air. Removing the full face piece causes a loss of visibility and/or cold shock to the face, all while trying to get the spare air regulator in the mouth. Once the face piece is removed, the diver needs to find the half mask from the buoyancy (BCD) compensating device pocket, put it on, and flush the water out of it by clearing it with air from the nose so the diver can see. It is necessary to do all of this without losing buoyancy and drifting down deeper or popping to the surface uncontrolled. This is a learned skill that divers must practice. However, engineered solutions allow the diver's spare cylinder to connect to the primary air system. This allows the diver to just adjust the valve position instead of removing the full face mask, but in these systems the redundant cylinder is no longer separate and independent.

The ability of PSDs to overcome low air and out-of-air events is directly related to their practical skills training and repetitive muscle memory. Repetitive skills training is very important for PSDs who often perform dive operations in extreme climate and water conditions that have limited or no visibility, extraordinary entanglement hazards, pollution, and challenging physical and mental conditions, while using heavy and cumbersome equipment. Many times, these skills are performed with gloved hands, limited vision, and reduced ability to hear commands from others, especially if the full face communications unit is removed. Repetitive skills training provides divers with an increased ability to perform the needed skills effectively and operate controls in a high-anxiety moment or an emergency.

It is possible to overcome many uncontrolled out-of-air emergencies by repetitive skills training. NIOSH investigators have identified air management as a contributing factor on many investigations of structural firefighter and firefighter SCUBA diver line-of-duty deaths. Fire departments should ensure that training on air management occurs at all levels of the command structure [NIOSH 2011, 2012]. The mastery of these skills is expensive and requires a commitment and a discipline from all levels of the agency(s) that are responsible for the team's operation. Performed in conditions that are controllable, such as pools, repetitive skills training helps build firefighters/divers' muscle memory so that in an emergency their hands are able to activate the controls with gloves on and the operation will become a second-nature response [NIOSH 2011, 2012].

The benefits of repetitive dive skills training with a SCUBA are to increase comfort and competency level, which in turn will:

- Decrease anxiety
- Lower air consumption
- Increase awareness of the user's air level (noticing and using the HUD when equipped) and an automatic muscle memory response for the vital function controls
    - Dive computer and air pressure function keys
    - Auto-inflate/deflate for the BCD
    - Inflate/deflate controls for the dry suit
    - Pulls for the detachable weights (or release handle/buckle for weight belts)
    - Purge button for the face piece to rid mask of water or method for evacuating water from a flooded half face piece.

When a relatively minor situation occurs, such as initially missing an air status change or air status check (milestone lights in heads-up display or audible alarm from dive computer), redundant safety measures, such as air status prompts from the tactical level or trained safety/accountability crew, along with learned equipment skills, can halt the escalation of the situation into an urgent response need. Once the initial situation goes beyond a simple adjustment or reaction, PSDs must react with learned skills on their redundant or backup breathing air system, communicate, and exit the danger.

Unfortunately, many public safety SCUBA dive incidents occur in little-to-no visibility conditions. Therefore, reading a depth and pressure gauge requires using an underwater light source. This is especially difficult if divers are using their hands to maneuver equipment, hold onto a descent line, manage a search rope, or even use the auto inflator/deflator to achieve neutral or desired buoyancy. Modern dive computers have audible alert signals that are programable to meet the needs of the diver (e.g., audible alarm sounding 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 versus sight) places the PSD at a much greater risk of missing milestone signals. PSDs should have a minimum of a full face diving mask with a heads-up display (HUD) inside the mask. Unlike recreational diving, visibility often is poor and audible sensory stimulation alone is insufficient. These factors and others can bring on anxiety.

Anxiety can lead to an increased heart and breathing rate and large air consumption rates. Proficiency, experience, and muscle memory with equipment can reduce anxiety before it develops into panic. Fight or flight response to underwater panic has a history of lethal consequences for PSDs. Very often, a distressed diver in a panic may dislodge a partner’s mask or regulator as happened in this incident and other PSD incidents as well [NIOSH 2003, 2012]. When any anxiety or panic begins, the only way that dive skills will stay second nature is if the divers overtrain on their use.

Divers control their buoyancy by adding weight to achieve neutral and negative buoyancy. This involves the use of ditchable or non-ditchable lead weights, which are either integrated or on a quick-release belt. They use devices such as BCDs, dry suits, and emergency air devices to achieve neutral and positive buoyancy, but they also can use full inflation of their lungs and manual propulsion by finning to achieve positive buoyancy. Understanding how to maintain control of all buoyancy is a critical skill that all PSDs must have a proficiency in and stay well trained in to ensure their safety.

Divers face extreme dangers that can result in death from conditions associated with ascending too rapidly. However, maintaining positive buoyancy once on the surface is critical. Normally, divers use their BCD to add air from their primary compressed air supply or they manually add air with an oral inflator. Divers also can add air into their dry suit for positive buoyancy. Divers need to understand that one of the most effective emergency means to achieve or maintain positive buoyancy is to ditch their weights. Divers should only use this procedure as an emergency action because of the severe consequences of a rapid uncontrolled ascent. In an out-of-air emergency, divers on or close to the surface cannot activate their redundant air, so they should consider ditching their weights.

Fire department dive teams need to provide regular refresher training on mitigating dive hazards by using buoyancy controls and the emergency release of dive weights. PSDs should have annual refresher training on these and other critical SCUBA diving skills. Because public safety diving is more dangerous than sport or recreational diving, PSDs need to use every margin of safety available [Hendrick et al. 2000].

Agencies offering advanced SCUBA levels of certification should stay consistent with national consensus standards. According to NFPA 1006 *Standard for Technical Rescuer Professional Qualifications, 2017 edition, Annex A* [NFPA 2017b]:

> "The committee is of the opinion that Advanced Open Water certification provided by most nationally recognized certifying agencies (agencies associated with the Recreational SCUBA Training Council) builds an acceptable foundation for the basic SCUBA skills required for dive technical rescuer. These courses do not, however, offer all of the skills required to meet these standards, and further training and experience in special hazards expected to be encountered in the [authority having jurisdiction's] territory should be sought."

As the director of the International Association of Dive Rescue Specialists Response Team, Chief Steven Orusa has taught the importance of advanced repetitive skill dive training beyond recreational dive skills for many years. Public safety SCUBA diving is a technical skill that greatly exceeds recreational SCUBA certification levels. He notes, "Recreational diving agencies provide safe and effective dive training for the enjoyment of the public. The business model of a recreational SCUBA agency is to teach the client to have fun underwater. John Q. Public is not performing dives in zero visibility, dives with prolonged bottom times, dives with entanglement hazards, dives requiring heavy physical exertion, dives at all times of the day and night, and dives in extreme weather conditions. That is public safety diving." [Orusa 2017].

In his book Chief Orusa notes: "Inadequate SCUBA skills may be the leading cause of PSD 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." PSDs should have training and experience in a variety of environments that are likely to occur during rescue operations, such as deep-water complex dives, limited visibility, cold water diving, ice, swift water current conditions, water contamination and hazardous materials, moisture retention within the dry suit, and lifting operations.

Annual confirmation of dive skills should help ensure continued competency. Dive teams need to stay current on training and annual skills evaluation. An example of an evaluation form to assess skills of PSDs, including controlling and maintaining buoyancy, is provided in Figure 2.

The level of knowledge, skills, ability, equipment, and support required for a PSD are outlined in NFPA 1006 [NFPA 2017b] and NFPA 1670 *Standard on Operations and Training for Technical Search and Rescue Incidents* [NFPA 2017c]. Throughout NFPA 1006 and NFPA 1670, hazard analysis and risk assessment are addressed. One of the most hazardous events a diver can encounter is the inability to solve problems or make decisions underwater.

The typical chain of events in a public safety diving accident is as follows:

- The PSD becomes cold and/or tired
- The diver's stress level, which is already high under such circumstances, increases
- The PSD encounters a problem or makes a mistake that is not solvable
- Panic ensues
- Death or serious injury results [Orusa 2017].

Annual refresher training should remind divers 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. *Note: An emergency buoyant ascent is difficult and hazardous and only used as a last resort to resolve an emergency, while the diver is venting air continuously (exhaling all the way to the surface).*

Divers having difficulty ascending should release their weight belt. Divers experiencing stress at the water's surface should drop the weight belt immediately to ensure that they will float [NOAA 2001]. If divers have traditionally used a weight belt and then transition over to integrated ditchable weights, they need to learn the muscle memory to release the weights. The first place they may reach for is the belt release if they have not relearned how to release the ditchable weights.

In basic SCUBA diving education, divers are taught to always breathe continuously and normally. They should never hold their breath, and they must exhale on ascent. However, instances have occurred where divers are distracted and unintentionally ascend while holding their breath. Divers need to have refresher training on common conditions that could cause ascent while holding their breath. Those conditions include:

- Panic moment or uncontrolled anxiety

- Uncontrolled out-of-air emergency or low-air event
- Overweighted (with dive weights or not having the ability to jettison weights, as in this incident)
- Accidental loss of a weight belt
- Preoccupation with an equipment issue, such as the mask
- Not managing buoyancy (failure to release necessary air in their BCD to maintain a controlled ascent, remembering that any air they autofill into their BCD at depth also will expand as they ascend
- Inability to maintain positive buoyancy
- Exertion during a difficult task
- Coughing, sneezing, or vomiting
- Breathing heavy in response to finding the target [Hendrick et al. 2000].

Lung overexpansion injuries include arterial gas emboli, pneumothoraces, mediastinal emphysemas, and subcutaneous emphysemas. It is possible for divers to induce each of these injuries by holding their breath for any reason during an ascent while on SCUBA or surface-supplied air [Hendrick et al. 2000].

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 2. Annual Basic SCUBA Skills Evaluation.
(*Figure courtesy of the International Association of Dive Rescue Specialists.)*

Understanding the 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 is half its original volume and its density is twice as great [Hendrick et al. 2000]. If individuals on the surface have 5 liters of air in their lungs and hold their breath and dive underwater, the pressure increases and the 5 liters of air are still there, but just occupying a smaller space. If they descend to 99 feet (where the pressure is four times what it is at sea level), the 5 liters will occupy only one-fourth the volume of space in the lungs. Then as they return to the surface—if they do not inhale or exhale—the air will return to its normal volume and density once they are on the surface [Hendrick et al. 2000].

When SCUBA divers inhale underwater, their lungs are filled with compressed air to keep their lungs the same size as 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 by using 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]. Sometimes these are life-threatening injuries, resulting in catastrophic incapacitation and death.

Many factors can lead to an underwater emergency. Planning and training to avoid the factors that lead to the emergency is the first step in prevention. 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 who are familiar with procedures can overcome these events.

Recommendation #2: Fire departments and public safety dive agencies should ensure that incident commanders, dive group leaders, and dive group members maintain situational awareness, accountability, and frequent and accurate air status on all divers.

Discussion: Incident commanders, along with dive group leaders and members, are perhaps in the best position to evaluate and advise on the conditions/performance of PSDs. Having the ability to recognize a PSD showing signs of distress requires knowledge of public safety diving and close and constant attention to the divers. This requisite knowledge may allow a dive group leader or safety officer better situational awareness on the air use of a particular diver or dive team in order to make adjustments for consumption rates. Dive team accountability is an important benchmark that not only provides information on the diver’s progress (depth and/or completion of search patterns), but keeps a constant check on the air status, as well as the diver’s physical and mental status. Poor air management has resulted in many structural firefighter and PSD deaths [NIOSH 2005, 2009, 2012]. PSDs 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 unforeseen occurrences or underwater emergencies.

Air management is a program that the fire service can use to ensure that PSDs have enough breathing air to complete their primary mission and allow enough reserve air to return to the surface or escape an unforeseen emergency. PSDs 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 individual PSD (task) level, the crew (tactical) level, and the command (strategic) level.

At the task level, PSDs need to ensure that their cylinder is full at the start of the dive, and they 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 that the regulator is accessible. They must see and recognize the dive computer, pressure gauge, and preset air warnings and then communicate that information to their crew members. Fire department dive teams should use a predive safety checklist, and the dive safety officer should witness the divers' equipment checks. The safety checks for surface supplied-air systems with bailout bottles are different than 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. It is necessary that the diver equipment assistants are also divers. They must understand the system they are assisting with. In addition, the dive safety officer needs to have familiarity with the system and witness the predive 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 communications 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 followed and requests additional resources based on predictions and 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). It is always necessary to check escape, redundant, or backup cylinders and systems and ensure they are 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.

It is the dive team leader's responsibility to plan the dive using proper air management techniques and dive protocols for the particular dive and depth, and then dive the plan. The technical rescue dive safety officer needs to review and agree with the dive plan. Air management is a constant and multilevel responsibility. Divers can become easily distracted with the difficulty of the assignment, environmental conditions, and civilian body recovery issues and lose track of their air supply. The multilevel air management system for public safety SCUBA diving has constant checks and balances because there is less room for error underwater.

Finally, air management at the strategic level ensures that the proper number of divers and the team's capabilities and competencies are matched. In most public safety dive events, time is of the essence to ensure capability, capacity, and competency of the resources. Once the incident is classified as a recovery mission, no urgent events should occur and incident commanders, group leaders, safety officers, dive team leaders, and dive team members need to carefully plan, coordinate, and execute the mission. They must 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, the dive team members' safety should be the focus.

At the strategic level, someone at the Command Post should monitor or ensure that air status is being monitored and recorded. In addition, 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 the crew has worked (estimating air supply usage) and also check on air status with the tactical-level crew leader. Command should ensure that the technical rescue team has all of the resources needed to achieve its mission. This includes multiagency, multi-jurisdiction cooperation and integration when appropriate. Command should ensure that all air management and accountability needs of the technical rescue dive team are met through the incident safety officer. Command should halt any mission when any of the team's needs are not met. Time is on the technical rescue dive team's side and because technical rescue SCUBA diving is such a high-risk/low-frequency mission, it is better to err on the side of diver safety and halt an operation when all aspects of the mission are not ready.

In some instances, PSDs 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 can occur for a number of reasons, including lack of familiarity with a new SCUBA gear setup (full face versus half face) or a lack of training. In modern firefighting SCBA, firefighters have HUD. Lights inside the face piece indicate air management milestones, such as full, three-fourths full, 50% flash, and 33% end-of-service-time indicator.

In this incident, the dive team leader called for air checks and responses were given. It is unclear if the diver was able to read the gauge correctly in the zero-visibility water. Additionally, the divers deployed from a helicopter prior to having back-up resources on land in place in case RIT was needed. Also, Diver 2 displayed signs of distress after surfacing; however, it is unclear whether he was able to verbalize any priority benchmarks via the diver communications line.

Recommendation #3: Fire departments and public safety dive agencies should ensure all PSDs use dive computers.

Discussion: Dive computers allow divers to monitor the depth of their dive and ascent to help avoid decompression sickness. These dive computers include wrist computers, console computers, compass computers, or hoseless computers, which access underwater data and keep divers informed. They eliminate the need to carry a separate dive watch and depth gauge. Dive computers track the divers' profile accurately and give the divers more time underwater than dive tables. It is possible to set up computers to audibly alert the diver at a given depth or time. Integrated dive computers monitor cylinder pressure and provide divers with an accurate remaining time based on their air consumption and current depth. A wrist-mounted computer can give the same information, but it relies on a transmitter from the first-stage regulator, which is not fail-safe. Dive computers are fairly easy to use and interpret after becoming familiar with their features. They allow divers to scrutinize the dive and create a dive log. If an issue arises, the data can help accurately answer related questions such as what depth the diver was when he ran out of air and what the time during the incident. While they are not foolproof, they do help eliminate mistakes that occur when using dive tables and relying on separate or multiple devices/gauges.

In this incident, the fire department dive team was not using dive computers. An audible alarm may have helped the diver know his air pressure without having to read a gauge in near-zero visibility water using a flashlight. In addition, the downloaded data may have provided time stamps and air pressures that would help answer questions about the sequence of events.

Recommendation #4: Fire departments, standard-setting organizations, public safety dive agencies, and SCUBA manufacturers should consider adding heads-up displays in all full-face mask SCUBA apparatus because of the frequent zero-visibility/silt-out conditions that are experienced.

It is extremely challenging for a diver without a HUD to report regular air status in low-light or zero-visibility conditions. In a low-light or zero-visibility condition at the bottom, even grabbing the dive computer with one hand and shining a light on it with the other hand can cause the diver to drift slightly down in a major layer of silt while following a search rope. Silt-out conditions can obscure the light source. Like firefighters, divers should never have to guess how much air they have. Once the remaining air drops below milestone indicators, at least two sensory stimulations should activate (e.g., sound, light, vibration). This ensures that the diver will not unknowingly pass through the remaining air benchmarks. Finally, the surface crew with wired communications need to ensure that air checks are requested and heard by the divers. The addition of HUDs allows PSDs to know their approximate air supply status by reading the milestone lights in their face piece.

In this incident, the river had a large amounts debris refuge and discarded matter with very limited visibility. This made using a flashlight to read a gauge accurately difficult. The use of a HUD would improve diver safety .

Recommendation #5: Fire departments and public safety dive agencies should ensure that a properly trained dive safety officer is on-scene and integrated into the command structure.

Discussion: Fire departments should include a dive safety officer trained in technical rescue SCUBA diving on-scene and as part of the command structure and tactical planning for dive responses. The planned dive rotation should not include the dive safety officer, but instead require the dive safety officer to remain at the dive site and available to the Command Post.

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 member to fulfill the duties of a safety officer with the specific knowledge and responsibility for the identification, evaluation, and where possible, correction of hazardous conditions and unsafe practices specific to the operational capabilities employed” [NFPA 2017c]. The assigned safety officer should meet the requirements specified in NFPA 1521 *Standard for Fire Department Safety Officer Professional Qualifications* [NFPA 2020a].

Safety officers assigned to special operations incidents, such as technical rescue SCUBA diving incidents, need to have expertise in the specific technical rescue field to effectively evaluate hazards and provide safe direction of all personnel. Qualified fireground safety officers might not possess the necessary expertise in water rescue. Therefore, they 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 (e.g., undertrained for the mission at hand). NFPA 1521 notes, "in cases where the designated 'safety officer' does not possess the technician-level training, appointing a technician-level trained assistant safety officer (ASO-HM) or technical specialist with the necessary training will help satisfy the safety needs of the technician-level members." [NFPA 2020a]

The dive safety officer has a critical advisory role to the ISO and the incident commander on the risk versus benefit on the strategic and tactical levels. A dive safety officer properly trained in the corresponding technical rescue field also can help prevent PSDs from attempting a skill beyond their level of training. The incident command structure should include the ISO.

A specifically trained and qualified dive safety officer should monitor the incident action/dive plan by making primary decisions regarding rescue/recovery, team capabilities, and the need for outside resources. They also should monitor dive conditions and 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 ISO also should witness the diver(s) predive safety checks, as well as monitor the health and well-being of the divers predive and postdive.

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 2020b]. NFPA 1561 paragraph 5.3.2 states, "the incident commander shall ensure that adequate safety measures are in place" [NFPA 2020b]. 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. It also is necessary to locate the safety officers for a technical rescue SCUBA incident at the dive operation. This allows the safety officer to monitor the operation, evaluate the resource status, ensure accountability and predive 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 safety for the technical discipline performed. They also should assign a safety officer for the incident scene. The Incident Command System (ICS) can expand to include functions necessary to effectively command and control an incident. Though the incident commander is still responsible for the safety and welfare of all members and first responders on scene, this responsibility is delegated to the ISO [NFPA 2020b]. Upon confirmation, the dive safety officer should meet with the incident commander, command staff, and dive team leader to discuss the needs and advise on the risk versus benefit analysis at the strategic and tactical level (i.e., Does the benefit of the operation justify the risks to the personnel to achieve it?).

The dive safety officer should obtain the following information:

- 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
- Adherence to the dive plan and accurate event monitoring and recording
- Back-up dive team assets
- ALS standby for the divers' medical care
- Establishment of the rehabilitation group
- Confirmation of established radio communications channels (command channel, tactical channel).

In summary, plan the dive and dive the plan.

The technical rescue group or dive safety officer should don the PPE appropriate for exposure to the potential hazards at the scene (e.g., autopersonal inflating or standard personal floatation device or float coat for colder weather). Also, a vest or helmet will help identify the dive safety officer.

The dive safety officer should meet with the technical rescue group leader, ISO, and incident commander to develop a communications plan and coordinate their activities. The ISO is responsible for the 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 safety officers can have advantages on large complex missions.

NFPA 1521 *Standard for Fire Department Safety Officer Professional Qualifications* defines the role of the ISO at an incident scene and identifies duties, such as:

- Reconning 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
- Ensuring established safety zones and other designated hazard areas are communicated to all members on scene [NFPA 2020a].

The presence of an ISO or technical rescue group dive safety officer does not diminish the responsibility of individual divers and group leaders for their own safety and the safety of others. The dedicated ISO and technical rescue group dive safety officer add a higher level of training, attention, and expertise to help the incident commander. The ISO 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 technical rescue group safety officer is focused on the safety of the divers, the ISO 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 is an extremely valuable resource. The technical rescue group dive safety officer 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, (different from the ISO). They must have the level of experience needed to recognize realistic mission goals, team and resource capabilities, team member capabilities, and team member limitations. They also must 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 rather than rescue mode, and time is on the team's side. The ISO working together with a trained and experienced 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 deputy district chief of Special Operations was the dive group supervisor and Command shore side. The deputy district chief was well qualified to act in the role of dive safety officer. However, the deputy chief already was filling the role of dive group leader on the shore. Several technical rescue SCUBA diving officers were at the scene who had the experience and perhaps training to oversee the diving operation as the dive safety officer. The Special Operations Division requires that battalion chiefs are ISO Certified and have PADI Diver Certification or an equivalent. It is not clear if BC15 had the latter certification.

Recommendation #6: Fire departments and public safety dive agencies should recognize public safety SCUBA diving as a high-risk/low-frequency event and ensure that PSDs are properly trained, equipped, and supported to perform public safety diving. The training and SOPs should include regional dive and water rescue team(s) that regularly respond with interagency cooperation.

Discussion**:** Although no evidence shows that the following recommendation would have prevented this fatality, it is 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 and use a risk assessment program to determine the extent to which they want to participate. During this assessment, departments can decide if they want to accept the risk (fully committed to equipping and training their own teams), 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).

Career Firefighter/SCUBA Diver Drowns While Searching for Civilian in an Industrialized River—Illinois

No standard scale is available to measure and evaluate frequency and severity of risk for the fire service. It is imperative 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 must incorporate a full range of control measures to use for limiting, reducing, or eliminating the probability that an undesirable outcome will occur.

The basis for the development of a risk management program is the preparation and maintenance of 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. The frequency and severity of risk starts with a thorough community risk assessment [NFPA 2014].

The tolerance for risk varies by fire department. The intent of the risk management process is for a fire department to develop a standard level of safety. This defines the parameters of the acceptable degree of risk within which members perform their job functions. No single method or solution is available for effectively managing risk. Determining how to manage risk is a decision each fire department must make based on the risk management model (see Figure 3) [NFA 2009].

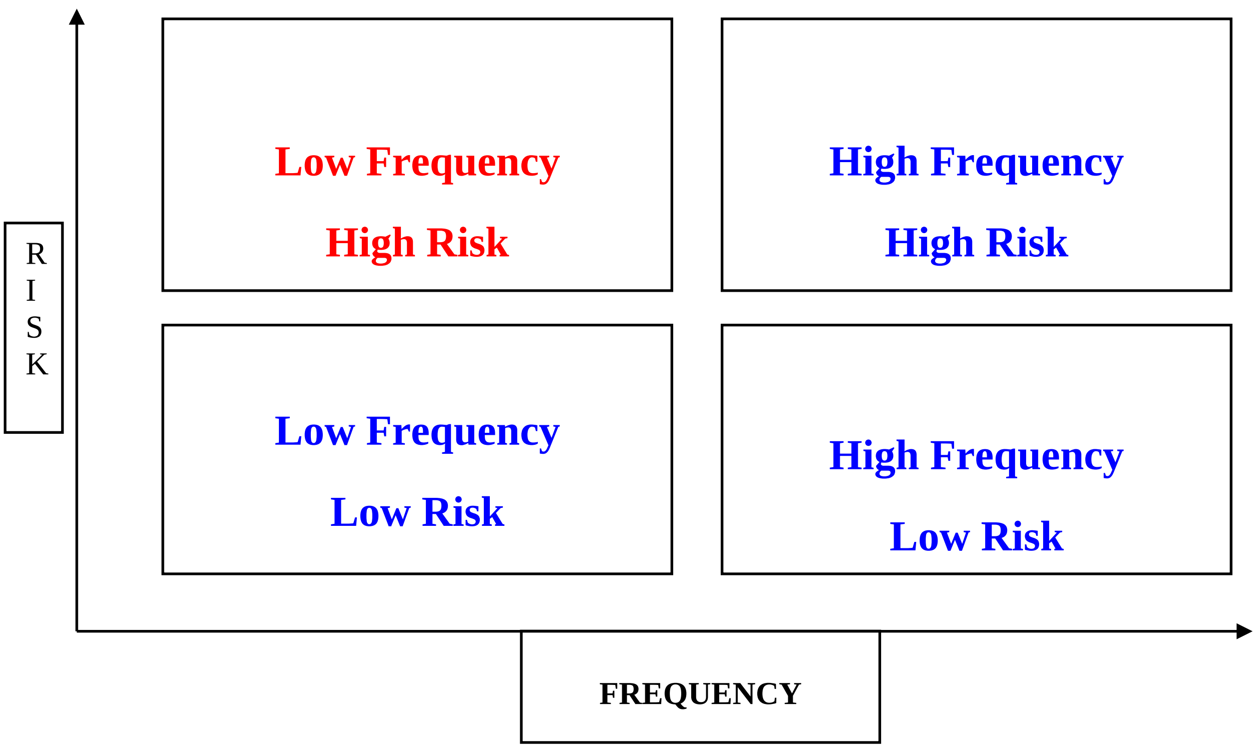

Figure 3: The Risk Management Model.
(Figure courtesy of Graham Research Consultants.)

Career Firefighter/SCUBA Diver Drowns While Searching for Civilian in an Industrialized River—Illinois

Fire department leadership should have a covenant with its public safety dive team through the department's or municipality's risk manager to make diver safety its top priority by managing the risk. The risk manager should focus on sound resources based on research, training, and experience. The leadership should consider sound risk management if it is going to commit to working in an underwater environment. The department has an ethical, moral, and legal duty to prepare effective PSDs. No greater responsibility exists in public safety SCUBA diving than safety [Orusa 2017].

Fire departments should prepare and maintain written policies and SOPs 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 and the evolutions that are necessary to perform 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 performed
- The number and types of apparatus and the number of personnel that are dispatched to different types of incidents
- The procedures that are employed to initiate and manage operations at the scene of an emergency incident [NFPA 2014].

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 also must understand that this involves a continuing commitment to advanced and recurrent training and also to equipment and marine apparatus purchasing and maintenance.

Managing risk includes mandatory continuing education and skills documentation programs. Chief 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 that a lack of basic diving skills is statistically identified as one of the leading causes of public safety diving fatalities. With 86% of the fatalities occurring in training and recovery mode (as was this incident), managing the components of the rescue and recovery mode and the risk/benefit analysis in water rescue operations and training are critical. Overwhelming documentation provides evidence of serious safety concerns when relying solely on recreational training for public safety dive teams.

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. When the team is faced with complex, deep, highly technical recovery dives, it is important to realize the team's limitations, when the team needs assistance, and when to call for additional resources (mutual aid). Some jurisdictions utilize regional teams to meet the goals of risk management for a specific risk (shared risk). Better communications are needed between the fire and police marine units. They need to ensure they have the proper equipment (radios, etc.) and a better real-time understanding of the plan and operational situation.

A key part of an overall rescue strategy should include 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. In addition, mutual aid can remove destructive competitiveness and rivalries between departments and/or agencies.

Because the resource requirements and commitments are very high, a shared risk approach may prove beneficial for some jurisdictions. Regional or mutual aid teams need to train together so they can recognize each team's strengths and work together to become aware of the level of coverage and/or redundancy present in joint operations. If regional teams are going to work and train together, they should consider integrating their 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 responders to tailor their actions to fit the situation. A set of SOPs would include any rules that are inviolable. For example, PSDs should always end their dive with 1,000 psi remaining for emergency reserve air (3,000 psi per 80-cubic-foot cylinder). Divers should not break the 1,000 psi rule. This is a good example of an SOP [Hendrick et al. 2000].

Fire department and other public safety dive agencies' SCUBA dive teams need to stay current on new available equipment, such as in-mask air supply status or 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 exposure to blind diving by working to locate and isolate a dive target to within 1 to 2 feet. Blind underwater searches using search ropes and gridding-off areas are very task-oriented and time-consuming and can require a significantly greater resource commitment for a much 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 time). This is accomplished by spending more time and available resources 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 (see Figure 2). Inadequately trained divers should not participate in technical rescue SCUBA diving incidents beyond their level of training.

In the incident, the fire and police marine units, as well as the U.S. Coast Guard share the same marine station, but they are separate. SOPs outline the duties and responsibilities of both the fire department's and police department's marine units. The lack of joint training contributed to unknown expectations and lack of knowledge of the activities of the other department during an event. Joint trainingwould facilitate working together as a team with each unit understanding and assisting the primary role of its partner agency to reduce risks.

Recommendation #7: Fire departments and public safety dive agencies should ensure helicopter SOGs/SOPs address divers in distress situations when divers are deployed prior to shore and/or marine unit arrival.

Discussion: Although no evidence indicates that the following recommendation would have prevented this fatality, it is provided as a reminder of best safety practice for the fire service. Many of the larger fire departments in the country have incorporated the use of helicopters in their firefighting operations. While supporting firefighting operations is the primary mission of the air operations program, they also serve in hoist-air rescue, short-haul air rescue, shoreline rescue, helicopter swift-water rescue, night vision goggle operations, patient transport, vehicle rescue, large animal rescue, fire mapping, infrared detection, disaster assessment, and high-rise fire incidents.

In this incident, as for the role of water rescue and diver deployment, SOPs were in place and followed. The helicopter unit 682 arrived in minutes and deployed divers just as Engine 39 and Battalion Chief 15 were arriving. Once divers were in the water, they hand-signaled the pilot that they were okay, and Unit 682 departed. No SOPs were in place to guide Unit 682 if the divers had signaled that they were not okay, and Engine 39 was not set up. In addition to an SOP, training on these deployment skills is recommended.

Recommendation #8: Fire departments and public safety dive agencies should ensure that communications equipment is reliable and has interoperability.

Discussion: Although no evidence shows that following this recommendation would have prevented this fatality, it is provided as a reminder of best safety practice for the fire service and public safety dive agencies. In the initial years, underwater communication systems relied on hand signals, slates and pencils, and rope tugs. These types of signals can and often are misunderstood and difficult to use when hands get cold or if divers are affected by moving water conditions. Today, the two choices of underwater communications are hardwired (uses a cable to transfer the communications) and wireless (uses the water to transfer the communications). Wireless freely provides individuals diving where they need to go with the ability to communicate easily and quickly, whereas hardwired communications confines divers to the length of a cable. Wireless underwater communications uses water to carry an acoustical signal from one transceiver to another, much like the use of sonar to communicate. Hardwired sends the signal down the cable, much like a landline. Like most products, multiple manufacturers exist, with models of various quality, functions, and price. In general, the equipment employed by the elite military units have a proven record of reliability, but usually come with a higher price tag.

At the incident scene, the communication between the fire and police marine units took place by either face-to-face communications or a patch through Dispatch. No interoperability occurred with the radios at the incident scene. This impacts real-time communications and the command structure.

During the interview process, several interviewees had mentioned that the wireless communications equipment used by Fire and Police Marine Units was subpar. The communications between divers and the boats were unreliable. The Fire and Police Marine Units communications may have been improved with military grade equipment..

Recommendation #9: Standards-setting organizations should consider developing and adopting national consensus standards for PSDs and equipment that address initial respirator performance training, as well as refresher training.

Discussion: Although no evidence indicates that the following recommendation would have prevented this fatality, it is provided as a reminder of best safety practice for the fire service. Currently, no national consensus standard is in place for PSDs. 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. Firefighters/divers have died during training, and the level of training varies throughout the country in different jurisdictions.

Proper equipment and continued administrative support are equally important and would benefit from a national standard. Administrative resource staff may not understand the importance of equipment that is designed for much more dangerous and extensive work than recreational SCUBA equipment. PSDs should have a minimum requirement of a high-quality, commercial grade heads-up display and a full face piece, dry suit, and wireless. Although the equipment is more expensive than recreational equipment, the safety and lifesaving benefits far outweigh the cost savings for departments that use recreational equipment.

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Investigator Information

This incident was investigated by Matt Bowyer, general engineer, and Stephen T. Miles, investigator, of the NIOSH Firefighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, located in Morgantown, West Virginia.

An expert technical review was provided by Captain Thomas Haus, Los Angeles Fire Department. He has more than 28 years of technical and water rescue experience.

Matt Bowyer was the author of this report.

Disclaimer

Appendix

Dive & Marine Consultants International, Inc., Report

DIVE & MARINE CONSULTANTS INTERNATIONAL, INC.

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July 9, 2018

Mr. Stephen T. Miles
Safety and Occupational Health Specialist
National Institute for Occupational Safety and Health
Division of Safety Research
1095 Willowdale Road MS 1808
Morgantown, WV 26505

Re: Scuba Equipment Inspection and Analysis
Decedent:
DOI: May 28, 2018
DMCI No.: 18-4489

Dear Mr. Miles:

Per your request the undersigned conducted an inspection of the above-referenced scuba equipment. The purpose of the inspection was to determine the function of the equipment at the time of delivery. The following is a summary of the results of the inspection and analysis:

The complete scuba system consisted of specialized equipment and configuration commonly used for public safety diving ("PSD"). The equipment consisted of the following: primary scuba cylinder, primary regulator connected to a full-face mask (FFM), wireless communications, buoyancy compensator (BC), totally redundant breathing supply (redundant scuba cylinder, regulator and conventional mask), drysuit and adjunctive dive equipment. The scuba system was delivered as an assembled unit. The choice and configuration of equipment is commonly used for PSD.

All equipment appears used but well maintained. The drysuit was cut off the diver and therefore destroyed, but otherwise appears to be in good condition (referring to the zipper, seals, inflator valve and vent valve). Both scuba cylinders were received gauge-empty (not enough gas pressure in the cylinder to register on a digital pressure gauge). Attached to the BC are two cutting tools and contained in the zippered pockets is a handheld underwater light and a conventional scuba mask. Attached to the diver at the time of recovery (but not delivered for inspection) was a conventional diver weight belt consisting of nylon webbing, a quick release buckle and 24 pounds of lead weight. Please refer to the enclosed Equipment Inventory and Inspection Notes for a list and evaluation notes of all equipment.

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The primary scuba cylinder consisted of an 80cuft, Aluminum, 3000psi working pressure cylinder. The cylinder is within the 5-year hydrostatic test date. The cylinder does not have a sticker evidencing visual inspection. The cylinder was received gauge-empty. Witnesses report this cylinder being "empty" at the time of recovery. Prior to pressuring the primary cylinder, it was delivered to Lawrence Factor laboratories in Miami, FL, where a vacuum was used to obtain a gas sample for analysis. This gas sample failed to meet Grade E breathing gas standards as result of excess water vapor. The excess water vapor is an artifact of the sample gathering procedure and not relevant to the original gas composition. All other values are within Grade E standards. See the enclosed gas analysis certificate (SN: HS008543).

The cylinder valve is a yoke style on/off with attached burst disc and dip tube. The cylinder valve is loose; i.e., light finger touch rotates the valve at the threaded cylinder connection. The maximum valve rotation is approximately ¼ of a full rotation whereupon the regulator hoses bind and prevent further rotation. Despite the loose valve, the cylinder/valve held gas when pressurized and the valve stopped any rotation at approximately 60psig.

The valve was removed and the interior of the cylinder was inspected with white and UV lights. There were no visible contaminates or UV detectible hydrocarbons. Thereafter the primary cylinder was pressurized to normal working pressure (3000psi), the primary regulator first stage was connected to the cylinder valve. The valve was opened to pressurize the gas delivery system and the equipment submerged in water. There were no gas leaks at the valve/first stage O ring or elsewhere on the primary gas delivery system. Despite having been delivered gauge-empty, the primary scuba system holds gas as designed.

The primary gas delivery system consists of a first stage regulator connected to an FFM via an intermediate pressure hose that has an inline high volume quick connect coupling. The first stage intermediate (over-ambient) pressure is 130psig, which is slightly less than manufacturer's specifications, but does not noticeably affect the performance of the regulator. The primary first stage has two intermediate pressure accessory hoses (one to power inflate the BC the other to power inflate the drysuit). Both accessory hoses are in good condition and function normally. The primary first stage also has a high pressure hose supplying high pressure gas to a submersible pressure gauge (SPG). The SPG appears new and displays accurate pressure readings through the pressure scale from 3000-0psig. The SPG is attached to a self-retracting retainer that is attached to a D ring on the lower left waistband of the BC. The retainer functions as designed and allows extension sufficient to easily view the SPG at eye level.

The FFM attached to the primary gas delivery system is a demand mask (not configured for positive pressure). It is equipped with an Ambient Breathing Valve (ABV) and underwater communications (front mounted push to talk microphone button and speakers mounted on the spider at each ear). The FFM was delivered with the ABV partially open, which will allow water intrusion into the FFM if in that position while underwater. The FFM's inhalation break pressure is 2.5 inches of water. The exhalation pressure is 2.0 inches of water. The FFM second stage is attached to the FFM frame via an insert and twist attachment and held in position by the communication port cover. The second stage exhaust valve is assembled correctly and withstands a negative pressure check indicating it does not leak water into the second stage housing. The frame, lens, seal and spider are all in proper functioning condition. The FFM functions as designed. Although the FFM was delivered with the ABV open (which allows water intrusion when underwater), the ABV had to have been closed during the dive to prevent flooding the FFM.

The buoyancy compensator (BC) is a make and model commonly used in PSD. The BC cylinder harness has been modified to enable attachment of a smaller redundant cylinder that is positioned parallel to the primary cylinder. The BC manufacturer's label is worn such that the original print is illegible. The BC is equipped with a conventional power inflator (using gas from the primary cylinder/regulator to inflate the BC). The BC holds gas as designed. The BC inflates, vents and reliefs over pressure as designed. The BC's harness, straps, cummerbund, adjustable fasteners, zippers, pockets, and attachment components are all present and in functional condition. The BC functions as designed.

The drysuit is a make and model commonly used in PSD. As previously stated, the drysuit was cut off the diver, therefore it is no long functional. However, the drysuit otherwise appears to be in used but functional condition. The watertight seals (zipper, inflator valve, vent valve, wrist seal, neck seal and material seams) all appear in good condition. The inflator valve and vent valve function as designed. Although in its present condition it is impossible to verify the watertight integrity of the drysuit, based on careful inspection and analysis of all the watertight components of the drysuit, there does not appear to be anything that would prevent the drysuit from holding gas as designed. Based on these assumptions, the drysuit would have functioned as designed to accommodate watertight integrity, equalization gas to prevent suit squeeze and inflation gas to function as a redundant source of positive buoyancy.

The adjunctive dive equipment includes fins, undergarment socks, wetsuit gloves, handheld underwater light, reserve conventional scuba mask, two cutting tools (a small blade knife and a pair if EMS sears) and an underwater communications system. The underwater communications system appears to be in good condition and properly configured, however it was not tested during this inspection. The best source of information as to whether the communications system was working properly during the subject dive and incident are those who were in communication with the decedent during the dive. All the other adjunctive equipment is in good condition and functions as designed.

The redundant scuba cylinder consists of a 19cuft, Aluminum, 3000psi working pressure cylinder. The cylinder is within the five-year hydrostatic test date. The cylinder does not have a sticker evidencing visual inspection. The cylinder was received gauge-empty. Witnesses report this cylinder having ~3000psig at the time of recovery. Thereafter, on or about June 12, this cylinder appeared to have ~2400psig. One day later this cylinder was observed to be gauge-empty. The aforementioned pressure estimates are gross approximations due to the fact the gauge read

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was from the "mini" pressure gauge attached to the redundant regulator first stage, which have a small viewport therefore impossible to read precisely. Prior to pressuring the redundant cylinder, it was delivered to Lawrence Factor laboratories in Miami, FL, where a vacuum was used to obtain a gas sample for analysis. This gas sample failed to meet Grade E breathing gas standards as result of excess water vapor. The excess water vapor is an artifact of the sample gathering procedure and not relevant to the original gas composition. All other values are within Grade E standards. See the enclosed gas analysis certificates (SN: CB0026394).

The redundant cylinder valve is a yoke style on/off with attached burst disc and dip tube. The redundant cylinder valve is loose; i.e., light finger pressure rotates the valve at the threaded cylinder connection. The maximum rotation is approximately ½ of a full rotation whereupon the regulator hose binds and prevents further rotation.

The redundant cylinder valve assembly failed to hold pressurized gas. The O ring between the valve and cylinder would not seal resulting in a massive and continuous gas leak. Upon careful examination the valve/cylinder O ring was found to be coated with a foreign substance that appears to be dried silt or mud. The redundant cylinder valve was removed and the interior of the cylinder was inspected with white and UV lights. There were no visible contaminates or UV detectible hydrocarbons on the interior of the cylinder.

The redundant valve/cylinder O ring was replaced and the cylinder was pressurized. At this time the valve O ring sealed and held pressurized gas as designed. The cylinder was pressurized to the normal working pressure (3000psi), and the primary regulator first stage was connected to the cylinder valve. The valve was opened to pressurize the gas delivery system and the equipment submerged in water. There were no gas leaks at the valve/first stage O ring or elsewhere on the redundant gas delivery system. Despite initially having a severe leak at the valve/cylinder O ring, once the O ring was replaced, the redundant scuba system holds gas as designed.

The redundant gas delivery system consists of a first stage regulator connected to a conventional second stage regulator. The first stage intermediate (over-ambient) pressure is 127psig, which is slightly less than manufacturer's specifications, but does not noticeably affect the performance of the regulator. The primary first stage has a mini submersible pressure gauge (mini SPG) attached to the high-pressure port. Although the viewport of the mini SPG is very small making it difficult to read, the gauge appears new and displays accurate pressure readings through the single digit pressure scale between 3-0psig. The second stage regulator inhalation break pressure is 2.8 inches of water and the exhalation break pressure is 1.7 inches of water. The redundant gas delivery system functions as designed.

For easy access in an emergency, the redundant second stage is intended to be attached to a D ring on the upper right chest of the BC. In the event the primary gas supply becomes interrupted (such as out of gas) the equipment configuration allows the diver to remove the FFM and breathe from the conventional second stage attached to the redundant gas supply system.

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However, with this configuration, if the primary scuba system is out of gas, there is no means of power inflating the BC or drysuit.

Equipment inspection summary:

1. The primary scuba system and adjunctive dive equipment functions as designed.
2. The redundant scuba system functions as designed.
3. Gas from each scuba cylinder meets Grade E breathing gas standards.
4. Configuration of the equipment prevents power inflation of the BC and drysuit when there is an interruption in the primary gas supply.
5. The diver's body was recovered with the weight belt attached.

Observations:

1. The diver's primary gas supply likely became exhausted while underwater.
2. The diver did not transition to breathing from the redundant gas supply.
3. Once out of primary gas, the BC and drysuit could not be power inflated to establish positive buoyancy.
4. The diver did not remove the weight belt to establish positive buoyancy.
5. Noteworthy is that the dive equipment did not include a depth gauge or time monitor. This death may have been averted if the diver had been using a gas integrated dive computer with visual and audio alarms warning the diver and his dive partner when approaching minimum safe cylinder pressure.

In conclusion; the scuba equipment functioned as designed, however the diver likely exhausted the primary gas supply, which created a task loaded situation that became too overwhelming for the diver resolve such that the diver sank back to depth unable to self-rescue using the redundant breathing system or establish positive byoyancy. I believe these factors may have contributed to the diver's demise and should be carefully evaluated in connection with other evidence to determine the cause of death.

Respectfully,

CRAIG S. JENNI

CSJ/jb
Enclosures:

1. Equipment Inventory & Inspection Notes
2. Gas Analysis Certificates (HS008543 & CB0026394)
3. Evidence Bag – Contaminated O Ring from 19cuft Cylinder
4. DVD – Photos of Subject Equipment