

# The Recovery of Human Remains from a Vehicle Submerged for 43 Years Using a Marine Venturi Vacuum System

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**ABSTRACT:** Forensic recovery of submerged human remains may present logistical challenges for forensic anthropologists. In the case reported here, a decedent was recovered from a submerged car that could not be moved or disassembled per environmental safety standards. A recovery approach uniting forensic anthropologists, dive teams, and private contractors operating a marine venturi vacuum system resulted in a successful and nearly complete recovery.

**KEYWORDS:** forensic anthropology, water recovery, submerged human remains, search and recovery

## Introduction

In July 1978, a 63-year-old woman disappeared from the small town of Gorham, New Hampshire, and, despite a rigorous investigation, she and her car were not located. She was last spoken to on the telephone on the day of her disappearance by a family member and was known to drive a blue Pontiac LeMans (manufactured 1972). The Androscoggin River, which flows through the town of Gorham, was periodically searched in the years following the woman's disappearance. By chance in 2021, a law enforcement officer read a chapter in the book *Tales Told in the Shadows of the White Mountains* (Jordan 2003) in which a journalist describes the details of the disappearance. The author noted that the missing woman had family ties in Vermont, in a town close to the state line, so the officer proposed that a search be conducted in that segment of the Connecticut River which forms the border between western New Hampshire and eastern Vermont.

Cursory searches of the river by the New Hampshire Fish and Game Department began in August 2021 with a side-scan sonar (Marine Sonic Arc Explorer model) survey. Side-scan sonar is a trawling unit attached to a watercraft that may be employed in searches for remains and artifacts

resting in low visibility waters on the bottom of lakes, rivers, and oceans (Atherton 2011; Maloney 2017). These units are increasingly used by law enforcement (Healy et al. 2015; Parker et al. 2010; Schultz et al. 2013) when investigating submerged vehicles and/or human remains.

After approximately an hour of searching with the side-scan sonar, the team located what they believed to be a motor vehicle resting upside down under 12 feet of water, downriver from the Mt. Orne covered bridge and 25 feet from the Vermont shoreline. A remote operating vehicle, or ROV (model VideoRay Pro-4), was then employed to capture images of the license plate. When the ROV was unable to locate the license plate, divers were deployed to examine the car. The plate was recovered from the silty river bottom in proximity to the vehicle and quickly confirmed to be registered to the missing woman. Once this connection was made, divers carefully entered the vehicle through a partially opened window and the fragmented undercarriage to perform a search for any human remains or identifying artifacts.

Divers encountered approximately 3 feet of mud and silt in the overturned vehicle. Using just their hands to feel their way through the accumulated mud and silt, the Fish and Game Dive Team recovered larger skeletal elements, such as the cranium and femur. Upon the recovery of human remains from the scene, the Dive Team members informed the New Hampshire Department of Environmental Services of the fragility of the vehicle, noting that the car was unlikely to be removed from the river intact. The New Hampshire State Police Cold Case Unit, in agreement with the Fish and Game Dive Commander, determined that a controlled, systematic search was necessary to recover remains from the deteriorated vehicle without disturbing the car on the river bottom.

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Shortly after the first recovery, law enforcement contacted the New Hampshire Office of Chief Medical Examiner (OCME) and the OCME's forensic anthropologist at the University of Maine (UM), who collaborated with University of New Hampshire (UNH) anthropologists and the Cold Case Unit to plan the second recovery of skeletal remains.

Detailed search methods within vehicles are often not reported in the literature; there are many references for forensic searches of bodies of water (see Becker 2013 for a comprehensive introduction), but few describe the methods employed when the body must be recovered without disturbing the remainder of the scene. In this case, the combination of the river current, the presumed degradation to remains due to postmortem interval, and the fragility of the vehicle were especially challenging. Here we describe a novel approach to a difficult forensic recovery that utilized law enforcement, anthropology, and private contractor resources. While recoveries of skeletal remains from submerged vehicles are not uncommon, the excavation of a car in situ is rare. The processes and methods used to recover remains while minimizing further damage to the vehicle and the skeletal elements are documented in this article.

## Materials

The collaborative recovery effort included members of the New Hampshire State Police (Cold Case Unit and Major Crimes Unit), local Vermont and New Hampshire police, UNH and UM anthropologists, contractors from Atlantic Aquasport (Rye, New Hampshire) and Dive Dock USA (Norwich, Vermont). One of the central materials utilized in this recovery was the Dive Dock USA mobile workboat, which was created to fulfill the needs of marine researchers, industrial and public safety divers, and marine construction firms. Since the work boat features built-in wheels for overland transport without a special permit, it could be driven to the rural location, launched from a primitive access point on the Connecticut River, and floated above the recovery site. On the mobile workboat bow, there was space for an air tank staging as well as a water entry area for divers via an elevator. Additionally, the bow (measuring 16x20 ft) provided an area for the secure location of two screens, the Venturi system (an apparatus that reduces pressure when fluid flows through a constriction or "choke" point of a pipe), and an analysis table for sorting and cataloging skeletal elements and artifacts.

UNH anthropologists supplied the screening system that was created using inexpensive materials readily available from a hardware store. The two-part screening system was composed of three heavy-duty plastic tubs (Commander brand, 27-gal. black tote with standard snap lid, model #44066). One end of each tub was removed with a hacksaw to allow for water flow (Fig. 1).

A 1x1 meter wooden frame with .25-inch mesh screen was secured to each tub with zip ties in each corner. The edges of the tub were notched to secure it with rope to the dock. The second part of the screening system, the wooden sluice, was built using recycled hardwood (Fig.1). The spaces between the planks of the sluice were caulked to prevent small materials from lodging in the gaps. The two sluices (approximate dimensions: 1m x 1m x 24cm) were created to direct water at a 30-degree angle. The screen was placed on top of the sluice, which had a stop board built in to prevent screen movement.

## Methods

The remains recovered with the first dive were transferred to the NH OCME's forensic anthropologist in Maine, who provided an initial inventory and reported on the taphonomic condition of the remains. She coordinated with the Cold Case Unit and the UNH anthropology team to plan for recovery of additional remains.

The second recovery took place in September 2021 using the Dive Dock, screening system, and Venturi system provided by Atlantic Aquasport. All personnel gathered near the Mount Orne covered bridge and embarked on Fish and Game boats to the Dive Dock floating above the submerged car. The assembled team practiced with the Venturi system briefly to control the suction and flow rates for the water pumped into the screen/sluice system. During the recovery, approximately 20 people were on the Dive Dock assembled into teams: (1) Fish and Game Dive Team rotating out two divers per shift, with their Dive Team Leader communicating via Ocean Technology Systems' Aquacomm wireless communication units; (2) anthropologists stationed at the screen/sluice system to recover remains and sort them on a small table set up on rear platform of the Dive Dock; and (3) the contractors supervising the Venturi system and the maneuvering of the Dive Dock platform above the submerged car.

### Recovery methods for the dive team

Fish and Game divers excavated the car in pairs, using the suction system to maneuver around the inside of the vehicle. The two-man team communicated their location in the car to the Dive Captain, who relayed the information to the anthropologists at the screen. The teams relieved each other at prescribed intervals. The car was excavated as fully as conditions would allow.

### Sorting and analysis for the anthropology team

The anthropology team, consisting of two professors and three students, set up the screening systems around the

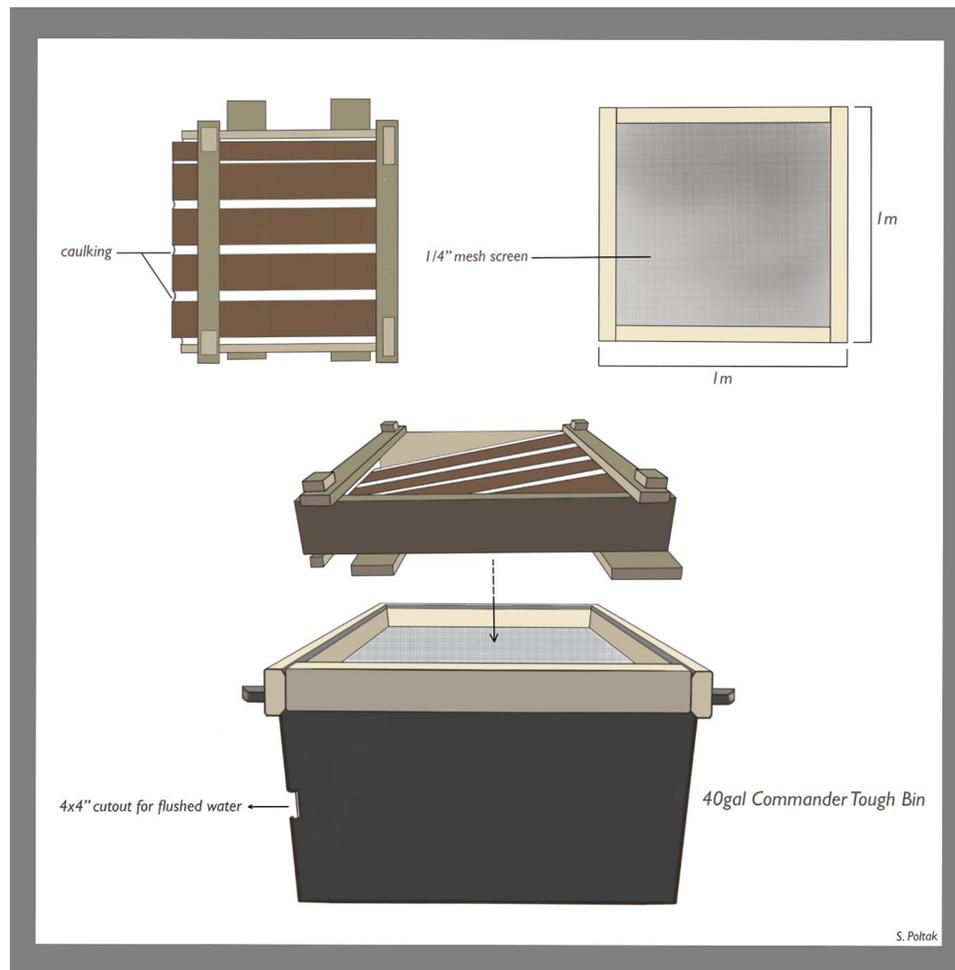


FIG. 1—Screening and sluice system.

removable center of the Dive Dock. Three people monitored the screens as materials were flushed out of the car via the Venturi system, one person selected elements of interest from the screen (bone and other artifacts) to bring to the analysis table, and one person oversaw the sorting and initial recording of skeletal elements.

### Control and operation of the Venturi system

Within the first 10 minutes of the recovery operation, the suction and flow rates were established after some experimentation. A Keene Engineering JetFlare dredge (4-in. pump aperture, 6.5-horsepower motor) outfitted with a Venturi system (2.5-in. diameter) affixed to a 4-inch diameter, 18-foot long double-jacket fire hose with aluminum couplings was used to achieve 8 pounds per square inch (psi) of lift under vacuum conditions. The rationale for applying a Venturi system to the dredge pump is best described through the Bernoulli equation.

The Bernoulli equation (Equation 1) theorizes that along a closed pathway, such as that created within the fire hose, the sum of all forms of energy within a fluid traveling along that pathway is the same at any two points.

Equation 1: Bernoulli equation for an incompressible fluid

$$\frac{v^2}{2} + \psi + \frac{p}{\rho} = \text{constant}$$

where:

- v: fluid velocity along pathway
- $\Psi$ : force potential
- p: pressure along pathway
- $\rho$ : fluid density

Per the Bernoulli equation, a decrease in the static pressure of a fluid and a decrease in its potential energy results

in an increase in fluid speed. Assuming negligible resistance due to drag based on the smooth rubber interior lining of the fire hose as well as no appreciable changes in fluid volume, application of Bernoulli principles and subsequent Venturi principles to applications such as this are permitted.

Under the Venturi principle, constriction of a section of the pathway (e.g., a choke or pinch point producing an hour-glass shape in the line) leads to an increase in fluid flow rate at that point, resulting in a simultaneous drop in pressure at the constriction point. Although there is a reduction in pressure at the point of constriction, the pressure remains high along other parts of the pathway before the constriction point. As there is now an imbalance in overall system pressure, fluid from the remainder of the system rushes to the constriction point. If an additional fluid source (i.e., via a hose or pipe) is connected to the source experiencing the constriction at the constriction point, then the fluid from that secondary source will be drawn into the post-constriction point main flow (Fig. 2).

For the purposes of this recovery, the dredge pump was outfitted with a 2.5-inch Venturi system providing constriction on the 4-inch aperture of the pump. The pump itself drew in air (a fluid), rather than water, into the system. At the point of constriction in the Venturi system, the 4-inch fire hose was introduced, permitting the inflow of water from the scene into the system. The passive introduction of water into the system at the Venturi system constriction point permitted the water from the scene to be vacuumed into the system while avoiding the pump. In future applications, Venturi system constriction point diameter may be altered to provide

greater control over the vacuum force of the system without requiring an increase or decrease in pump horsepower. Primary, pre-Venturi system air flow rate and intra-line turbidity were mediated via throttling of the dredge motor to reduce potential damage to the remains and associated artifacts.

The equipment utilized in this recovery included a section of fire hose that was 18 feet long, which was the required length to reach from the pump system on the floating dock to the scene. Without alterations, this system configuration would be effective for distances up to 30 feet in length with only minor degradation in exit flow rates anticipated.

### Taphonomy and Evidence of Perimortem Trauma

Both the taphonomic degradation and substantial perimortem trauma added to the complexity and challenge of the recovery. The remains had been in a closed vehicle submerged in cold, moving river water for 43 years. Although remains were partially protected by burial within two to three feet of river silt within the fairly intact vehicle, they were initially fractured in the accident and subsequently abraded by the sandy silt over several decades.

The Connecticut River is considered to be a coldwater habitat for fish and sometimes freezes over. The location of the recovery is in the northerly section of the river, about 40 miles from the Quebec border. Thus, the environmental context could be characterized as cold to very cold. Although

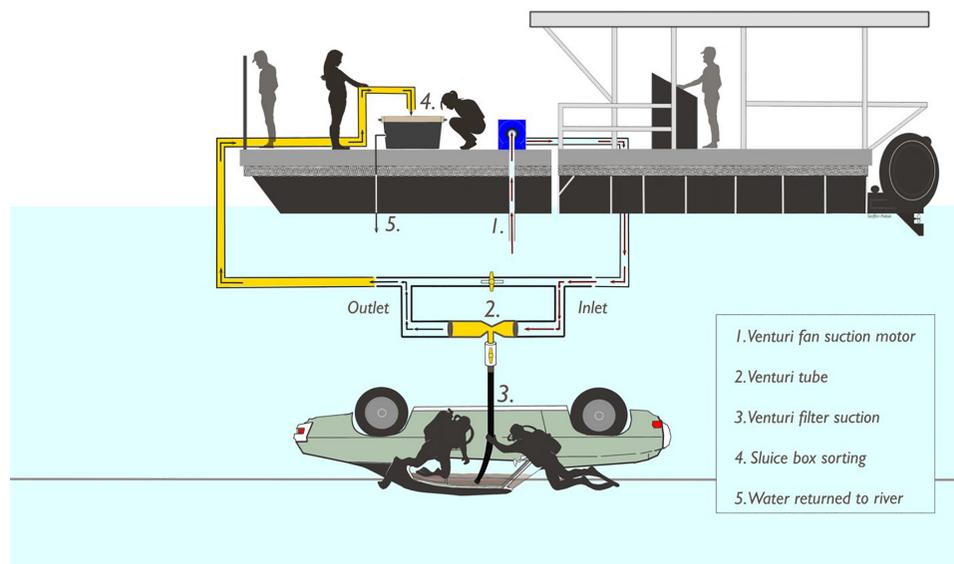


FIG. 2—Illustration of recovery system using the Venturi system, with members of the anthropology and dive teams on the Dive Dock floating over the submerged vehicle and underwater.

largely protected from major disturbance by river currents, the sandy context would have created constant abrasion with water movement. Bacteria and small organisms would have had access to the remains. Remarkably, there is substantial adipocere in the cranial cavity. This case is somewhat more deteriorated than another New Hampshire case, submerged 19 years in a vehicle in a very similar coldwater river setting. Both cases had preserved adipocere in the cranial vault.

Despite the technically very difficult recovery, and although the remains recovered are nearly all degraded and somewhat fragmentary due to the lengthy postmortem interval, most skeletal elements are represented. Aside from the cranial adipocere, the remains are fully skeletal with some degradation and loss due to generalized abrasion by water and sand. Some bones came through the recovery system entirely intact. Other elements appeared to have been fragmentary prior to recovery, and did not appear to have been damaged in the recovery process.

The degradation is fairly symmetrical and related to bone density, e.g., nearly identical loss of both scapular bodies, with retention of the edges. The cranium and mandible are nearly complete. The only complete major long bones are the upper extremities: right and left humerus, right and left radius, and right ulna (the left ulna was not recovered). The pelvis and leg bones had the most deterioration, probably associated with the multiple traumatic fractures.

There are several disconnected areas of reddish brown liquid staining on the cranium. Although one of these overlaps with the probable compression injury on the back of the cranium, the other areas are not associated with injury sites. The staining is possibly due to prolonged contact with small, unidentified, rusting iron mechanical objects that were also recovered with the remains.

There is evidence of multiple blunt trauma of the head and neck, shoulders, hip, and leg bones. These injuries include bilateral avulsion of the rectus capitis lateralis origins and insertion, cranial compression injury near lambda with partial diastatic separation, probable bilateral avulsion fractures of the coracoid and acromion processes, fracture of the right acetabulum, and probable spiral fracture of both left and right femoral and tibial midshafts, although the perimortem status of the left side fractures are less certain due to subsequent taphonomic degradation.

## Results

The recovery was completed in approximately five and a half hours, with all team members working efficiently on the platform and underwater. Initial concerns that the Venturi dredge system may contribute to the fragmentation of the remains were unwarranted. None of the retrieved remains

exhibited postmortem damage from the recovery process; all fractures observed were perimortem. The screen/sluice system worked well to capture all materials coming out of the hose, as the pressure could be adjusted based on density of materials pumped out of the car.

Approximately 75% of the skeleton was recovered. Personal effects recovered included clothing, a button, a small piece of what appeared to be a barrette, brassiere clasps, and a clothing tag. Other evidentiary material recovered included the rearview mirror; metal fragments, some with paint; a penny minted in 1961; a plastic knob from window crank; blue/green fabric and thread, likely from upholstery; windshield glass; and the gas pedal.

## Discussion

Despite significant postmortem diagenetic changes to the remains, the decedent was positively identified through DNA comparison of a femoral sample to a buccal swab from a living relative.

Interestingly, the recovered remains were similar in overall appearance to an individual submerged in a Tennessee lake for 52 years, including the cortical erosion observable on the lower limb bones, the heavy fragmentation of the vertebrae and ribs, the complete clavicles, and the nearly pristine radius and ulna (Marks et al. 2019).

The Venturi system coupled with the innovative Dive Dock proved to be an efficient method used by anthropologists and law enforcement to recover remains from a vehicle that could not be disturbed. The ability to excavate the interior of the car without generating environmental damage or losing remains to the river current resulted in a successful recovery of the decedent.

Other researchers, especially those involved in underwater archaeology, have noted the applicability of the Venturi system in recovery efforts (Allotta et al. 2015; Dobson 2005; Viduka 2012). In a review of the underwater forensic archaeology missions undertaken by the Joint POW/MIA Accounting Command-Central Identification Laboratory (now deactivated by the Department of Defense as a standalone unit and merged into the Defense POW/MIA Accounting Agency), Pietruszka and colleagues (2015:456) described the “innovative system . . . comprising venturi suction dredges and catchment lifting baskets . . . to remove, contain, and segregate the matrix.” In this case, the catchment baskets were eliminated and successfully replaced with the traditional archaeological screening system augmented with the sluices for water flow. Anthropologists on the workboat could communicate with the Dive Team Commander to ease or increase the suction and flow rates based on the volume and fragility of remains coming out of the dredge pump. The double screening system with attached sluices allowed for

Careful and thorough inspection of all materials in the screen. The Venturi system efficiently removed both mud and water, creating a slurry that was easily screened by anthropologists on the workboat surface.

## Conclusion

In typical search and recovery cases, forensic anthropologists can see and control the excavations and collection of remains directly. Since this excavation and recovery took place underwater, clear protocol and communication techniques had to be established at the outset. The anthropologists and dive team communicated effectively at the scene to dynamically adapt the recovery plan depending on volume of artifacts, flow of river, and fragility of remains. The donation of the Venturi system and the mobile workboat was critical in this case, but anthropologists can create the remaining equipment necessary with low-cost materials from hardware stores. Law enforcement may find willing civilian contractors eager to donate their time and machinery to assist in similar recoveries. We offer this technical note as one possible blueprint for environmentally sound recovery of remains from submerged vehicles.

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## References

- Allotta B, Costanzi R, Ridolfi A, Colombo C, Bellavia F, Fanfani M, et al. The ARROWS project: Adapting and developing robotics technologies for underwater archaeology. *IFAC-PapersOnLine* 2015;48(2):194–199.
- Atherton MW. *Echoes and Images: The Encyclopedia of Side-Scan and Scanning Sonar Operations*. Vancouver, BC: OysterInk Publications; 2011.
- Becker RF. *Underwater Forensic Investigation*. Boca Raton, FL: CRC Press; 2013.
- Dobson NC. Developmental deep-water archaeology: A preliminary report on the investigation and excavation of the 19th-century side-wheel steamer SS Republic, lost in a storm off Savannah in 1865. In: *Proceedings of OCEANS 2005 MTS/IEEE*, September 17–23, 2005; Washington DC.
- Healy CA, Schultz JJ, Parker K, Lowers B. Detecting submerged bodies: Controlled research using side-scan sonar to detect submerged proxy cadavers. *Journal of Forensic Sciences* 2015;60(3):743–752.
- Jordan CJ. *Tales Told in the Shadows of the White Mountains*. Lebanon, NH: University Press of New England; 2003.
- Maloney MS. *Death Scene Investigation: Procedural Guide*. Boca Raton, FL: CRC Press; 2017.
- Marks MK, Bethard JD, Mileusnic-Polchan D. Lacustrine Skeletal Taphonomy from Southeastern Tennessee. In: *Case Studies in Forensic Anthropology*. Boca Raton, FL: CRC Press; 2019:117–125.
- Parker R, Ruffell A, Hughes D, Pringle J. Geophysics and the search of freshwater bodies: A review. *Science & Justice* 2010; 50(3):141–149.
- Pietruszka AT. Forensic archaeology underwater: JPAC's inventory, investigation, and recovery of US casualties of war from submerged sites. In: Groen WJM, Márquez-Grant N, Janaway RC, eds. *Forensic Archaeology: A Global Perspective*. Hoboken, NJ: Wiley; 2015:453–461.
- Schultz JJ, Healy CA, Parker K, Lowers B. Detecting submerged objects: The application of side-scan sonar to forensic contexts. *Forensic Science International* 2013;231(1):306–316.
- Viduka AJ. Intrusive techniques in underwater archaeology. In: *Training Manual for the UNESCO Foundation Course on the Protection and Management of Underwater Cultural Heritage in Asia and the Pacific*. Bangkok, TH: UNESCO Bangkok; 2012: (Unit 10) 1–29.