NTSB/MAR-02/01
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Marine Accident Report

Sinking of the Amphibious Passenger Vehicle *Miss Majestic*, Lake Hamilton, Near Hot Springs, Arkansas, May 1, 1999

National Transportation Safety Board
Washington, D.C.

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National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2002. ***Sinking of the Amphibious Passenger Vehicle Miss Majestic, Lake Hamilton, Near Hot Springs, Arkansas, May 1, 1999 Includes Marine Accident Brief Reports Sinking of the Alvis Stalwart M/V Minnow, Milwaukee Harbor, Milwaukee, Wisconsin, September 18, 2000, and Sinking of the M/V DUKW No. 1, Lake Union, Seattle, Washington, December 8, 2001.*** **Marine Accident Report NTSB/MAR-02/01. Washington, DC.**

Abstract: This report discusses the sinking of the amphibious passenger vehicle *Miss Majestic* during an excursion tour of Lake Hamilton near Hot Springs, Arkansas, on May 1, 1999. Of the 21 people on board, 13 passengers, including 3 children, died. The vehicle damage was estimated at $100,000.

The Safety Board's investigation of this accident identified safety issues in the following areas: vehicle maintenance, Coast Guard inspections of the *Miss Majestic,* Coast Guard inspection guidance, reserve buoyancy, and survivability. Based on its findings, the Safety Board made recommendations to the U.S. Coast Guard and the Governors of the States of New York and Wisconsin.

Following this sinking accident, the Safety Board investigated two other accidents involving amphibious passenger vehicles, which are the subjects of brief reports published in an appendix of the *Miss Majestic* report. The first brief discusses the September 18, 2000, sinking of the *Minnow*, a 21-foot-long Alvis Stalwart-type amphibious passenger vehicle in the Milwaukee, Wisconsin, harbor. No deaths or injuries resulted from this accident, and the vehicle damage was estimated at $170,000.The second brief discusses the December 8, 2001, sinking of the *DUKW No. 1*, a 33-foot-long amphibious passenger vehicle, in Lake Union, in Seattle, Washington. No deaths or injuries resulted from this accident, and the vehicle damage was estimated at $100,000.

Contents

Acronyms and Abbreviations

CFR	*Code of Federal Regulations*
COI	Certificate of Inspection
EMS	Emergency Medical Service
gpm	gallons per minute
ICAO	International Civil Aviation Organization
MSO	Marine Safety Office
NVIC	Navigation and Vessel Inspection Circular
OCMI	Officer in Charge, Marine Inspection
RHIB	Rigid Hull Inflatable Boat
UTB	utility boat

Executive Summary

On May 1, 1999, the amphibious passenger vehicle *Miss Majestic,* with an operator and 20 passengers on board, entered Lake Hamilton near Hot Springs, Arkansas, on a regular excursion tour. About 7 minutes after entering the water, the vehicle listed to port and rapidly sank by the stern in 60 feet of water. One passenger escaped before the vehicle submerged but the remaining passengers and the operator were trapped by the vehicle's canopy roof and drawn under water. During the vehicle's descent to the bottom of the lake, 6 passengers and the operator were able to escape and, upon their reaching the water's surface, were rescued by pleasure boaters in the area. The remaining 13 passengers, including 3 children, lost their lives. The vehicle damage was estimated at $100,000.

The Safety Board's investigation of this accident identified the following major safety issues:

- Vehicle maintenance,
- Coast Guard inspections of the *Miss Majestic,*
- Coast Guard inspection guidance,
- Reserve buoyancy, and
- Survivability.

The National Transportation Safety Board determines that the probable cause of the uncontrolled flooding and sinking of the *Miss Majestic* was the failure of Land and Lakes Tours, Inc., to adequately repair and maintain the DUKW. Contributing to the sinking was a flaw in the design of DUKWs as converted for passenger service, that is, the lack of adequate reserve buoyancy[1] that would have allowed the vehicle to remain afloat in a flooded condition. Contributing to the unsafe condition of the *Miss Majestic* was the lack of adequate oversight by the Coast Guard. Contributing to the high loss of life was a continuous canopy roof that entrapped passengers within the sinking vehicle.

As a result of this investigation, the Safety Board makes recommendations to the U.S. Coast Guard and the Governors of the States of New York and Wisconsin.

[1] Reserve buoyancy is the internal volume of a vessel that is not flooded or capable of being flooded.

Factual Information

Events Preceding the Accident

On Thursday, April 29, 1999, the *Miss Majestic,* an amphibious commercial passenger vehicle that had been converted from a U.S. Army DUKW,[2] was nearing the end of the waterborne portion of a tour in Lake Hamilton, Arkansas. (See figure 1.) As the vehicle approached the shore, the operator said she saw that the Higgins pump, a dewatering pump in the bilge system, was intermittently discharging water. In addition, the forward electric bilge pump that automatically activated when water accumulated amidships in the hull was continuously discharging water from the vehicle. The operator radioed a report of her observations to Land and Lakes, Inc., (Land and Lakes) the owner/operator of White and Yellow Duck Tours, before arriving at the usual return ramp, where she drove the *Miss Majestic* out of the water.

Figure 1. The *Miss Majestic.* When the DUKW was converted for commercial passenger service, a steel frame was installed around and over the passenger compartment. The *Miss Majestic* had a vinyl canopy over the frame to protect passengers from the weather.

[2] A DUKW (pronounced "duck") is an amphibious landing vehicle that was designed to transport military personnel and supplies for the U.S. Army (Army) during World War II. The Army acronym DUKW indicates that the vehicle model was designed in 1942 (D) and that the vehicle is amphibious (U) and has both front-wheel drive and rear-wheel drive capability (K and W, respectively). Records indicate that more than 21,000 DUKWs were built. After the war, many DUKWs were sold as surplus and, like the *Miss Majestic*, were converted to commercial excursion passenger vehicles that are in operation today.

In the meantime, Land and Lakes dispatched its senior mechanic, who arrived at the exit ramp while the *Miss Majestic* was still in the lake. He, too, observed that the water was discharging from the Higgins pump's outflow point in a brief and intermittent manner rather than in a steady stream.

The operator said that after she drove the *Miss Majestic* up the ramp and onto dry land, water continually leaked from the hull for about 10 minutes. During the same time, water continuously discharged from the forward electric bilge pump.

After the mechanic examined the vehicle and determined that the source of the leak was a tear in the forward rubber boot[3] on the rear driveshaft housing (figure 2), the operator drove the *Miss Majestic* to Hot Springs, where she completed the land tour and dropped off passengers. She then drove the *Miss Majestic* to the company garage for repairs.

On April 30, at the garage, the maintenance mechanic began work after 1200[4] on the *Miss Majestic* after conducting daily checks on three other DUKWs that were being used for tours that day. To repair the leak, he replaced the forward boot with a rubber boot that had been obtained from sources such as Army surplus. In the course of making the repair, he discovered a small tear in the aft boot for the rear driveshaft housing; however, he did not have time to replace the aft boot before the end of his workday. The next morning, the day of the accident, the mechanic replaced the aft boot with a previously used boot. The *Miss Majestic* was then returned to service.

Accident Narrative

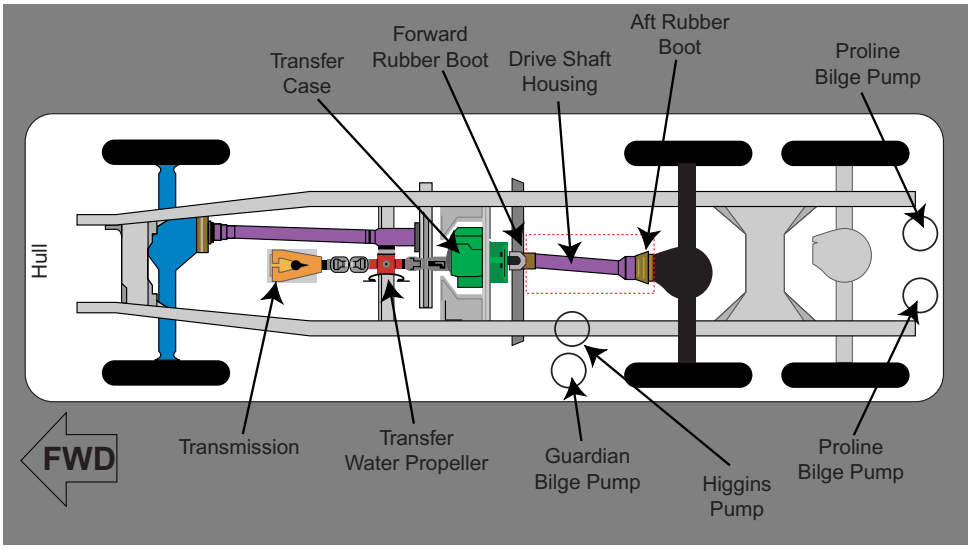
About 1130 on May 1, 1999, the operator of the *Miss Majestic* first picked up 18 passengers at the White and Yellow Duck Tours ticket office in Hot Springs and then two passengers at a regular White and Yellow Ducks stop at a nearby park, for a total of 20 passengers. The operator served not only as the operator of the vehicle but also as the narrator for the tour. After conducting a land tour of Hot Springs, the operator drove the DUKW south on U.S. Route 7 to Lake Hamilton for the waterborne portion of the tour.

On the northwest side of Saint John's Island, the operator arrived at the boat ramp owned by Land and Lakes and, in preparation for entering the water, turned on the toggle switch to power the three electric bilge pumps.[5] The operator then stood up, faced the passengers, and briefed them on the water tour sights and safety instructions. She warned them that smoking was prohibited by the U.S. Coast Guard (Coast Guard) and was punishable by a fine. The operator pointed out that the lifejackets were stowed on wooden

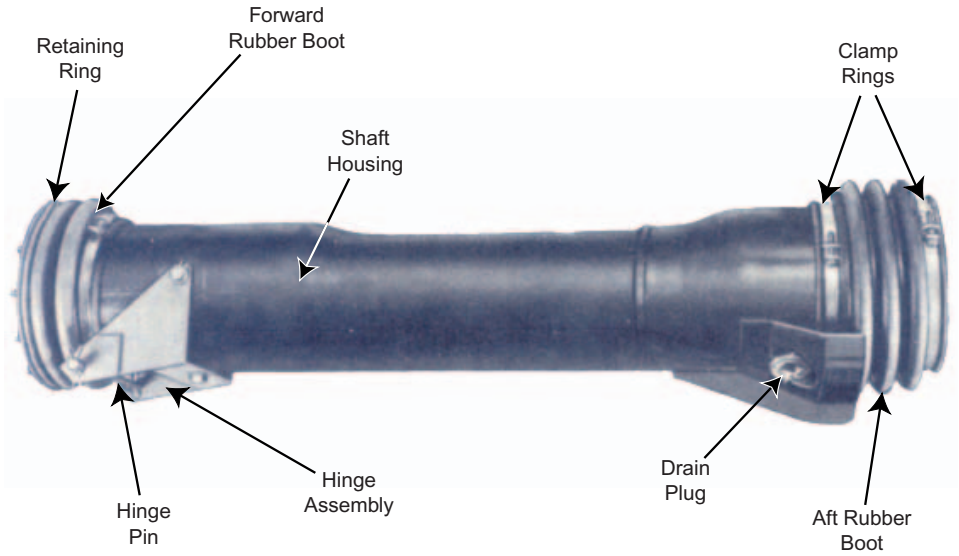
[3] The driveshafts for the wheels penetrated the hull and were protected by cylindrical steel housings. The housings were fitted with rubber boots to maintain the watertight integrity of the hull. The boots were held in place by hose clamps. If the boots had holes or were dislodged, water could freely enter the hull.

[4] All times are central daylight times, based on a 24-hour clock.

[5] The forward electric pump operated only when its float switch was activated by the presence of water. The aft electric pumps were activated by the operator turning on a toggle switch on the dashboard.



Plan view of the *Miss Majestic*'s drive shaft and chassis assembly. The area indicated by a dotted line includes the drive shaft and its rubber boots, which were designed to provide a waterproof seal for the drive shaft's penetration into the hull.



Above is the drive shaft housing and hinge pin assembly as shown in the Army technical manual for DUKWs. The hinge pin assembly, which holds the housing in position relative to the hull, was missing from the *Miss Majestic.*

Figure 2. Top illustration shows the *Miss Majestic*'s assembly and the approximate locations of the Higgins pump and the three electric bilge pumps. Bottom illustration shows a side view of the driveshaft housing and components as designed by the Army.

shelving underneath the overhead canopy covering the passenger compartment of the vehicle.

While briefing the passengers about the lifejackets, the operator tried to pull one out of the storage rack (see figure 3) to demonstrate how to don it. When she could not pull a lifejacket free, the operator gave up trying.[6] According to passengers, as the operator retook her seat at the forward part of the vehicle, she pointed to the lifejackets and said, "They're up there." The passengers said that the operator neither offered lifejackets to anyone nor explained how to get off the vehicle in case of an emergency on the water.

The operator then put the DUKW's transmission into neutral, engaged the vehicle's propeller, and let the vehicle roll down the ramp into the water. The DUKW followed along the shore of Saint John's Island, traveling about 4 knots. While she had been driving on land, the operator had raised the windshield and secured the curtains on the corner windows on either side of the windshield. She left the windshield up for the lake tour.

Figure 3. Postaccident view of the *Miss Majestic*'s main passenger compartment looking forward from the aft seating area. The lifejackets were stored in open racks above the passengers' seats.

[6] Safety Board investigators examined other DUKWs belonging to the company and found the lifejackets jammed tightly into the storage racks.

During an interview with Safety Board investigators, a 15-year old boy who had been sitting in the third row on the port side stated that shortly after the DUKW entered Lake Hamilton, he took off his shoes. After the DUKW had been on the lake about 4 to 5 minutes, he felt his feet getting wet and, upon looking down, saw that the deck area near his seat was filled with water a little less than a ½-inch deep. The DUKW was riding so low that, from his seat, he could reach down and touch the surface of the lake. He said that he observed a stream of water pouring out of a plastic hose near the operator's seat. The boy likened the water discharge to that of a water stream from a 1-inch garden hose. Two other passengers sitting on the port side also recalled seeing water discharging overboard near the operator's seat. The boy in the third row said that he thought the condition was normal and that the operator did not notice the discharging water.

The operator later stated that, about 5 to 7 minutes after the *Miss Majestic* entered the lake, she noticed that the DUKW was handling sluggishly and had a small list to port. She looked back at the passengers and asked a large man (6 feet 6 inches tall and 260 pounds) who was sitting in the sixth row on the port side to move to the starboard side of the vehicle. (See figure 4.)

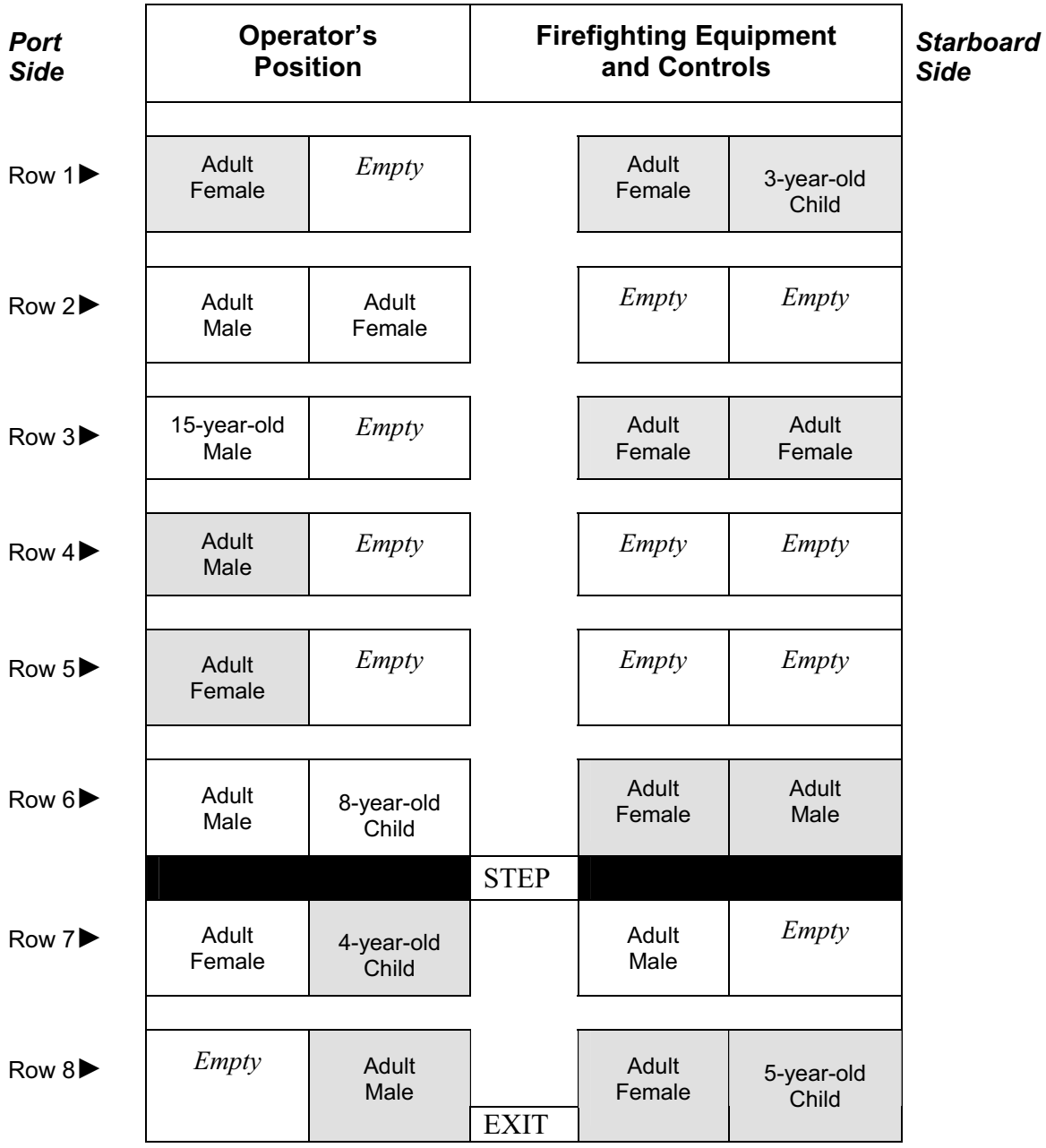
As he got up to change seats, the man saw water enter the vehicle over the stern and realized the danger. He started pulling lifejackets from the overhead stowage area and throwing them to other passengers, shouting at them to "get out." He said that passengers in the row across from him initially remained in their seats and did not move.

At that time, the operator, who had been busy narrating the tour, looked aft and saw water pouring over the stern into the passenger compartment. Upon seeing the inrush of water, she immediately turned the *Miss Majestic* to port and headed towards shore.

The operator later stated that she had not observed discharges from either the Higgins pump or the forward electric bilge pump during the tour; the discharge pipes were to her left. She had been turned to her right, to narrate the tour to the passengers, when the vehicle had begun to flood. She had also throttled the engine down while narrating. The operator stated that she radioed Land and Lakes on the designated VHF channel. The owner stated that he and his employees were by their radios, but no one heard a call.

The operator and the passengers provided different time estimates of how long it took the *Miss Majestic* to sink below the surface of the lake after the DUKW began to take on water over the stern. Some individuals said that the DUKW sank within 15 seconds; others stated that the *Miss Majestic* took up to about 1 minute to sink. A boater in the area who had noticed that the *Miss Majestic* was riding very low in the water said that, as he attempted to approach the vehicle to warn the operator, the *Miss Majestic* sank by the stern and quickly disappeared below the surface.

In the meantime, the 15-year-old male in the third row tried to assist other passengers by providing lifejackets. He later stated that he was able to pull a few lifejackets from the stowage area but said that doing so "was kind of hard." Before the vehicle submerged, he exited the port side window and crawled on top of the canopy as the vehicle quickly slipped beneath the water's surface.



Note: Shaded seats show where the fatality victims were seated before the DUKW sank. The children in rows 7 and 8 actually were in the laps of the women sitting next to them. They are shown occupying a seat to indicate their location in the DUKW. The operator asked the adult male in row No. 6, portside, to move to the opposite side of the DUKW when the vehicle began to list.

Figure 4. Passenger seating arrangement on the *Miss Majestic*.

The large male passenger who had been tossing lifejackets to others said that water rushing into the vehicle swept him forward and pinned him against the windshield. He could not recall how he exited the vehicle. He said that he considered himself a strong swimmer but that the water's force overcame him. He said that his wife, one of the accident fatalities, did not know how to swim.

A passenger in the second row said that, when he realized that the *Miss Majestic* was submerging, he jumped out the port side window. His wife, at first, tried to use the aisle to move to the front of the vehicle; however, upon observing other passengers beginning to panic and seeing that the windshield blocked any exit from the forward part of the vehicle, she returned to the portside opening where her husband had exited. As the woman moved toward the opening, a child who had been in the sixth row grabbed and held onto her. The woman said that she initially swam downward to free herself from the vehicle before beginning her ascent to the surface. She said that her ascent took a long time and that her nose was bleeding when she reached the surface of the lake. She later stated that she was not aware that a child had grabbed hold of her until she surfaced and people assisted the two of them into a recreational vessel.

In the meantime, a woman in the seventh row had her feet propped up on the seat across from her when water began pouring into the stern. The woman said that she had hardly had time to put her feet on the deck when the incoming water was over her head. The woman said that she was not a swimmer. As the vehicle sank deeper, she could see nothing in the murky green, increasingly dark water. She said that she held on tightly to the metal frame at the aft edge of the canopy; however, she was unable to overcome the force of the water and was swept out the stern window opening. She floated to the surface, where she was rescued.

On the starboard side of the vehicle, a man and woman in the seventh and eighth rows were attempting to place a lifejacket on a child when the incoming water poured over them. The man said that he attempted to swim in what he thought was a forward direction; however, he felt something in his way. He did not know through which opening he exited the vehicle; he stated that it took him a while to get to the surface.

The operator stated that she felt along the line of the roof and, upon finding an area where the windscreen had become detached, pulled herself through the opening. She stated that the water was dark. Although she was a strong and practiced swimmer, she struggled to reach the surface of the lake. Upon surfacing, she noted that her clothing was covered with dirt, which she thought was silt, indicating she had been on the lake bottom.

The operators of at least six pleasure boats that happened to be in the area responded to assist the *Miss Majestic*'s eight survivors as they surfaced. One of the responders used a cellular telephone to call 911. The call was relayed to State and area response agencies, including the Lake Hamilton Fire Department Emergency Medical Services (EMS), the Garland County Sheriff's Department, the St. Joseph's Regional Health Center, the National Park Service, the Hot Springs Police Department, the Arkansas State Police, and area representatives of the U.S. Red Cross.

The eight survivors advised responders that they were not injured physically. Divers from the Garland County Sheriff's Department recovered the bodies of all of the remaining passengers, 13 victims, over a 2-day period.

Injuries

The injuries sustained in the *Miss Majestic* accident, shown in table 1, are categorized according to the injury criteria of the International Civil Aviation Organization (ICAO). The Safety Board uses the ICAO injury criteria in all its accident reports, regardless of transportation mode.

Table 1: Injuries sustained in the *Miss Majestic* accident.

Injuries	Passengers	Crew	Total
Fatal	13	0	13
Serious	0	0	0
Minor	0	0	0
None	7	1	8
Totals	20	1	21

49 *Code of Federal Regulations* (CFR) 830.2 defines a fatal injury as: any injury that results in death within 30 days of the accident. It defines serious injury as that which requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; results in a fracture of any bone (except simple fractures of fingers, toes, or nose); causes severe hemorrhages, nerve, muscle, or tendon damage; involves any internal organ; or involves second or third degree burns, or any burn affecting more than 5 percent of the body surface.

Damage

Examination of the vehicle after it was salvaged revealed that the DUKW did not suffer any structural damage or failure and that all hull plugs were in place. Damages from the accident were estimated at $100,000. The Safety Board's observations of the DUKW's condition during postaccident examinations are included in the section below, "Vehicle Information."

Personnel Information

Vehicle Operator

The *Miss Majestic*'s operator was hired by Land and Lakes in August 1998. Before joining the tour company, she had worked as a substitute school bus driver in Mount Ida, Arkansas, from 1997 though 1998, and as a school bus driver in Rockford, Illinois, from 1996 through 1997.[7] She had also worked as a machinist in Rockford from 1988 until August 1995. She stated she had operated a motorboat and had 2 to 3 years experience helping aboard "party barges" and fishing craft.

The operator stated that, in preparation for her Coast Guard examination to become certified to operate a DUKW, she had accompanied and observed licensed DUKW operators for perhaps 3 to 4 months. On December 11, 1998, she was issued a license as master of steam or motor vessels measuring less than 25 gross tons upon inland waters that limited her to operating DUKW vehicles no more than 250 yards offshore in Lake Hamilton.[8] The license was valid for 5 years. The operator stated that, after receiving her license, she drove various DUKWs under the supervision of more experienced operators for "probably a week or two." She was then permanently assigned by Land and Lakes as operator of the *Miss Majestic* and, unless the vehicle was not available, normally drove that DUKW.

The operator described herself as being in generally good health, with a history of arthritis. She stated that she had been taking Motrin before the accident.

Contract Employees

Land and Lakes contracted with a senior mechanic[9] to perform maintenance and repairs on its DUKWs. The senior mechanic, in turn, employed a maintenance mechanic to assist him.

The senior mechanic had been associated with Land and Lakes for 1 1/2 years. Before then, he had worked as a mechanic on automobiles, boats, and motorcycles, and had done part-time maintenance for another DUKW company. His training included 2 years at a vocational school, where his instruction focused primarily on small engine mechanics.

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[7] The operator held an Arkansas State Commercial Driver's License (CDL) that was valid through March 16, 2002. The Class B license included motorcycle and passenger endorsements and was restricted to vehicles without air brakes. She had previously held an Illinois CDL.

[8] The Coast Guard requirements for issuing an operator's license for steam or motor vessels measuring less than 25 gross tons, which are contained in 46 CFR Subchapter B, Part 10, Subpart D, include minimum age, citizenship, physical suitability (including drug and alcohol testing), character (including criminal history and driving record), training in first aid and CPR, successful completion of a written examination, and vessel experience.

[9] Because he served in a supervisory capacity, this report will refer to the contract mechanic as the senior mechanic.

The maintenance mechanic had been employed by the senior mechanic to assist him with the Land and Lakes contract work for about 2 months. Before this contract job, he had worked for 2 years for a company where he drove and performed maintenance on dump trucks. The maintenance mechanic had previously worked for Land and Lakes for 11 years as a DUKW driver. During that time, he also had performed some maintenance work on the DUKWs.

As assistant to the senior mechanic, the maintenance mechanic said he performed general work on DUKWs, including testing lights, checking fluid levels and pumps, repairing brakes, and replacing starters, alternators, universal joints, and worn or damaged boots.

Work and Rest Schedules

The *Miss Majestic*'s operator regularly worked Tuesdays through Saturdays and was off Sundays and Mondays. She provided a summary of her work and rest schedule during the 3 days before the accident, which is shown in table 2. The maintenance mechanic provided a brief account of his 72-hour history before the accident, which is also included in table 2.

Table 2: Seventy-two hour history of the operator and mechanic

Day	*Miss Majestic*'s Operator	Maintenance Mechanic
Thursday, April 29	0600—Arose, fed horses, had breakfast, showered, and went to work. Had coffee and took a 1-hour nap. 1100—Gave first tour of day. Had two additional tours, the last of which was at 1800. During the last tour, noted and reported atypical bilge-pump operations. 1915—Left work and went home. Went to bed about 2100.	Not scheduled for work. Performed light work at home. 2200—Went to bed.
Friday, April 30	0600—Arose and prepared for work. 1100—Drove the *Miss Andrea* DUKW because the *Miss Majestic* was being repaired. 1600—Drove the *Miss Sands* DUKW because of gear shift problems experienced with the *Miss Andrea*. Went home after 1600 tour. 2130—Went to bed after riding horses and having supper.	0630—Arose. 0730—Reported to work. Performed routine daily maintenance on the DUKWs, including the *Miss Majestic*. Time went to bed not provided.
Saturday, May 1	0530—Arose and prepared for work. Dropped off daughter at the Little Rock, Arkansas, airport and reported to work about 0815. 1130—Departed with tour group. Shortly before noon—*Miss Majestic* sinks.	Time arose not provided. Performed maintenance on the *Miss Majestic.*

Vessel Information

The DUKW that was converted to passenger use and became the *Miss Majestic* was built in 1944 as an amphibious landing vehicle designed to transport Army military personnel. According to the Coast Guard's Navigation and Vessel Inspection Circular[10] (NVIC) No. 1-01, *Inspection of Amphibious Passenger Carrying Vehicles*, the Army DUKWs were designed:

> …for the purpose of making beach landings and then proceeding onshore to provide limited troop transportation away from the beachhead. These vehicles were built with a life expectancy of only a few months. Although mechanically rugged, hull construction was simplified for the sake of the accelerated production schedule and the vehicle's anticipated short life expectancy.

The *Miss Majestic* was inspected and certificated by the Coast Guard as a small passenger vessel[11] meeting the requirements of 46 CFR Parts 175-185 (Subchapter T). The Coast Guard Certificate of Inspection (COI) permitted the *Miss Majestic* to operate voyages not exceeding 30 minutes on Lake Hamilton no more than 250 yards from shore.

The characteristics of the *Miss Majestic* are summarized below.

Length:	31 feet
Beam:	8 feet 2 inches
Gross Tonnage:	5
Crew:	1 (operator)
Passenger capacity:	32 (24 in the main area, 8 in the raised rear platform)
Propulsion:	140 hp V-8 Chevrolet 350 gasoline engine, radiator cooled
Transmission:	Turbo Hydromatic 400 automatic 4 speed

The *Miss Majestic*'s hull was constructed of 7/64 (0.109)- and 5/64 (0.078)-inch steel sheet metal with welded stiffeners. The vehicle had no internal watertight subdivision bulkheads; except for minor structural interferences such as tunnels and hull stiffeners, the vehicle's internal hull was open forward to aft. The DUKW had a three-bladed, right-hand-turning propeller in a half tunnel at the stern. When fully loaded, the *Miss Majestic* trimmed by the stern with a freeboard of about 2 feet forward and 8 to 12 inches aft.

[10] The Coast Guard Headquarters issues NVICs to disseminate *recommended* [*emphasis* added] policy, requirements, procedures, or guidance for Coast Guard marine safety personnel and the marine industry.

[11] A vessel of less than 100 gross tons carrying more than six passengers for hire.

As part of the *Miss Majestic*'s conversion for commercial use, the following passenger accommodations were added:

- At the centerline of the stern, a hinge-mounted ladder was added for passenger entry from and exit to land. After boarding, the ladder was hinged up and secured. (See figure 1.)
- Eight rows of passenger seats were added, with the last two rows on a raised deck aft. Each row had two seats on each side of the centerline aisle. (See figures 2 and 3.) The aisle width in both the main passenger compartment and the after deck area was 12 inches. The distance from seat front to seat front in the main passenger compartment was 26 inches. The after deck area contained two rows of seats that faced each other. The distance between the two facing seat fronts was 14 inches.
- A steel frame was installed around and over the passenger compartment. The vertical members of the frame created 28-inch-high "windows" at the seat rows. From forward to aft, the six windows in the main compartment had a clearance width of 33, 18, 33, 33, 33, and 40 inches, respectively. The width of the window at the seat row on the raised deck was 51 inches.
- A vinyl canopy was installed over the steel frame of the passenger compartment to protect passengers from the weather.
- Clear, roll-up, vinyl side curtains were added along both sides of the passenger compartment. When the curtains were rolled up, the window clearance was 21 inches.

The aisle in the main passenger compartment was 14 feet long; on the after deck, the aisle was 4 feet, 4 inches long. Thus, the entire length of the *Miss Majestic*'s centerline aisle was 18 feet, 4 inches.

Federal regulations contained in 46 CFR 177.30-1 stipulate that the width of aisles more than 15 feet long should be no less than 30 inches and the distance from seat front to seat front should not be less than 30 inches. According to the Coast Guard, the *Miss Majestic* had been granted a waiver for meeting the aisle width and seat separation requirements. Coast Guard files for the *Miss Majestic* contained no record indicating how the acceptable dimensions were determined.

According to Coast Guard documents, the *Miss Majestic* met regulations in Subchapter T, which require that a vessel pass an intact stability test to demonstrate that its freeboard will not immerse should passengers move from one side of the vessel to the other.

Design and Components

Driveshaft Housing and Boot System. The aft driveshaft that ran from the transfer case to the rear differential and drive wheels of the *Miss Majestic* had a housing for watertight protection. In the DUKW design, the shaft housing was supported and held

in position, relative to the hull, by a hinge assembly and, relative to the differential, by a support bracket. The hinge prevented the shaft housing from shifting forward and aft.

Each end of the aft shaft housing had an accordion rubber boot. The aft rubber boot was attached to the aft end of the shaft housing and the differential using hose clamps. The forward rubber boot was clamped onto the housing using a hose clamp and bolted to a cutout in the chassis. The two rubber boots together with the shaft housing were to provide a watertight barrier where the drive axle penetrated the hull.

The *Miss Majestic* had a similarly configured forward shaft housing to protect the front wheel driveshaft.

Bilge Pump System. Federal regulations contained in 46 CFR 182.520 stipulate that vessels must be equipped with bilge pumps. The number of the required pumps and their minimum capacity depends upon the length of the vessel and the number of passengers that it carries. The *Miss Majestic* was required to have two bilge pumps: one with a pumping capacity of 10 gallons per minute (gpm) and a second with a pumping capacity of 5 gpm. The *Miss Majestic* had three electric pumps, one Guardian model 1100 and two Proline model 22702s.

The Guardian 1100, manufactured by Attwood Corporation, was a submersible-style, 12-volt electric pump that automatically float-activated when water accumulated amidships in the hull. The Guardian pump was equipped with a 1-inch diameter plastic discharge hose and had a maximum discharge capacity of 18 gpm. On the *Miss Majestic*, the Guardian pump was located on the hull bottom, immediately forward of the Higgins pump. The Guardian's hose discharged athwartships to port at the port gunwale, immediately to the left of the operator's station.

The Proline Model No. 22702, manufactured by Mayfair Marine, was a submersible-style, 12-volt electric pump that activated when the operator turned on a toggle switch. The Proline Model No. 22702 pump had a maximum discharge capacity of 12.5 gpm. On the *Miss Majestic*, the two Proline pumps were installed near the stern, where water usually collected because of the vehicle's trim. One Proline pump was located behind the port rear wheel well and the other Proline pump was behind the starboard rear wheel well. The discharge points for the Proline pumps were at the stern deck, on either side of the passenger embarkation step; the pump discharge hoses were directed aft.

A single toggle switch on the dashboard provided power to the three electric bilge pumps. The operators' practice was to turn on the switch before entering the water and to turn it off when exiting the water to prevent the Proline pumps from running dry and failing prematurely while the vehicle traveled on land. A red light on the control console indicated when the switch was on.

As with most amphibious vehicles converted from Army DUKWs, the *Miss Majestic* had a Higgins pump, which was not required by Federal regulation. The Higgins pump had a maximum capacity of 250 gpm. The pump was chain-driven from the water

propeller driveshaft through a keyed sprocket on the pump shaft and operated whenever the propeller's driveshaft was engaged. (See figure 5.) The Higgins pump discharged straight upward and overboard through an opening on the port side gunwale, near the second row of seats.

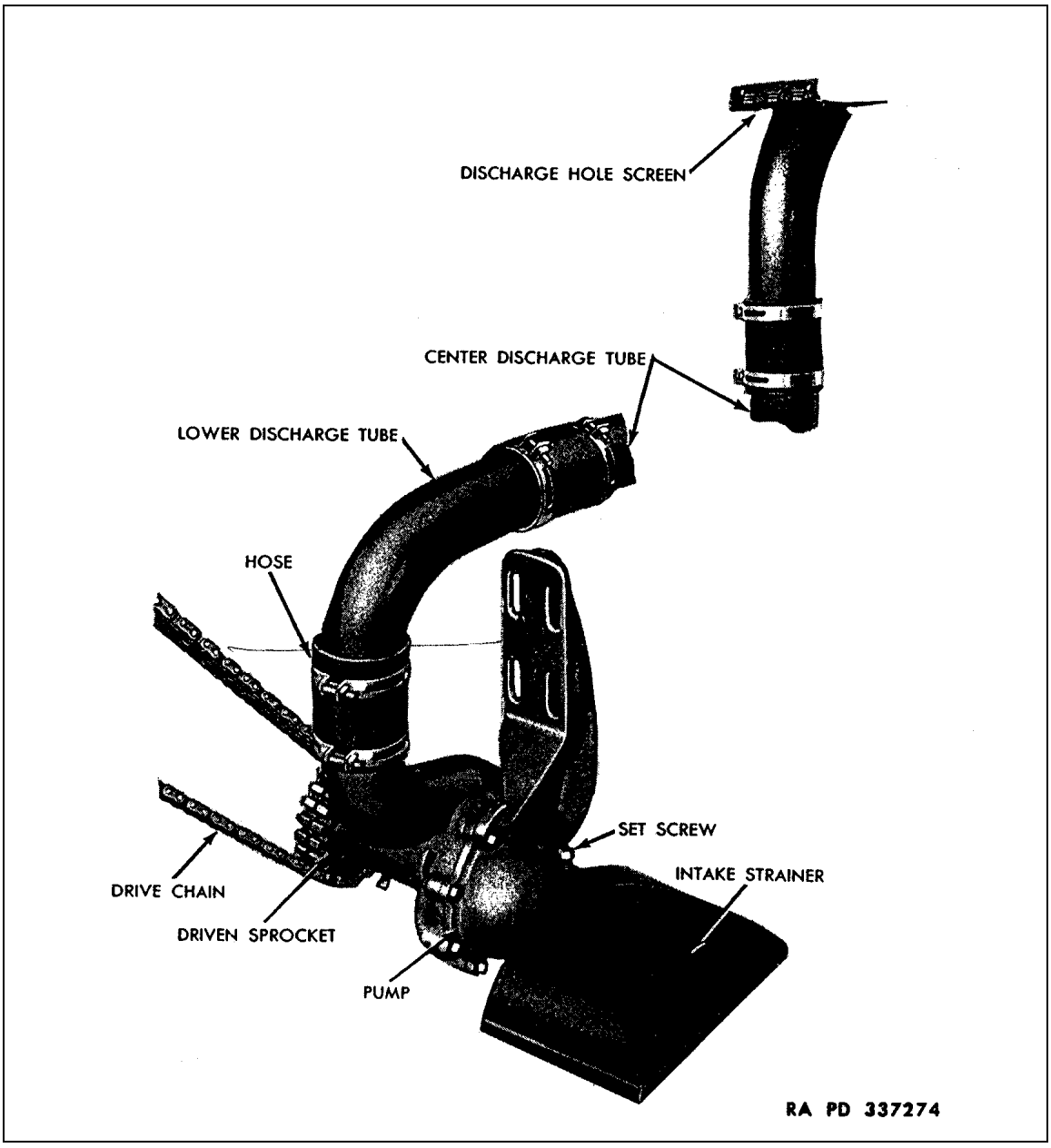

Figure 5. The Higgins pump arrangement. The centrifugal-type, bronze pump had a 4-bolt mounting bracket, which, in the case of the Miss Majestic, attached the pump onto the port longitudinal girder (channel) under the passenger compartment. The face of the pump's intake (suction) strainer was about 1 1/2 inches above the bottom of the vehicle. The 2 1/2-inch-diameter discharge pipe extending upward from the pump had three sections: a lower discharge tube, a center discharge tube, and an upper discharge tube. A short section of hose with clamps connected the lower discharge tube to the pump discharge.

Bilge Alarm. In 1996, Subchapter T was revised to require that vessels at least 26 feet long be equipped with high-level bilge alarms. The regulations stated that existing vessels, such as the *Miss Majestic*, had until March 11, 1999, to comply with the high-level alarm requirement. On the day of the accident, the *Miss Majestic* was not equipped with a bilge alarm.

Hull Plugs. For ease of maintenance, the *Miss Majestic* had three 4-inch screw-type access plugs on the hull bottom: one plug was under the transmission, one was under the propeller transfer box, and one was under the main drive transfer casing. The vehicle had five 1-inch screw-type drain plugs, including a plug at the differential end of each of the forward and aft shaft housings, a plug on the hull centerline just forward of the front axle chase tunnel, and a plug in each of the pods aft of the aft wheel wells. All plugs were secured in place at the time of the accident.

Postaccident Examination of the Vehicle

Driveshaft Boots. Shortly after the *Miss Majestic* was salvaged from Lake Hamilton, Safety Board investigators found that the aft rubber boot had separated from the rear shaft housing. (See figure 6.) Upon attempting to replace the boot on the housing, investigators found that the hose clamp holding the rubber boot onto the aft shaft housing was sufficiently loose to enable them to turn the boot by hand. Investigators were able to reclamp the boot onto the housing by tightening the hose clamp screw with two to two and a half turns of a screwdriver. The hose clamp securing the boot on to the differential was tight.

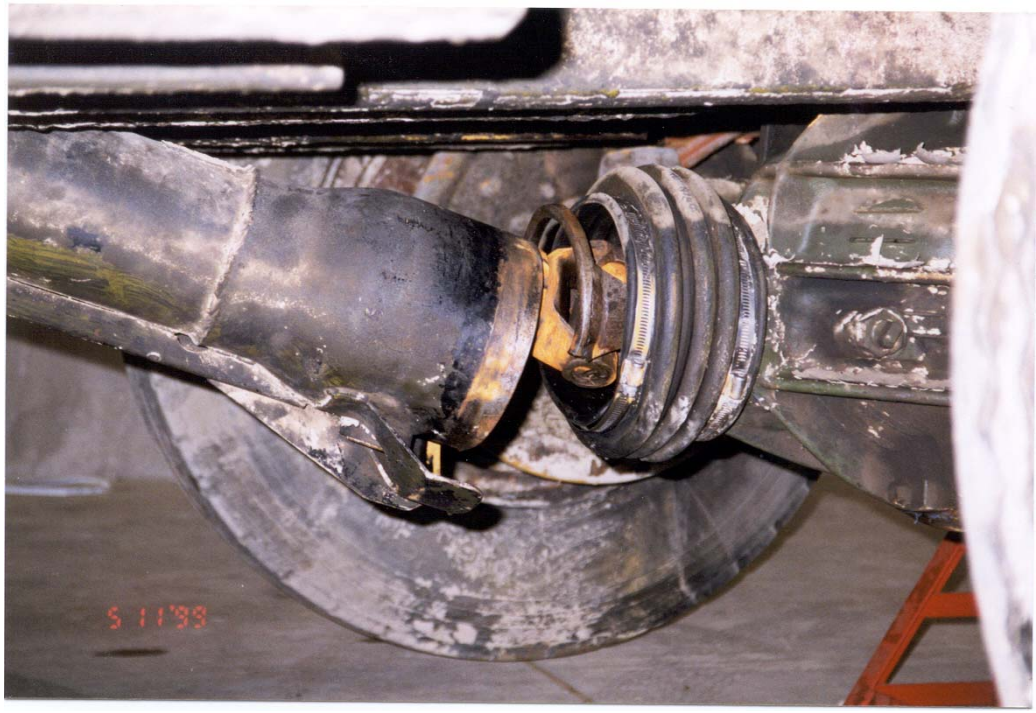

Figure 6. Postaccident view of the rear driveshaft boot.

Investigators found that the hinge pin assembly bracket at the forward end of the shaft housing had been removed.

Hull. During the on-scene examination of the vehicle, Safety Board investigators visually examined the hull and found an irregularly shaped 14-inch-long by 6-inch-wide silicone rubber repair patch covering a corroded area above the right rear wheel leaf spring support. The hull area below the waterline, near the vehicle centerline, had a ½-inch by ¼-inch hole about 2 feet forward of where the propeller shaft entered the hull. The area around the hole was corroded. Investigators also found a pinhole in the right rear wheel well, about 1 foot from the rear end of the well.

Higgins Pump. Safety Board investigators found that the key attaching the pump shaft to its drive chain sprocket was missing. The sprocket appeared old and had excess play on the pump shaft. Investigators noted that the play in the sprocket allowed the drive chain to rub against the hull frame; they also observed several abrasion marks on the frame. The pump impeller turned freely at the time of the examination. Investigators found that a 1 ½-inch portion of an impeller blade's leading edge was sheared off.

The intake strainer was found detached from the pump suction and lying on the vehicle's bottom inside the hull.

The overboard discharge pipe had separated from the hose connecting it to the pump discharge. The hose was rotted. The U-clamp that secured the discharge pipe to the chassis girder was missing. (See figure 7.)

A description of the Safety Board's laboratory examination of the Higgins pump and other components appears under the "Tests and Research" section.

Electrical pumps. Investigators tested the three electrical pumps on scene. The Proline pump on the aft port side was inoperable; the other two pumps were operable.

Waterway Information

The accident occurred in Lake Hamilton, an 18.5-mile-long man-made lake located in the southwestern part of Arkansas, near the city of Hot Springs. The water depth was about 60 feet where the *Miss Majestic* sank, about 200 yards from shore.

Lake Hamilton was created by the construction of the Carpenter Dam on the Ouachita River in 1932. After the dam was constructed, the created lake was regarded locally as a State waterway. In 1976, the Coast Guard assumed authority over the waterway. In 1982, Land and Lakes, the owner of the *Miss Majestic* and other DUKWs, successfully contested in Federal District Court the Coast Guard's authority over the lake. In 1988, the U.S. Court of Appeals reversed the previous ruling stating that Lake Hamilton was a navigable waterway because it had been formed from a portion of the Ouachita River, which is a navigable river of the United States, and, therefore, was under the jurisdiction of the Coast Guard.

Figure 7. The discharge hose of the Higgins pump was broken and missing the U-clamp that connected the pump to a chassis girder of the vehicle.

Operations

Company Information

The owner/president of Land and Lakes stated that he had operated DUKWs in Hot Springs for 40 years. He had operated under State regulations for the first 20 years and under Coast Guard regulations for the remaining time. Land and Lakes operated under the business title "White and Yellow Ducks." Seven of the company's 12 vehicles were licensed for passenger operations. Four of the seven were in service at the time of this accident.

The company employed three operators who were assigned to specific DUKWs. Tours were scheduled to start at 0900, 1100, 1230, 1400, 1600, and 1800 (plus 2000 in summer), depending upon the availability of at least six passengers, and lasted about 90 minutes.

The owner had no written instructions or operational policies for the operators and the mechanics. He stated that he believed frequent verbal instructions were sufficient for

the operators and mechanics to know what was expected of them. He said that he frequently asked the operators about the daily checks they made of their assigned vehicles. Further, he said he was frequently present when the DUKWs arrived at the office, at which time he would listen for noises that might indicate a mechanical problem. He also said that he often asked the operators whether they had heard any new sounds or noises from their DUKWs or whether they had experienced any problems. He stressed his opinion that it was important for each driver to be assigned to a specific DUKW because each one had its own characteristics and this knowledge aided the operators in recognizing any change in noise or operation of their DUKW.

The owner stated that he relied on the Coast Guard inspectors to provide guidance regarding Coast Guard requirements and what he needed to do to be in compliance with Federal regulations.

Vehicle Maintenance

According to the senior mechanic, the daily maintenance practice was for the mechanics to visually inspect under the DUKWs' hoods each morning for leaks, turn on the electric pumps and listen to them work, check the brakes, start the engines, and check the fluid levels.

The company did not have a preventive maintenance program. With the exception of routine oil and seasonal antifreeze changes and periodic lubrication of joints, the maintenance mechanics made repairs only after problems, including leaky boots, were reported or discovered. The company also had no preventive maintenance schedule for the Higgins pump.

The company had no written procedures for conducting vehicle maintenance or for testing or checking to verify the effectiveness of repairs, such as testing the boots while the vehicle was in the water. The senior mechanic stated that the band clamp attaching the rubber seal to the shaft housing could have been inadvertently installed in a cocked position because of the difficulty of working under the vehicle, and that a cocked clamp could have caused the boot to come loose. The senior mechanic said that he did not check the maintenance mechanic's installation of the boot on the day of the accident.

The senior mechanic stated that the company did not have a policy of keeping regular written maintenance or repair records or logs. He stated that the maintenance mechanic occasionally filled in maintenance logs on his own. The senior mechanic provided logs to Safety Board investigators for work performed on December 31, 1997, April 26, 1999, and May 1, 1999. No maintenance records for 1998 and for the period preceding April 26, 1999, were available. The senior mechanic stated that the records were stored in a file cabinet, but he was not aware of any follow-up process for reviewing or taking action on the maintenance records. He stated that driveshaft universal joints (U-joints) on all DUKWs were greased weekly; however, no records of the work were kept.

The maintenance log dated May 1, 1999, indicates only minor maintenance on the *Miss Majestic*. It states that the bilge pumps were working, boots were installed on the aft shaft housing, new caps were put on the U-joints, and the brakes were adjusted. The maintenance sheet for April 26, 1999, indicates that the U-joints were greased, the brakes were adjusted, and the bilge pumps were working; no other problems were noted. The maintenance record for December 31, 1997, which is unsigned, shows that more significant repairs were made, including installation of a new carburetor and fuel pump, replacement of alternator wiring, and repair of the cooling system, the bushing in the rudder shaft, and the front end bearing and seals.

Although technical manuals that provide maintenance guidance for the DUKWs are still available from the Army, neither the company nor its mechanics had technical manuals or drawings providing information about the DUKWs' special features. Some portions of the manuals, however, do not apply to passenger DUKWs because of the modifications made when they were converted to commercial service. The mechanics stated that they did not know the purpose of the hinge pin assembly (which had been removed earlier). The senior mechanic stated that the hinge assembly rattled and its presence made accessing the U-joints for greasing more difficult. Further, he had seen the hinge assembly removed from other DUKWs. He said that he did not know when the hinge assembly had been removed from the *Miss Majestic*.

The senior mechanic stated that it was difficult to obtain replacement rubber boots as they were no longer manufactured.[12] Land and Lakes generally used Army surplus rubber boots. He further stated that often these boots had clamp marks, indicating previous usage, and fine surface cracks.

The senior mechanic stated that he performed major repairs and overhauls for engines, transmissions, and Higgins pumps at Land and Lakes; however, he was unable to provide maintenance records, repair dates, or receipts for major overhauls or repairs. He said that he represented the company during Coast Guard inspections. He usually performed repairs that the owner directed.

The maintenance mechanic said he performed general maintenance work on DUKWs, including testing lights, checking fluid levels and pumps, repairing brakes, and replacing starters, alternators, U-joints, and worn or damaged boots. He said he also performed a weekly greasing of the U-joints in the driveshafts, a procedure that involved loosening the clamps on the boots and sliding the boots and housing back to gain access to the U-joints. He said he usually performed repairs and maintenance at the direction of the senior mechanic. His work was not checked or inspected by the senior mechanic. He had never repaired a Higgins pump.

He said that the leaking forward rubber boot that he replaced before the accident had dry-rotted and cracked. While replacing it, he noticed that the aft boot was also torn, so he replaced that as well. He stated that, during his current and previous period of work

[12] In discussions with other DUKW owners, Safety Board investigators determined that a few larger companies either make their own rubber boots or have them made.

with Land and Lakes, he had replaced numerous boots. He had found that most boot leaks and failures had resulted from dry rot and cracking from age.

Meteorological Information

The May 1, 1999, National Weather Service report issued for Hot Springs at 1150 stated that the weather was clear and sunny with a 25-mile visibility. The wind was southeasterly at 6 knots, and the air temperature was 72° F.

Medical and Pathological Information

Medical Findings

The eight survivors advised EMS personnel that they had no physical injuries. Divers retrieved the bodies of the 13 fatality victims inside and outside of the sunken vehicle and transported them to the Garland County Coroner's Office in Hot Springs on May 1 and 2. The results of the postmortem examination determined that the cause of death in each instance was fresh water drowning. The 13 victims, 7 female and 6 male, varied in age from 3 to 50. Three of the victims were minor children ages 3, 4, and 5. One adult victim was disabled.

Toxicological Testing

The operator provided a blood sample at 1550 on May 1, within 4 hours of the accident. The employer told the Safety Board that he did not realize that a urine sample also was required until he was so advised by the Coast Guard. He then contacted the operator about 2215 advising her that she had to provide a urine sample. She immediately reported for testing and provided a sample about midnight.

The results of the urinalysis testing conducted pursuant to 46 CFR 4 (amphetamines, cocaine, marijuana, opiates, phencyclidine) were negative. The blood sample analysis was negative for ethyl alcohol and positive for Ibuprofen (< 5 m/ml) and the sedative Lidocaine. Although the concentration of Lidocaine was unspecified, the Safety Board's medical officer determined from discussions with the forensic laboratory technicians conducting the test that the quantity was within the trace-to-therapeutic range and was not indicative of excessive use. The operator advised Safety Board investigators that she normally did not take sedatives, but did so that evening about 2030 in an attempt to calm herself after the accident.

Survival Aspects

Emergency Response

First Responders. The first responders to this accident were pleasure boaters who happened to be operating their boats in the area at the time of the accident. About 1200, a pleasure boater left a waterfront restaurant and boarded his boat. He stated that he was "idling along" and saw the *Miss Majestic* about 60 to 80 yards ahead of his boat. He watched the *Miss Majestic* as it turned and noticed that the vehicle's stern appeared to be riding low in the water. He said that within 6 or 7 seconds, he saw the *Miss Majestic* stop and begin to sink by the stern. He did not see whether any of the occupants got off the vehicle before it sank. The boater immediately went to the area where the vehicle sank, where another boater joined him. They started throwing lifejackets into the water as people began surfacing and then pulled the people into their boats. The operators of other boats joined the first two responders and pulled people out of the water. One responder used a cellular telephone to call 911.

Area Response Agencies. The 911 operator notified the Lake Hamilton Fire Department, which dispatched EMS personnel at 1158 to the accident site. In turn, the Garland County Sheriff's Department (sheriff's department) was notified of the accident at 1159, and immediately responded to the scene. The marine patrol supervisor from the sheriff's department arrived on scene about 1204 and, after speaking with the first responders, radioed for ambulances and additional emergency responders to be dispatched to the accident site. St. Joseph's Regional Health Center (St. Joseph's) dispatched a Lifemobile ambulance, and the National Park Service dispatched its area EMS personnel. In addition, the Hot Springs Police Department and the Arkansas State Police responded to assist.

About 1300, personnel from the Red Cross and a grief counselor were sent to the scene to provide comfort to the survivors.

In the meantime, the marine patrol supervisor served as the incident commander overseeing the diving operations. A fireboat was sent to the scene for divers to use as a recovery platform.

Divers reported that the average water depth was 57 feet and the maximum water depth was 60 feet in the search area. The water temperature was 68° F at the surface and 59° F at the lake bottom; visibility was no more than 2 feet. When divers located the DUWK, it was sitting in an upright position. The stern was in deeper water than the bow. The DUWK appeared to have rolled backward for several feet leaving tire track ruts behind.

Over a 2-day period, divers from the Garland County Sheriff's Department recovered the bodies of 13 victims. Seven bodies were found within the main passenger compartment, including five near the forward bulkhead. Three victims were still in their seats or on the deck; four victims were found floating in the canopy. The bodies of six

victims were found on the lake bottom 45 to 105 feet from the vehicle. The diving operations were completed at 1030 on May 2, 1999.

Tests and Research

JMS Flooding Calculations

After the accident, the Safety Board contracted with JMS Naval Architects and Salvage Engineers (JMS) of Groton, Connecticut, to calculate the flooding rate of a DUKW in various scenarios. JMS calculated that a DUKW having the same number and placement of passengers as the *Miss Majestic* would sink in about 6 to 7 minutes after entering the water if the aft boot was loose and the Higgins pump was inoperative.

The contractor was asked to explore the feasibility of making a DUKW capable of staying afloat when flooded by equipping the vehicle with bulkheads or flotation material. JMS determined that a DUKW carrying up to 28 passengers and an operator could be kept afloat when flooded if watertight bulkheads were added aft of the main engine at the firewall and aft of the rear wheel well and if buoyant foam were added between the fore and aft wheel wells along the sides of the vehicle. The Safety Board did not contract JMS to perform detailed engineering to implement the concept.

Laboratory Examination

Investigators sent several of the *Miss Majestic*'s parts that were involved in the accident to the Safety Board's Materials Laboratory in Washington, D.C., for examination. The findings are summarized below.

Electric Pumps. A test in the laboratory confirmed field test results that one of the Proline pumps at the vehicle stern functioned sporadically and shut down soon after starting. The other Proline pump and the Guardian pump functioned normally.

Higgins Pump: The pump suction strainer is attached to the intake flange of the pump's housing by a setscrew. The intake flange of the housing for mounting the suction strainer showed two sets of setscrew marks, about 90 degrees apart. Each set of marks contained multiple circular impressions from multiple contacts with the setscrew. The strainer body showed a brazed repair around the square headed setscrew.

The filter element of the strainer was missing a triangular section with sides 2.5 inches by 4 inches.

The pump's driving sprocket is attached to the pump shaft by 2 screws: one that screws down on a key between the sprocket and shaft and another that screws down on the shaft. The socket screw heads were cracked or rounded from over tightening.

The pump shaft was not of uniform diameter along its length and had necked down in the area of the sprocket. Much of the surface of the shaft contained circumferential rubbing marks. The shaft surface also had impressions consistent with contact from a set screw.

The driving sprocket was found to be installed with the sprocket hub facing toward the pump. The Army Maintenance Manual TM-9-803 shows that the sprocket should have been installed with its hub facing away from the pump. One side of the sprocket teeth was discolored compared to the other, suggesting that one side was kept clean by the chain due to misalignment of the sprocket.

A section of an impeller blade was found missing, and the tips of the two remaining ones were damaged. The roots of the blades were cracked. The inside of the impeller housing showed discolored rub markings.

Rubber Boots. The Safety Board also examined the rubber boots and observed that the rear boot that slipped off the housing had patches of dull green paint with a pattern of cracks. Multiple circumferential lines adjacent to the clamp suggest numerous installations of a hose clamp on this seal. The forward seal for the housing also showed imprints of numerous previous installations of a hose clamp.

Other Information

U.S. Coast Guard Inspection Policy

According to senior Coast Guard officials, the local Officer in Charge, Marine Inspection (OCMI) reviews and approves the plans and design of DUKWs for conversion to passenger service. Subchapter T vessels typically receive local reviews as opposed to plan review by Coast Guard Headquarters. The approval of DUKWs is usually based on a 5-year history of successful service and compliance with Subchapter T regulations. The local OCMI's review for initial certification involves the review of plans required to be submitted by regulations, inspections during the conversion process, and the final inspection of the hull and all systems before the vehicle is granted a COI.

Under the Coast Guard inspection program, after an inspector determines that the vehicle passes an inspection for certification, it is issued an initial COI, which is valid for 3 years. For the two anniversary dates following the issuance of the COI, the vehicle was required to undergo annual reinspections. The COI would be reissued every third year, upon satisfactory completion of a subsequent inspection.

This inspection for certification includes examining and testing the vehicle's structure, machinery, and equipment, including lifesaving and firefighting equipment. The scope for inspection for certification is defined in 46 CFR 176.404, which states:

> The owner or managing operator shall conduct all tests as required by the marine inspector….In addition, the OCMI may require the vessel to get underway as part of the inspection for certification. The inspection is conducted to determine if the vessel is in satisfactory condition, fit for the service intended, and complies with the applicable regulations in this subchapter.

The scope of the reinspection is the same as the inspection for certification but in less detail unless a major change has occurred since the last inspection.

According to Coast Guard officials, at the time of the *Miss Majestic* accident, about 63 DUKWs were under Coast Guard jurisdiction. The vehicles operated in 12 different marine inspection zones throughout the nation. Also at the time of the accident, the Coast Guard had not developed uniform nationwide DUKW inspection policies. Marine Safety Office (MSO) Memphis, Tennessee, which was the local Coast Guard office in charge of inspecting the *Miss Majestic,* had no written policy for DUKW inspections. However, MSO Chicago, Illinois, and MSO St Louis, Missouri, had independently developed inspection policies addressing different inspection issues that had arisen in their respective areas. These policies were not coordinated through Headquarters for dissemination to other MSOs. MSO Chicago had issued "DUKW Inspection Procedures," dated April 14, 1998, for inspectors in its local inspection zone, while MSO St. Louis had issued Policy File Memo 1-89, Change 1 (2-91) on "Waivers/Equivalencies" for DUKW inspections, for inspectors in its local zone. These policies did not address inspecting the integrity of rubber boots and clamps or testing the bilge pumps with water.

Coast Guard Inspections of the Miss Majestic

The Safety Board reviewed the Coast Guard inspection records for the *Miss Majestic* for the past 6 years and interviewed the inspector who conducted the last annual inspection, which was on February 23, 1999. Table 3 summarizes the Coast Guard findings for the inspections conducted between March 23, 1994, and February 23, 1999.

The inspector who examined and who determined the *Miss Majestic*'s fitness for duty on February 23, 1999, said that he inspected the bottom of the vehicle from the side, without getting under it. He stated he saw no deficiencies with the condition of the hull, boots, or clamps. He reminded Land and Lakes to install a high-level bilge alarm by March 11, 1999, and noted that the owner was making arrangements to obtain the alarm. The inspector later testified that, because he had been assured by the senior mechanic that the alarm would be installed by the March deadline, he did not follow up to ensure the installation had taken place. After the *Miss Majestic* was salvaged, Safety Board investigators found that the alarm had not been installed.

Table 3. Coast Guard inspections of the *Miss Majestic* for 1994 through 1999

Date	Inspection Type	Comments
February 23, 1999	Annual	Inspection book states, "Boarded vessel parked at the owner's shop…The engine compartment, mid-body void, and the fuel tank compartment were entered and all areas of the hull interior and exterior were accessible and examined during this inspection. All drive shaft boots and clamps were found to be satisfactory…Visually examined the steering cable, main propulsion, bilge, ventilation, and electrical systems. Owner is in the process of installing the required high-level bilge alarms required by 11 Mar 99. Owner is also researching availability of flammable vapor detection system required by 11 Mar 99 iaw [in accordance with] CFR 182.480; issued CG-835 ['Notice of Merchant Marine Inspection Requirements']. "
March 5, 1998	Annual	No deficiencies noted. Inspection records states, "The engine compartment, mid-body void, and the fuel tank compartment were entered, and all areas of the hull interior and exterior were accessible and examined during this inspection. All driveshaft boots and clamps were found to be satisfactory."
March 11, 1997	Recertification	No deficiencies noted. The inspection record states that all driveshaft boots and clamps were in satisfactory condition, and that the inspector witnessed the satisfactory operation of the bilge pumps, the main propulsion, and the steering.
March 13, 1996	Annual	No deficiencies noted.
March 15, 1995	Annual	Inspection book states, "Repair the chain driven bilge pump and prove operation prior to carrying passengers, but not later than 15 April 1995," and "replace all driveshaft tube rubber boots, all were checked and dry rotted." These deficiencies were subsequently rectified.
March 23, 1994	Recertification	No deficiencies noted

None of the inspections during the 6-year period were conducted in the water; all inspections were conducted at the owner's garage. The operation of the Higgins pump was never tested with water[13] during the 6 years. The Coast Guard policy required "operational checks" for bilge pumps. According to Coast Guard officials, this did not mean that pumps needed to be tested with water. The inspector who conducted the February 23, 1999, annual examination of the *Miss Majestic* said that he believed that checking a pump implied "just an overall visual" examination of the pump and turning the operating switch on and off.

[13] Participants at the Safety Board forum and other inspectors stated that testing a 250-gpm Higgins pump with water had practical difficulties. They indicated that a special testing arrangement would have to be developed.

Inspector's Experience and Training

The Coast Guard inspector who had last inspected the *Miss Majestic* before the accident had previously conducted a total of four inspections on two DUKWs about 5 years earlier, on his previous tour at MSO New Orleans. He had not received any special training in inspecting DUKWs, and was not aware of any Coast Guard inspection policies specific to DUKWs. He stated that he had talked to other inspectors to come up to speed on DUKWs. In addition, the OCMI and the supervisor of marine inspectors at MSO Memphis had never personally inspected a DUKW or were aware of any Coast Guard inspection policy specific to DUKWs. The inspector was a qualified marine inspector for small passenger vessels, barges and ships (hull and machinery), with 6 years of marine inspection experience.

Postaccident Actions by the U.S. Coast Guard

Following the *Miss Majestic* accident, on December 11, 2000, the Coast Guard issued NVIC No. 1-01, *Inspection of Amphibious Passenger Carrying Vehicles*, which had been developed in concert with the amphibious vehicle industry. The NVIC discusses lessons learned from the sinking of the *Miss Majestic*, which were the basis for the guidance for improving the safety of DUKWs in order to prevent similar accidents. The NVIC discusses DUKWs only, and does not describe other types of amphibious vehicles such as Stalwarts, Lighters, Amphibious Resupply, Cargo (LARCs), and Hydra-Terras.

This document sets forth guidance for local Coast Guard authorities to follow for conducting a plan review and inspection and certification of DUKWs. The stated purpose of the NVIC is to:

- Summarize and consolidate technical information pertaining to the design and inspection of amphibious DUKW vehicles;
- Promote uniformity in the approach to certification requirements among various Coast Guard marine inspection offices; and
- Consolidate best practices currently being used in the DUKW industry.

Further, the NVIC states that certification of DUKWs should be through a systems approach that results in an equivalent level of safety to that of other conventional Subchapter T vessels. Equivalencies or operational controls would be considered where appropriate.

Some examples of the inspection guidance contained in the NVIC are summarized below:

- The external and internal hull should be inspected with special attention to areas that are vulnerable to corrosion.
- The vehicle should be operated in the water and all through hull penetrations checked for watertightness.

- The condition and function of all bilge pumps and all other mechanical equipment should be operationally tested or simulated.
- The shaft housing rubber boots, clamps, and housing brackets should be examined.
- The drain plugs should be examined to verify proper fit and function.
- High-level bilge alarms should be installed.
- A vehicle's regulatory history, including waivers and equivalencies, should be documented.
- The OCMIs should ensure that marine inspectors have proper training regarding the operation and inspection of these vessels.

Postaccident Actions by the Safety Board

As a result of the *Miss Majestic* accident and recognizing that more than 1 million passengers are carried each year on board more than 250 amphibious passenger vehicles in the United States, the Safety Board conducted a public forum on amphibious passenger vehicle safety December 8–9, 1999, in Memphis, Tennessee. The forum brought together representatives of the Coast Guard, State governments, amphibious passenger vehicle operators and refurbishers, and the public to discuss safety issues relating to the design, regulation, maintenance, and operation of the vehicles. Forum participants considered the following issues:

- Conversion from military to civilian amphibious passenger vehicles,
- Passenger egress and survival,
- Lifesaving equipment,
- Design and stability,
- Maintenance and inspection policies and certification,
- Operational safety, and
- Operator qualifications.

At the forum, a JMS representative made a presentation on the flooding characteristics of DUKWs and stated that he estimated that the cost of installing the bulkheads and foam would be about $2,000 per DUKW plus about $10,000 for detailed engineering of the installations.

Based on its investigation of the *Miss Majestic* accident and the information presented at the forum about the vulnerability of amphibious passenger vehicles to flooding and sinking, and recognizing that the regulatory process addressing the deficiencies is time-consuming, on February 18, 2000, the Safety Board issued the following safety recommendation to 30 operators and refurbishers of amphibious passenger vehicles in the United States:

M-00-5

> Without delay, alter your amphibious passenger vessels to provide reserve buoyancy through passive means, such as watertight compartmentalization, built-in flotation, or equivalent measures, so that they will remain afloat and upright in the event of flooding, even when carrying a full complement of passengers and crew.

To date, the Safety Board has received responses or information from 16 amphibious passenger vehicle companies. Most of the responses expressed the opinion that installing watertight bulkheads and flotation foam would be difficult and would require detailed engineering. Some of the responses detailed other actions that companies were taking such as installing flow restrictor plates, additional bilge pumps, and high water bilge alarms. Only three companies indicated that they were trying to install reserve buoyancy into their vehicles.

A Missouri company, Ride the Ducks, stated that it was building a prototype aluminum DUKW that incorporated foam buoyancy into the design in accordance with the recommended action.

A South Carolina company, Cool Stuff, advised the Safety Board that it had built a new type of amphibious vehicle called the Hydra-Terra, which was designed especially for commercial passenger service. The vehicle's aluminum hull has foam-filled compartments that provide sufficient flotation certified by the manufacturer to remain afloat even with the drain plugs removed and the engine compartment flooded. The Coast Guard has approved the Hydra-Terra for the carriage of up to 49 passengers and a two-person crew. Several amphibious vehicle operators in Alaska, California, and Maine have purchased these vehicles and have placed them in commercial passenger operations.

A company in Massachusetts, Boston Ducks, stated that it had retrofitted a single watertight bulkhead on one of its DUKWs on a trial basis; however, the company has not had a naval architect evaluate the effectiveness of the bulkhead.

In its correspondence with these three safety recommendation recipients, the Safety Board stressed that Safety Recommendation M-00-5 did not limit companies to using foam or watertight bulkheads as the only means for achieving passive flotation; the recommendation states that other "equivalent measures" would be acceptable. The Safety Board stated that equivalent measures would include adding buoyancy chambers, known as sponsons, to the hull or installing inflatable buoyant bladders. Such inflatable bladders are used on skids of helicopters that operate over water.

On March 23, 2001, Safety Board staff met with the operator of another Massachusetts amphibious passenger vehicle company, Moby Ducks, and his naval architect regarding Safety Recommendation M-00-5. During the meeting, the naval architect stated that the company's LARCs vehicles did not have the requisite internal volume to add sufficient flotation foam so that the vehicles would remain afloat and upright in the event of flooding. Further, watertight bulkheads could not be installed in the

LARCs because their engineering systems relied on unobstructed airflow that would be compromised by the barriers.

In a June 13, 2001, follow-up letter to Moby Ducks, the Safety Board stated that the underlying premise of asking for "stay afloat" measures was to ensure the survivability of the passengers and crew by preventing them from being trapped in the event of flooding, as occurred with the *Miss Majestic*. The Safety Board stated that the intent of the recommendation could be achieved by the owner having his naval architect attest that either the LARCs operated in water so shallow that they would not sink if they were holed or they were designed in such a way to prevent occupants from being trapped in the event of flooding. The Safety Board stated that the design arrangement could be achieved by the LARCs not having a canopy and by their having a seating arrangement that did not hinder emergency egress. In addition, to ensure passenger safety, the company would have to require that all passengers wear lifejackets.

Based on information received, the Safety Board classified Safety Recommendation M-00-5 "Open—Acceptable Response" to five companies (Boston Ducks, Cape Cod Duck Mobile, Dells Duck Tours, Moby Duck Tours, and Ride the Ducks) and "Closed—No Longer Applicable" to two companies (Peter Pan Bus Tours and to White and Yellow Ducks) that are no longer in business.

The Safety Board classified Safety Recommendation M-00-5 "Open—Unacceptable Response" to Original Wisconsin Ducks, which indicated that filling the hull with foam or installing a watertight bulkhead was not possible.

The Safety Board received responses from five companies (Chicago Duck Corporation, D.C. Duck Tours, Just Ducky Tours, Metro Ducks, and Ride the Ducks-Seattle.[14]) The information provided, however, did not include how they planned to provide reserve buoyancy. Accordingly, the Safety Board classified Safety Recommendation M-00-5 "Open—Await Response" to the five companies.

On August 17, 2000, the Safety Board sent a follow-up letter to the recipients who had not responded asking what action they had taken or were planning to take to implement the recommendation. At the time of this report, responses from Lowcountry Duck Tours and Plymouth Amphibious Tours are being reviewed. The recommendation is classified "Open—Response Received" to these two companies. Information was also received during the course of the investigation from Cool Stuff. As of the date of this report, 14 companies have not provided information to the Safety Board.[15]

[14] Correspondence from Ride the Ducks-Seattle was received after the Safety Board mailed its August 17, 2000, follow-up letter.

[15] The 14 companies that have not provided information to the Safety Board are Aqua Traks, Inc; Austin Ducks; Buffalo Point; Chattanooga Ducks; Chicago Duck Tours; Ducks Amphibious Renovation/Sales; Land and Sea Tours; Maui Duck Tours; Naples Land and Sea Tours; National Park Duck Tours; Outfitter Kauai; Ozark Mountain Ducks; Sterling Equipment; and South Padre Water Sports/Breakaway.

Other Amphibious Passenger Vehicle Accidents

After the *Miss Majestic* accident, the Safety Board investigated two other amphibious passenger vehicle accidents, neither of which resulted in injuries to the passengers or crews. The complete marine accident brief reports are contained in appendix B.

The *Minnow*. On September 18, 2000, the *Minnow*, a 21-foot-long Stalwart-type amphibious sightseeing vehicle, with 2 crewmembers and 17 passengers on board, was proceeding through the Milwaukee, Wisconsin, harbor when the operator heard a "mechanical noise" and felt the vehicle "shudder." Shortly thereafter, the bilge alarm sounded. The operator turned back to shore; however, the vehicle's engine stopped, flooded and the operator had to radio for assistance. The marine police and Coast Guard personnel responded and safely transferred all of the *Minnow*'s passengers to their vessels. The *Minnow* then sank in 25 feet of water.

The investigators observed that the blade of the port waterjet impeller had cut through the waterjet tunnel housing the impeller, leaving a 1/8-inch-wide circumferential gap through which water from the port waterjet tunnel could enter the amphibious vehicle.

Investigators sent components of the vehicle to the Safety Board materials laboratory for examination. The Safety Board's laboratory determined that the port propulsion unit failed because its aft shaft bearing failed from inadequate lubrication. Severe corrosion on the shaft bearing retaining nut indicated that the integrity of the bearing and oil cavity had been compromised for a significant period before the accident, allowing water to enter the oil chamber, corrode the nut, and degrade the lubricating oil. The laboratory determined that severe degradation of the bearing had occurred for a long time before the accident voyage, during which the bearing finally broke up.

The DUKW No. 1. On December 8, 2001, *DUKW No. 1*, a 33-foot-long amphibious sightseeing vehicle, with an operator and 11 passengers on board, began flooding when it entered the water for a tour of Lake Union in Seattle, Washington. About 5 minutes into the tour, the bilge alarm sounded and the Higgins pump began discharging water, whereupon the operator immediately headed for shore. After the DUKW's wheels touched ground, a passing boat transferred all passengers ashore without injury. Later, the DUKW sank when the Harbor Patrol attempted to tow it across the lake. After the vessel was salvaged, investigators determined that a 4 ½-inch access plug was missing from its hull, which had allowed water to flood the hull. The Safety Board calculated the flooding rate through the opening at about 330 gpm, which exceeds the maximum capacity of a Higgins pump. *DUKW No. 1* had features recommended in NVIC 1-01, including a restrictor plate installed over the driveshaft hull penetration, double-clamped boot assemblies, bilge alarms, and an intact hinge pin assembly. In addition, the company's operator and maintenance personnel used a maintenance checklist as recommended in the NVIC.

Analysis

General

This analysis first identifies factors that can be readily eliminated as causal or contributory to the accident and determines why the *Miss Majestic* sank. The report then discusses the following major safety issues, which were identified during the investigation:

- Vehicle maintenance,
- Coast Guard inspections of the *Miss Majestic,*
- Coast Guard inspection guidance,
- Reserve buoyancy, and
- Survivability.

The analysis also considers the actions of the *Miss Majestic*'s operator in this accident.

Exclusions

The weather was clear and mild on the day of the accident. Toxicological testing of the operator was negative for alcohol and showed no evidence of illicit drug use. The 72-hour history provided by the operator revealed that she had maintained a fairly regular schedule and had obtained ample nighttime sleep. Moreover, her work schedule allowed her time to rest before her tours. The amount of sleep and rest that she received, together with the short length of the DUKW tours and the limited demands of her work, suggest that fatigue was not a factor in the operator's performance. Therefore, the Safety Board concludes that the weather, drug and alcohol use, and operator fatigue were not factors in the sinking of the *Miss Majestic*.

The maintenance mechanic's potential involvement in the accident was not identified until after the Safety Board investigators examined the *Miss Majestic.* Accordingly, no toxicological test was requested or available on this individual. According to his supervisor, he did not exhibit any behavior that might suggest he was impaired. Based on the maintenance mechanic's testimony, he had a comparatively light work and rest schedule and did not deviate from his normal routine before the accident occurred. However, because drug and alcohol testing of the maintenance mechanic was not conducted and because a complete 72-hour history of his activities and sleep could not be reconstructed, the effect of these factors on his performance cannot be determined.

The Sinking

When the vehicle was salvaged from the water and examined, Safety Board investigators found that the hull was wasted through in some areas, but the holes were not large enough to allow the massive flooding experienced by the *Miss Majestic*. The leakage through these holes would have been relatively light. Detailed examination of the vehicle's hull and plugs did not reveal a structural failure through which massive flooding could have occurred. However, the aft boot, which was supposed to maintain the watertight integrity of the driveshaft housing, had separated from the housing at one end. An annular opening existed between the 3-inch-diameter driveshaft and the 4 7/8-inch housing around it. With the boot off its housing, water could freely enter the vehicle's hull through this annular opening. When investigators fit the rubber boot back on the housing, they found that the clamp used to attach the boot to the housing was loose. Upon further examination, investigators found that the hose clamp setscrew needed an additional 2 ½ turns to tighten the clamp so that the boot would be securely attached to the housing.

On the morning of the accident, the maintenance mechanic replaced the aft boot because the original boot had a tear and was leaking water into the vehicle. After replacing the boot, he reattached the clamps. The senior mechanic testified that, although replacing boots was not a complex task, it was possible to install a clamp improperly because working in the cramped conditions underneath the DUKW was difficult. No one checked the maintenance mechanic's work, and no checks were conducted with the vehicle in the water after the repairs were completed. Thus, on the day of the accident, movements or vibrations of the *Miss Majestic* after it left the repair shop, such as the drive to the lake or the downward movement of the vehicle's rear axle and wheels as the DUKW entered the water from the ramp, could have caused the unsecured rubber boot to slip off its housing.

The Safety Board, therefore, concludes that water initially entered the *Miss Majestic* through the gap between the driveshaft and its housing because the securing clamp for the watertight rubber boot had not been adequately secured by the maintenance mechanic.

As the *Miss Majestic* entered Lake Hamilton, water began to enter the vehicle and progressed throughout its underdeck. The DUKW had no bulkheads to contain the water within an interior division or other means of restricting the amount of water flooding the vehicle. The *Miss Majestic* trimmed by the stern with a small aft freeboard of 8 to 12 inches; thus, the floodwater accumulated at the stern. The DUKW had no built-in flotation or other reserve buoyancy to counter the flooding. The Higgins pump, which was the primary dewatering pump, and one of the electric bilge pumps were inoperable. Although the other two electric pumps were operating, their combined pumping capacity was considerably less than the capacity of the Higgins pump. Thus, there was no active means of eliminating the water build-up nor bilge alarm or Higgins pump discharge to alert the operator to the vehicle's condition. The vehicle, therefore, sank deeper by the stern.

The Safety Board made calculations to simulate the time for the *Miss Majestic* to sink and estimated that the rate of water inflow through the annular opening between the

3-inch driveshaft and the 4 7/8-inch housing was at least 170 gpm. At this rate of ingress, the stern deck would have been awash within about 7 minutes. Once the stern slipped below the surface of the lake, water poured into the passenger compartment and swamped the vehicle, causing it to sink.

To verify the accuracy of its estimates, the Safety Board contracted with JMS, a recognized naval architectural firm, to perform detailed calculations. JMS confirmed that a vehicle such as the *Miss Majestic* carrying 20 passengers would sink from uncontrolled flooding in as little as 6.4 minutes after water started entering the vehicle. These estimates reasonably agree with the operator's estimate of about 7 minutes between the time the vehicle entered the lake and water began to swamp it. The Safety Board, therefore, concludes that the *Miss Majestic* sank because the DUKW had no watertight bulkheads and no reserve buoyancy and because its Higgins pump, which had been designed for significant dewatering capacity, did not operate.

Vehicle Maintenance

The number and nature of deficiencies found during the on-scene investigation and the laboratory examination prompted Safety Board investigators to take a close look at the maintenance and repair policies and procedures used by Land and Lakes.

The Safety Board's laboratory examination of the rubber boots from the *Miss Majestic*'s shaft housing revealed cracks that indicated the boots were old. The boots had been installed immediately before the accident. The Land and Lakes senior mechanic confirmed that, because obtaining new boots was difficult, the company normally used Army surplus stock, which showed signs of previous use.

Portions of the underwater hull, near the rear axle, were severely corroded in easily visible locations. A ½-inch by ¼-inch hole had wasted through the hull below the waterline near the vehicle's centerline about 2 feet forward of the point where the propeller shaft entered the hull. The area around the hole appeared weak when tested with a mallet[16] and was corroded. A pinhole was noted (daylight shining through) in the right rear wheel well. Of even greater concern was an approximately 14-inch-long silicone rubber repair patch that was used to seal a corroded area in the starboard hull. When investigators removed the patch, it exposed a severely corroded area of hull plating.

The use of silicone rubber patches on a steel hull is not an acceptable method of making permanent repairs to steel plating and would likely exacerbate corrosion and jeopardize hull integrity. Corrosion of a steel hull in fresh water is a long-term degradation process. The degree of wastage on the *Miss Majestic* indicated that these conditions had existed for a long time.

[16] Striking a steel hull with a hammer is a standard testing procedure used by Coast Guard inspectors to determine the integrity of the area.

Not only was the vehicle's hull in poor condition, but the vehicle's equipment was as well. A review of the undercarriage determined that an essential hinge pin assembly was missing. Without the hinge pin assembly, the housing's rubber boots would carry higher stresses than intended, making them more vulnerable to failure.

The Safety Board's examination of the bilge pumps on board the *Miss Majestic* showed multiple deficiencies. One of the Proline bilge pumps was practically inoperative, operating sporadically for only about 20 seconds before shutting off.

The Higgins dewatering pump had so many deficiencies that it was inoperative. The discharge hose was broken and rotted, the strainer had a large hole and was detached, rendering it useless, and one of the pump's impeller blades was badly damaged. Further, the driving sprocket was loose and had been installed backwards; the key attaching the sprocket to the shaft was missing. A setscrew had been used to attach the sprocket to the pump shaft. Without a key, however, the sprocket could rotate freely on the pump shaft. The pump's impeller was missing a bolt, which was never found, indicating that it probably had fallen out some time before this accident.

After observing the poor condition of the *Miss Majestic's* hull and equipment, the Safety Board endeavored to determine the depth of understanding that the company and its mechanics possessed concerning DUKWs. When investigators sought to review the maintenance records for the *Miss Majestic*, they discovered that the company did not routinely maintain such records. Investigators further discovered that the mechanics did not have the technical manuals and drawings needed to understand the safety purpose of special features of DUKWs, such as hinge pin assemblies, and to properly conduct maintenance and repair.

An effective preventative maintenance program should establish and implement, among other things, procedures and schedules for planned maintenance; daily, weekly, and annual inspections; postrepair testing and verification, retention of maintenance and repair records; tracking of maintenance and repair trends; and verification that maintenance and repairs were promptly and effectively conducted. However Land and Lakes did not have an effective preventive maintenance program and did not routinely keep maintenance records. According to the mechanics, the company only conducted repairs after breakdowns or when leaks developed.

After examining the condition of the *Miss Majestic* and reviewing the company's maintenance practices, the Safety Board is convinced that the threat to passenger safety had existed for a long time. The problems described above could only have manifested themselves after a long period of inadequate maintenance and repair. Had the rubber boot not failed, it was only a matter of time before one of the aforementioned problems probably would have manifested itself. Therefore, the Safety Board concludes that Land and Lakes long-term vehicle maintenance was inadequate and directly compromised the safety of the *Miss Majestic* and its passengers.

Since this accident, Land and Lakes has gone out of business. Thus, the remedial action on the part of the company is no longer possible.

Coast Guard Inspections of the *Miss Majestic*

After reviewing the Coast Guard inspection records for the *Miss Majestic*, examining the physical condition of the vehicle, and interviewing the inspector who last examined the vehicle, the Safety Board found deficiencies with the Coast Guard inspections.

The Coast Guard inspector who conducted the last examination of the *Miss Majestic*, which was on February 23, 1999, said that he inspected the bottom of the *Miss Majestic* by looking underneath the vehicle from its side. He did not get under the vehicle.

The Coast Guard inspector noted that the *Miss Majestic* did not have a high-level bilge alarm. He later testified that he advised Land and Lakes' senior mechanic of the regulatory requirement for existing T-boats to be equipped with high-level bilge alarms no later than March 11, 1999. The inspector said that because the senior mechanic assured him that the alarm would be installed by the March 11, 1999, deadline, he did not follow up to ensure the installation had taken place. After the *Miss Majestic* was salvaged, Safety Board investigators found that the alarm had not been installed. Had the *Miss Majestic* been equipped with a high-level bilge alarm, the operator might have had positive early warning that the vehicle was flooding. As it was, the operator remained unaware of the flooding until it was too late for her to do anything about it. Because she was not aware of the emergency until the very end, the operator could not inform passengers that an emergency had developed and that they should don lifejackets and prepare to abandon the vehicle.

Survivors stated that the lifejackets on board the *Miss Majestic* were packed so tightly into their stowage area beneath the canopy that the operator could not even pull one out for demonstration. The Coast Guard inspection record for the *Miss Majestic* does not indicate any problems related to the stowage of lifejackets. The Land and Lakes owner testified that, for each Coast Guard inspection, company personnel laid out the lifejackets on the garage floor for examination. This procedure might enable the inspector to examine each lifejacket for compliance, but it does not reveal problems with stowage. An effective inspection should include looking not only at the lifejackets, but also their stowage arrangements.

The Safety Board determined that the last inspector's lack of attention to detail was not unique to him. None of the inspectors had noted any deficiencies regarding the hull plating of the *Miss Majestic* since 1994. Safety Board investigators found pinholes in the hull resulting from severe corrosion and a repair using a rubber patch to conceal a large wasted area of the hull. Hull corrosion is a slow process, especially in fresh water where the *Miss Majestic* operated. The hull, therefore, probably had been corroding for several years. Although the corrosion was easy to see, none of the inspection records indicate that the Coast Guard inspectors had either noted any difficulties with or required any repairs to be made to the corroded areas. The identification of such obvious areas of corrosion, improper patching, and degradation of hull integrity is rudimentary to Coast Guard inspections of all steel vehicles and vessels. In the case of the *Miss Majestic* and other

DUKWs, the hull plating is so thin that it is susceptible to quicker holing through wastage and harder to repair.

The Safety Board found that none of the inspections during the last 6 years had been conducted in the water. Coast Guard regulations do not require that inspections be conducted in the water; however, examining the vehicle while it is in the water can identify safety problems, especially those related to the watertight integrity of the hull, that inspections on land do not necessarily reveal.

Coast Guard regulation 46 CFR 182.520 requires that small passenger vessels like the *Miss Majestic* carry one fixed bilge pump with a capacity of 10 gallons per minute and a portable hand pump with a capacity of 5 gallons per minute. The *Miss Majestic* also had a dewatering pump known as the Higgins pump, which was not required by regulation. According to the March 15, 1995, Coast Guard inspection records, the inspector identified deficiencies affecting its operation.

The operation of the bilge pumps had not been tested with water. The Coast Guard policy required "operational checks" for bilge pumps. At the Safety Board's forum in December 1999, a representative from the Coast Guard's Inspection Division said that he interpreted this to mean that bilge pumps need not be tested with water. The inspector who last examined the *Miss Majestic* said that he believed that testing of pumps implied visually checking the pump and turning the operating switch on and off. Although the pumps passed inspections, the Safety Board's on-scene and laboratory analysis found that one of the Proline pumps was practically inoperative and the Higgins pump and its discharge piping showed evidence of longstanding poor maintenance.

The Safety Board concludes that the Coast Guard's inspections of the vehicle were inadequate and cursory.

Coast Guard Inspection Guidance

A number of different Coast Guard inspectors conducted inadequate inspections of the *Miss Majestic* over several years. While these inspectors should have been able to identify corrosion of the hull and problems with bilge pumps and lifejacket stowage, some safety deficiencies relate to the unique features of the vehicle that require specialized guidance for inspectors to understand and detect the problems.

Although Coast Guard regulations place DUKWs in the same category as conventional small passenger vessels, DUKWs are uniquely designed and pose safety concerns that are different from those of conventional vessels. The Safety Board finds it significant that the Coast Guard's report of the *Miss Majestic* sinking concluded, and the Coast Guard Commandant concurred with, the following:

> DUKWs have features which [sic] make them inherently less safe than conventional commercial passenger vessels.

In support of this conclusion, the Coast Guard report cited the following features, among other items:

- Heavy metal chassis and heavy wheel drive systems, with minimal buoyancy;
- Multiple external appendages with moving parts that are part of the watertight envelope;
- Use of a single band clamp on the smooth sealing surface of shaft housings;
- Thin hull plating, susceptible to quicker holing through wastage and harder to repair; and
- Manufactured parts not readily available, largely due to the 54-years lapse in DUKW production.

The Safety Board agrees with the Coast Guard that these features make DUKWs inherently less safe than conventional commercial small passenger vessels, not only for the reasons cited in the Coast Guard report. In addition, DUKWs have hull penetrations for driveshafts that are made watertight by rubber boots and clamps, which are unconventional sealing methods by standards for traditional small passenger vessels. These boots require special attention for safety oversight. Similarly, the DUKW relies on a high capacity Higgins pump in the event the vehicle is flooded, which in turn requires that the pump be carefully maintained and inspected. However, neither the Subchapter T regulations nor other Coast Guard guidance documents for Coast Guard field inspectors mention how to inspect these vital items.

Before the *Miss Majestic* accident, the Coast Guard had not developed any nationwide guidance to field inspectors for inspecting DUKWs; the *Marine Safety Manual* only addressed radiator cooling of DUKW engines. Although a few Coast Guard MSOs had independently developed local policies for their inspectors, these policies did not address or emphasize several critical areas, such as inspecting the integrity of seals, clamps, or the need for operational testing of dewatering and bilge pumps. The local policies addressed different inspection issues that had arisen in each MSO. These policies were not disseminated to other MSOs.

DUKWs are old vehicles that have been certificated for service by various local Coast Guard officials over the years through waivers and equivalencies to Subchapter T regulations. The waivers and rulings of equivalencies were not granted based on uniform national criteria for DUKWs, but on various opinions and experiences of individual local officials. The supporting rationale for the waivers and equivalencies were not documented at MSO Memphis, the Coast Guard office with jurisdiction over the *Miss Majestic,* and were not available to individual inspectors. Consequently, inspectors assumed that any discrepancies from Subchapter T regulations, for example seat spacing and aisle widths, had been previously accepted and they did not need to revisit those issues. An inspection guidance document, coordinated and disseminated by Coast Guard Headquarters, would have made plan review for DUKWs consistent among MSOs and would have clarified the scope of work to field inspectors.

Coast Guard inspection guidance for DUKWs would have been especially useful to the inspector who last examined the *Miss Majestic* because his experience with inspecting DUKWs was limited. He had received no special training in inspecting these vehicles. He had only inspected two DUKWs about 5 years earlier during his previous tour at MSO New Orleans. He told Safety Board investigators that he was unaware of any Coast Guard inspection policies or procedures for DUKWs. He stated that he had only talked to other inspectors to come up to speed on DUKWs. Neither the OCMI nor the supervisor of inspectors at MSO Memphis had ever inspected a DUKW or were aware of any Coast Guard inspection procedures for DUKWs.

The Safety Board concludes that the lack of Coast Guard guidance and training for the inspection of DUKWs contributed to the inadequate inspections of the *Miss Majestic*.

While investigating the *Minnow* accident, the Safety Board found that, as in the case with the principals in the *Miss Majestic* accident, the operators, refurbishers, and inspectors had an inadequate understanding of the risks posed by amphibious passenger vehicles. Following the *Miss Majestic* accident, the Coast Guard issued NVIC 1-01, which is titled *Inspection of Amphibious Passenger Carrying Vehicles*, to provide its inspectors and industry with necessary background information and guidance about DUKWs. In reviewing the NVIC, the Safety Board found that it does not address the inspection issues of other types of amphibious passenger vehicles such as Stalwarts. Thus, guidance and background information relating to maintenance, inspection, and operation of Stalwarts is not readily available for use by owners, operators, refurbishers, and inspectors. The Safety Board concludes that industry and Coast Guard inspectors need to become familiar with the unique safety issues and general background for all types of amphibious vehicles, including Stalwarts, to improve the maintenance, inspection, and operation of specialized amphibious vehicles. The Safety Board, therefore, believes that the Coast Guard should develop and promulgate guidance for all amphibious passenger vehicles similar in purpose to the NVIC 1-01.

Reserve Buoyancy

After its on-scene investigation of the *Miss Majestic* accident, the Safety Board researched the available accident history of amphibious passenger vehicles. Coast Guard data show that between March 6, 1991, and May 1, 1999, at least 18 amphibious passenger vehicles had been involved in accidents, and that six of the accidents had resulted in some degree of flooding. As a result, the Safety Board decided to hold a public forum in December 1999 on amphibious passenger vehicle safety to bring together the Coast Guard, the amphibious passenger vehicle industry, and technical experts to discuss amphibious passenger vehicle safety.

As the Safety Board opened its forum, the Coast Guard issued its final report on the sinking of the *Miss Majestic,* which concludes, in part:

> Had the *Miss Majestic* been fitted with watertight compartmentation or flotation materials, the vehicle would not have sunk or would have sunk so slowly that passengers would have had ample time to escape the vehicle.

During the Safety Board forum, participants considered the following issues:

- Conversion of amphibious vehicles from military to civilian use,
- Passenger egress and survival,
- Lifesaving equipment,
- Vehicle design and stability,
- Maintenance and inspection policies and certification,
- Operational safety, and
- Amphibious vehicle operator qualifications.

The forum produced important insights into the operation of such vehicles, safety issues unique to them, passenger accommodations design, and industry practices. One major outcome of the forum was the realization by participants that amphibious vehicles pose unique and unresolved safety risks to the public, but that the vehicles could be made safe by installing safety features that would prevent them from sinking when flooded. JMS, the naval architect contracted by the Safety Board, evaluated whether retrofitting DUKWs with foam and bulkheads would provide adequate reserve buoyancy to keep a DUKW afloat when it was flooded and fully loaded with passengers. JMS found such retrofitting to be feasible.

On February 18, 2000, the Safety Board issued an advance safety recommendation (M-00-5) calling for amphibious passenger vehicles to be altered to provide reserve buoyancy through passive means so that they would remain afloat and upright in the event of flooding, even when carrying a full complement of passengers and crew.

In support of this recommendation, the Safety Board stated that a passive safety system is more reliable than active systems because it requires no deliberate action or operation to deploy and generally facilitates fail-safe performance of the vehicle. For example, a DUKW is equipped with a Higgins pump that is powered by the DUKW's propeller shaft. Reliable operation of the pump cannot be assured because so many factors affect its proper performance, including, but not limited to, the operating condition of the pump, the operating condition of the main engine, and the vehicle operator's continuous depression of the gas pedal, which keeps the propeller shaft turning and the pump operating. Any shortcomings in maintenance of either the pump or the main engine, failure to identify a problem, use of poor repair techniques, or other causes can render the active system useless in an emergency. In addition, realistically, operators cannot be

expected to remain seated and depressing the gas pedal during an emergency, when they probably would have to move to instruct or assist passengers.

In contrast, a passive safety system requires no deliberate action or operation to deploy and generally facilitates fail-safe performance of the vehicle. Some examples of passive safety systems that can prevent a vehicle from sinking include compartmentalization with watertight bulkheads, installation of buoyant material inside the hull, and incorporation of buoyant sponsons exterior to the hull. Only the inherent reliability and fail-safe nature of a passive safety system can ensure the level of dependability essential to safeguarding the lives of passengers.

The Safety Board was pleased that the Coast Guard, in its final report on the sinking of the *Miss Majestic,* agreed with the Safety Board's position on the need for adequate reserve buoyancy. With summer coming and the likelihood of a large number of passengers being put at risk, the Safety Board issued Safety Recommendation M-00-5 asking that amphibious passenger vehicle operators and refurbishers take voluntary action to ensure that their vehicles remain afloat and upright in the event of flooding by altering them to provide reserve buoyancy through passive means such as built-in flotation, watertight compartmentalization, or equivalent measures.

In the interim, the Coast Guard initiated action to address some of the safety deficiencies identified at the Safety Board's amphibious passenger vehicle forum and in the Coast Guard's own investigation of the *Miss Majestic* accident. The Coast Guard met for 2 days in February 2000 with representatives of the amphibious passenger vehicle industry to develop comprehensive guidelines containing best practices on the inspection and operation of these vehicles. In December 2000, when the Coast Guard issued NVIC No. 1-01, agency officials stated that the NVIC was developed using the information gleaned from this meeting.

The NVIC contains 40 pages of information and guidance on such items as unique design features, inspection and certification, construction and arrangement, intact stability and seaworthiness, watertight integrity, lifesaving equipment and arrangements, and fire protection equipment. The NVIC contains a short history segment, numerous pictures, diagrams, and charts. The circular also provides inspectors with a list of 19 modifications that might have been made to a DUKW when it was converted to passenger service. Further, the NVIC offers sample calculations for flooding, as well as expected scantlings. In the Safety Board's opinion, the document is very well done as far as it goes; however, it does not adequately address passenger egress and survivability. For further discussion, see the analysis section entitled "Survivability."

The response to Safety Recommendation M-00-5 by the amphibious passenger vehicle industry has been disappointing. The Safety Board sent the recommendation to 30 different amphibious passenger vehicle companies and received responses or information from only 16. Most of the responses expressed the opinion that installing watertight bulkheads and flotation foam would be difficult and would require detailed engineering. Some of the responses detailed other actions that companies were taking such as installing flow restrictor plates, additional bilge pumps, and high water bilge alarms. Only three

companies indicated that they had done or were doing anything to provide reserve buoyancy to their vehicles as requested in the safety recommendation.

Cool Stuff advised the Safety Board that it had built a new type of amphibious vehicle called the Hydra-Terra, which is designed especially for commercial passenger service. The vehicle's aluminum hull has foam-filled compartments that provide sufficient flotation certified by the manufacturer to remain afloat even with the drain plugs removed and the engine compartment flooded. The Coast Guard has approved the Hydra-Terra for the carriage of up to 49 passengers and a 2-person crew. Several amphibious vehicle operators in Alaska, California, and Maine have purchased these vehicles and have placed them in commercial passenger operation. The Safety Board is please that the Hydra-Terra shows that it is practical and feasible to design an amphibious passenger vehicle to meet the Safety Board's reserve buoyancy criterion. Accordingly, Safety Recommendation M-00-5 is classified "Closed—Acceptable Action" for Cool Stuff.

Ride the Ducks, a Missouri company, stated that it was building a prototype aluminum DUKW that incorporates foam buoyancy into the design. Once completed, this prototype is expected to meet the reserve buoyancy criterion specified in recommendation M-00-5, but it will not affect the other amphibious passenger vehicles in service nationwide that do not meet the criterion.

Boston Ducks, a Massachusetts company, stated that it had retrofitted a single watertight bulkhead on one of its DUKWs on a trial basis; however, the company has not had a naval architect evaluate the effectiveness of the bulkhead.

Thus, with the exception of the Hydra-Terra, the Safety Board is not aware of any other production model amphibious passenger vehicles that currently meet the intent of Safety Recommendation M-00-5 or any effective retrofit to improve the reserve buoyancy of existing DUKWs.

The Safety Board notes that 14 companies have never responded to the Board's February 18, 2000, initial letter or the August 17, 2000, follow-up letter. Based on the lack of information provided, the Safety Board classifies Safety Recommendation M-00-5 "Open—Unacceptable Response" to the following: Aqua Traks, Inc.; Austin Ducks; Buffalo Point; Chattanooga Ducks; Chicago Duck Tours; Ducks Amphibious Renovation/Sales; Land and Sea Tours; Maui Duck Tours; Naples Land and Sea Tours; National Park Duck Tours; Outfitter Kauai; Ozark Mountain Ducks; Sterling Equipment; and South Padre Water Sports/Breakaway.

In its correspondence with the safety recommendation recipients, the Board stressed that Safety Recommendation M-00-5 did not limit companies to using foam or watertight bulkheads as the only means for achieving passive flotation; the recommendation stated that other "equivalent measures" would be acceptable. Equivalent measures would include, but not be limited to, adding buoyancy chambers, known as sponsons, to the hull or installing inflatable buoyant bladders. Such inflatable bladders are used on skids of helicopters that operate over water.

Because NVIC 1-01 is only an advisory document, it is not certain whether all amphibious passenger vehicle operators have incorporated the circular's advice into their vehicles or vehicle operations. Furthermore, the OCMIs and inspectors need additional training to interpret the NVIC, and because OCMIs rotate, the continuity in its application is not assured.

Safety Recommendation M-00-5 was under consideration by the industry when the Safety Board learned of another amphibious passenger vehicle accident. On September 18, 2000, the *Minnow,* a 21-foot Stalwart-type amphibious sightseeing vehicle, with 2 crewmembers and 17 passengers on board, was proceeding through the Milwaukee, Wisconsin, harbor, when the bilge alarm sounded. The vehicle operator turned back to shore; however, the vehicle's engine stopped when water entered the engine compartment. Fortunately, the accident occurred within sight of Coast Guard personnel and the Marine Police, who both dispatched boats to the scene and transferred all *Minnow* passengers to their vessels. All passengers were taken ashore; no injuries resulted from this accident. About 30 minutes after the flooding started, the *Minnow* sank in 25 feet of water. Postaccident examination showed that the bearings for the port waterjet impeller had failed, causing the impeller blades to cut a 1/8-inch gap in the waterjet tunnel housing through which water entered the vehicle. This was another means of water ingress that had not been previously identified, and it prompted the Safety Board to include information on this accident when writing to recommendation recipients.

NVIC 1-01 had been in effect for a year when, on December 8, 2001, *DUKW No. 1*, with an operator and 11 passengers on board, began flooding during a tour of Lake Union in Seattle. When the bilge alarm sounded repeatedly and the vehicle's Higgins pump began discharging water, the operator headed for shore. After the DUKW's wheels touched ground, a passing boat transferred all passengers ashore without injury. The local harbor patrol, not knowing that the problem was the result of a missing 4 ½ inch-diameter access plug, attempted to tow the *DUKW No. 1* back across the lake. The harbor patrol asked the operator to turn off the engine and to leave the DUKW. Because the engine was not operating and, in turn, the Higgins pump was not operating to dewater the vehicle, the DUKW sank when water continued to flood the hull through the access plug opening. The Safety Board calculated that the flooding rate through the opening was about 330 gpm (a greater rate than a failed rubber boot), which exceeds the maximum dewatering capacity of a Higgins pump. Therefore, the vessel might have sunk even if the Higgins pump had been operating.

The Safety Board investigated the sinking of the *DUKW No. 1* and determined that the vehicle owner had made improvements suggested in the Coast Guard's NVIC, including installing a restrictor plate over the driveshaft hull penetration, double-clamped boot assemblies, bilge alarms, and hinge pin assembly. The vehicle also had a structurally sound hull and a working Higgins pump. Despite these attributes, the *DUKW No. 1* sank because of a simple human error that occurred during routine maintenance. For a DUKW hull to have watertight integrity, perfect maintenance and operation is essential. In the case of the *DUKW No. 1*, company procedures required that, before a tour is conducted, both the mechanic and the operator sign the daily maintenance checklist attesting that they have

checked 55 items, including engine fluid levels, tires, brakes, driveshaft rubber boots and clamps, and hull plugs. On the day of the accident, however, because the operator was in a hurry to pick up waiting passengers, he did not take the time to examine all the items listed on the safety checksheet; however, he told Safety Board investigators that he thought the maintenance access plug had been in place. A review of the daily maintenance checklist for *DUKW No. 1* shows not only that all items were checked, but also that both the operator and the mechanic had attested that the items had been checked. Therefore, a checksheet is no guarantee that necessary maintenance will be performed.

If the *DUKW No. 1* had been provided with sufficient reserve buoyancy through passive means, the vehicle would not have sunk regardless of whether the plug had been replaced. Consequently, the Safety Board concludes that flooding from failed boots, open hull plugs, hull damage, collisions, groundings, mechanical failures, improperly preformed maintenance, and other scenarios continue to present serious risks of rapid flooding and sinking in amphibious vehicles lacking reserve buoyancy.

While three amphibious vehicle owners have attempted to comply with the intent of Safety Recommendation M-00-5, most amphibious passenger vehicle operators have either not responded to the Safety Board's requested action or have taken other measures, such as installing flow restrictor plates and carrier bearings, additional bilge pumps, and high-water bilge alarm systems. The Safety Board does not consider the installation of such devices to be equivalent to the safety measures stated in Safety Recommendation M-00-5 and remains concerned about the safety of amphibious passenger vehicle operations nationwide. While restrictor plates reduce the rate of water ingress and the carrier bearings close the hull penetration at the shaft seal, these devices do not increase the vehicle's reserve buoyancy. Further, while additional bilge pumps increase pumping capacity and alarms provide warning of flooding, they are subject to malfunction and do not provide the same level of safety as built-in sufficient reserve buoyancy.

Despite the negative response from amphibious passenger vehicle owners concerning the practicality of providing reserve buoyancy to DUKWs, they have not disputed the concept. Owner comments have focused on the detailed engineering required. Owners and manufacturers, however, have used and can use various methods to increase the survivability of amphibious vehicles in the event of flooding. In addition to the installation of transverse watertight bulkheads and the addition of built-in flotation materials to the hull, owners could take equivalent measures. It is clear, however, from the responses received from the industry, that with the exception of a few owners, voluntary action will not be taken by the rest of the industry to address the need for adequate reserve buoyancy on amphibious passenger vehicles.

As a result, an unacceptable level of risk to passenger safety continues to exist on these vehicles. Because the industry has, by and large, refused to take voluntary action to address this risk, the Safety Board considers it imperative that the Coast Guard takes steps to ensure that all amphibious passenger vehicles will not sink in the event of an uncontrolled flooding event. The Safety Board believes that the Coast Guard should require amphibious passenger vehicle operators to provide reserve buoyancy through passive means, such as watertight compartmentalization, built-in flotation, or equivalent

measures, so that the vehicles will remain afloat and upright in the event of flooding, even when carrying a full complement of passengers and crew.

The Safety Board is aware that Wisconsin and New York have commercial amphibious vehicle operations that are not subject to Coast Guard jurisdiction and whose vehicles carry thousands of passengers annually. The amphibious vehicles under State jurisdiction in Wisconsin and New York pose the same risks as the amphibious vehicles under Coast Guard authority. The Safety Board, therefore, believes that the States of Wisconsin and New York should require the amphibious passenger vehicle operators under their jurisdiction to provide their vehicles with reserve buoyancy through passive means, such as watertight compartmentalization, built-in flotation, or equivalent measures, so that the vehicles will remain afloat and upright in the event of flooding, even when carrying a full complement of passengers and crew.

Survivability

The *Miss Majestic* was certificated by the Coast Guard under a set of regulations that required the Coast Guard to review the design and construction features of the vehicle before it was placed into passenger service. The *Miss Majestic*, like similar amphibious vehicles, was originally designed for landing military cargoes during wartime and not for commercial passenger service. When the seats were retrofitted, the seating arrangement did not comply with the regulations under which the vehicle was certificated. The width of the aisle was 60 percent less than required (12 inches versus 30 inches) and space between seats was about 12 percent less than required (26 inches versus 30 inches). Coast Guard officials stated that they must have granted the *Miss Majestic* a waiver for the dimensions of these spaces, although the agency had no documentation on the waiver. Further, agency officials could provide no rationale for how the dimensions were determined.

Although the survivors did not state that the reduced aisle width or space between seats hindered their escape, the reduced spacing would have made seating cramped and restricted their movement. In the circumstances of this accident, the impact of these features on the egress of the passengers who did not survive cannot be definitively determined.

Following the *Miss Majestic* accident, the Coast Guard issued NVIC 1-01, which provided new dimensions for fixed seating arrangements on DUKWs. Regarding aisle width and seat separation, NVIC 1-01 states:

> Because of the limiting design and construction of DUKWs and relatively short in-water operations on protected waters, these vehicles should be granted special consideration from the aisle width and fixed seating criteria. Aisle widths may be allowed to be reduced to no less than 14 inches and the fixed seating criteria to no less than 17 inches per passenger. In addition, the distance from seat back to seat back may be reduced from 30 inches to 28 inches.

While the proposed "special consideration" cited above for minimum aisle width and fixed seating criteria for DUKWs exceeds those found on the *Miss Majestic*, the Safety Board questions whether "limiting design and construction" and "relatively short in-water operations" justify a departure from regulatory requirements. There is no basis provided for the waiver to show that the minimum criteria will not impede emergency egress. Be that as it may, the Safety Board considers that the major consideration in assessing the ability of passengers to escape from a sinking DUKW is the overhead canopy. All but one of the survivors stated that the canopy was an impediment to their escape. One man said,

> …if you had the cover [canopy] off, everybody would have had a chance. With that cover on, there's too many people didn't have a chance because that thing [the *Miss Majestic*] sank so quick [sic].

In the case of the *Miss Majestic* accident, the force of the water rushing in over the stern was strong enough to sweep a 6-foot 6-inch, 260-pound man standing near the sixth row forward and pin him against the windshield. As the *Miss Majestic* sank, the metal framework on both sides of the passengers and the continuous canopy over their heads essentially caged them, making escape in the limited available time extremely difficult.

As the vehicle sank to the bottom of the lake, the natural buoyancy of the passengers' bodies forced them into the overhead canopy, which acted like a net to entrap them and to prevent their vertical escape. Of the seven fatalities found inside the vehicle, four were found trapped in the canopy. At least two survivors testified that they had to swim downward in order to escape from the canopy. Most of the survivors could not explain how they were able to get out of the vehicle.

Six victims were recovered from the lake bottom at various distances from the vehicle. These six people might have been able to escape the vehicle but drowned before they could reach the lake's surface. If the vehicle had not had a canopy, the passengers would not have had a barrier to vertical escape. They would not have been trapped inside the vehicle, and fewer passengers might have been killed. The Safety Board therefore concludes that the canopy on the *Miss Majestic* was a major impediment to the survival of the passengers.

The canopy on the *Miss Majestic* is a common feature in amphibious passenger vehicles. The Safety Board notes that, while the Coast Guard's NVIC 1-01 recognizes canopies as an impediment to passenger egress, it does not address the safety implications of canopies over the passenger seating areas or their negative impact on passenger survival in the event of sinking. Regarding canopies, the NVIC states:

> Canopies and canopy supports can impede the egress of passengers. Again, the primary egress on these vehicles is over the side. Canopy supports should be positioned to allow the majority of passengers unobstructed egress. If a canopy support is located directly adjacent to a passenger's seat it should be shown, through a practical test, that the passenger can adequately egress the vehicle. The window framing vertical distance should be sufficient for a passenger to exit while wearing a lifejacket. A vertical distance of 32 inches from gunwale to

> canopy appears sufficient for most installations. Overhead storage of lifejackets should not impede the egress of passengers.

Once again, however, the Coast Guard provides no basis to show that the minimum dimensions will not impede emergency egress. The Safety Board issued Safety Recommendation M-00-5 not only because of concern for the vulnerability of amphibious vehicles to rapid sinking but also in recognition of the extreme difficulty that passengers would have trying to escape such vehicles, as demonstrated by the *Miss Majestic's* sinking. Following this accident, almost all survivors stated that the canopy on the *Miss Majestic* was an impediment to escape.

In the Safety Board's opinion, canopies present major safety risks that need to be addressed, especially in light of the fact that amphibious passenger vehicles in service in this country carry more than 1 million passengers each year, including a great many children. This unique vehicle is often promoted to and used by school groups. Typically, such groups of children are accompanied by a limited number of adults. Each of the four children under age 15 on the *Miss Majestic* was accompanied by at least one adult. Of these children, three did not survive and the fourth survived by mere happenstance. Children are particularly vulnerable when traveling as passengers on amphibious passenger vehicles and, even if an adult accompanies them, their survival can be jeopardized. If children are permitted to board a DUKW without donning lifejackets, adults will probably have insufficient time to help the children don lifejackets in the event of an emergency. If the children don the lifejackets upon boarding and the canopy is retained, the adults traveling with the children likely will not have time to help the children egress the vehicle before it sinks. If the adults are not successful in placing the children or themselves outside the vehicle before it sinks, all could likely become trapped in the overhead canopy. The Safety Board is particularly concerned that both adults and children wearing lifejackets are at risk of being drowned if entrapped by the overhead canopy.

A more realistic approach to ensure passenger safety would be to afford passengers a reasonable opportunity to escape by removing the canopy. The Safety Board therefore concludes that, on amphibious passenger vehicles that cannot remain afloat when flooded, canopies can represent an unacceptable risk to passenger safety.

In looking at the operation of DUKWs, the Safety Board recognizes that the removal of the canopy, by itself, is not adequate to ensure survivability of passengers in the event of sinking. Even though passengers would not be trapped inside the vessel when it sank because the canopy was removed, they could still drown after they entered the water. As shown by the *Miss Majestic* accident, DUKWs without adequate reserve buoyancy will sink rapidly once water begins to flood into the hull, leaving little or no time for passengers to retrieve and don lifejackets or to assist children in donning lifejackets. Consequently the Safety Board concludes that wearing lifejackets before the vehicle enters the water would enhance the safety of passengers on board DUKWs without adequate reserve buoyancy where canopies have been removed. Therefore the Safety Board believes that, where canopies have been removed on amphibious passenger

vehicles for which there is not adequate reserve buoyancy, the Coast Guard should require that all passengers don lifejackets before beginning waterborne operations.

Some of the owners of existing amphibious passenger vehicles have stated that the installation of adequate reserve buoyancy through passive means to existing vehicles is not practical. In the Safety Board's opinion, if providing existing amphibious passenger vehicles with sufficient reserve buoyancy through passive means to remain afloat and upright in the event of flooding is not practical, then alternative action that prevents passengers from being trapped inside the vehicle in the event of sinking should be taken. Such action should include removing the roof canopy before water operations so that passengers will float clear of the vehicle in the event of sinking and requiring passengers to don lifejackets. In addition, owners should be required to reduce through-hull penetrations. For example, some access holes used to perform maintenance inside the hull could be sealed. Following the *DUKW No. 1* accident, the owner of the vehicle decided to seal the larger access plugs[17] in all his DUKWs to reduce the likelihood of flooding. The change required some reengineering. Instead of using the forwardmost access plug to access the engine oil sump and filter, the plug was sealed and a portable pump is used to drain the sump. The oil filter has been relocated to be accessible through the vehicle's hood. Other amphibious passenger vehicle owners should be able to modify their vehicles to eliminate the risk to passenger safety.

As shown earlier in this report, Higgins pumps require maintenance and are subject to multiple failure modes. If a Higgins pump malfunctions and the DUKW vehicle lacks sufficient reserve buoyancy to remain afloat, it can rapidly sink, risking serious injury or death to passengers, as shown by the *Miss Majestic* accident. Further, the operation of the pump is contingent upon the operation of the engine. The sinking of the *DUKW No. 1* in Seattle clearly demonstrates what can happen to a vehicle without sufficient reserve buoyancy if it experiences flooding and if it relies on the Higgins pump for dewatering. The Coast Guard NVIC 1-01 recognizes the need for an independent backup for the Higgins pump sufficient to provide enough dewatering capacity to offset flooding through the largest penetration of the vehicle's hull. In the Safety Board's opinion, dewatering capacity is essential to at least partially compensate for the lack of installed reserve buoyancy. While such capacity is not the equivalent to built-in reserve buoyancy sufficient to keep the vehicle afloat in the event of unrestricted flooding, dewatering at least provides some measure of additional protection that may help to keep the vehicle afloat longer, giving passengers more time to escape before the vehicle sinks.

The Coast Guard NVIC 1-01 acknowledges the critical role dewatering pumps play in the safety of DUKWs. The circular states:

> The methodology to be used in calculating the bilge pump capacity should be similar to that of the original military methodology. Provide bilge pumps for normal operations and for emergency operations, which can offset uncontrolled flooding of the largest penetration in the hull until the vehicle can be safely beached…Hence an originally equipped DUKW should have a bilge pumps or

[17] The small (¾-inch-diameter) plugs used to drain the hull after the vehicle leaves the water were not sealed.

pumps with a combined capacity of over 220 gpm to control flooding or it could sink in approximately 8 minutes if left unchecked.

While the Coast Guard NVIC 1-01 recommends the installation of such additional pumps, the document is advisory in nature and not mandatory. Thus, compliance by DUKW operators is more or less voluntary. In the Safety Board's opinion, until such time as reserve buoyancy requirements come into effect for DUKW passenger vehicles, a provision for dewatering capacity should be made mandatory.

As discussed above, the means exist to eliminate or reduce hull penetrations by welding access plugs closed, installing restrictor plates or carrier bearings, and using double clamped boots. An in-water inspection on each occasion that a through hull penetration has been removed or uncovered would assure the maintenance of watertight conditions before the amphibious vehicle was returned to service. Verifying the vehicle's watertight condition before each waterborne departure would further reduce risks to passengers in amphibious passenger vehicles.

Consequently, the Safety Board believes that, until such time as an amphibious vehicle owner establishes sufficient reserve buoyancy to remain upright and afloat in a fully flooded condition, the Coast Guard and the States of New York and Wisconsin should require the following (1) removal of canopies for waterborne operations or installation of a Coast Guard-approved canopy that does not restrict either horizontal or vertical escape by passengers in the event of sinking, (2) reengineering of each amphibious vehicle to permanently close all unnecessary access plugs and to reduce all necessary through-hull penetrations to the minimum size necessary for operation, (3) installation of independently powered electric bilge pumps that are capable of dewatering the craft at the volume of the largest remaining penetration to supplement either an operable Higgins pump or a dewatering pump of equivalent or greater capacity, (4) installation of four independently powered bilge alarms, (5) inspection of the vehicle in water after each time a through-hull penetration has been removed or uncovered, (6) verification of a vehicle's watertight condition in the water at the outset of each waterborne departure, and (7) compliance with all remaining provisions of NVIC 1-01.

Actions of the Operator

In addition to evaluating the design and maintenance of the vehicle, the Safety Board also evaluated the operator's performance to determine the impact, if any, of her actions upon the outcome of this accident.

The *Miss Majestic* operator was required by Coast Guard regulations to provide passengers with a safety briefing before the waterborne portion of the tour. The briefing that she gave did not cover some safety issues. For example, she did not demonstrate how to don lifejackets and did not mention procedures for abandoning the vehicle. Land and Lakes did not have any formal policies or procedures for its vehicle operators to follow in providing safety briefings to passengers. The Safety Board clearly recognizes the

importance of safety briefings and has made several recommendations for requiring such briefings as a result of past accident investigations.

Under the circumstances of this accident, however, the operator and passengers had insufficient time between their first recognition of danger and the vehicle's sinking to take any emergency actions. From the time that they recognized a problem until the time that the *Miss Majestic* completely sank was a matter of seconds. Although survivors indicated that a passenger had distributed lifejackets when he first saw the flooding, the vehicle sank so rapidly that no one was able to don a lifejacket before the vehicle completely submerged. The adult passengers did not have time to put lifejackets on the children. The father of one surviving child said that his wife had tried to put a lifejacket on their daughter, with no success. He said that he was convinced that if his wife had been successful, the daughter would have perished. As it was, the child grabbed hold of another passenger who was able to escape the vehicle.

While the safety briefing provided by the operator of the *Miss Majestic* was not comprehensive, the lack of instructions to the passengers regarding emergency egress most likely did not affect the survival of the passengers in this accident.

After her safety briefing, the operator turned on the electric bilge pumps and entered the lake to begin the waterborne portion of the tour. She provided a continuous commentary as part of her routine duties. In order to do this, she turned to her right, in the direction of the passengers, as she proceeded along the lake. While her attention was focused on steering the vehicle and narrating the tour, she did not notice that the forward electric bilge pump, which was to her left, was discharging water over the side. As the tour progressed, the vehicle began to list and to maneuver sluggishly, which was the operator's first indication of anything out of the ordinary. Moments later, as she was instructing a passenger to move from the port to the starboard side, water began to flood over the stern and the vehicle sank. Thus, between the time that the operator first recognized a problem and the time that the vehicle sank was only a matter of seconds. In the Safety Board's opinion, the time factor precluded the operator from taking any action that might have been effective in altering the outcome of the accident.

Earlier warning that the vehicle was flooding would have provided the operator with the opportunity to head for shore and to at least alert the passengers to the emergency. Two days before this accident, the actions of the operator demonstrated that she recognized the safety implications of water being discharged by the Higgins pump and an electric bilge pump. Upon seeing the water streams, she immediately cut short the water tour and exited to the safety of land. On May 1, however, she did not receive any such warning because the Higgins pump was inoperative and the required high-level bilge alarms had not been installed.

The Safety Board concludes that given the circumstances of this accident, the operator could not have taken any meaningful action to avert or mitigate its fatal outcome.

Conclusions

Findings

1. Water initially entered the *Miss Majestic* through the gap between the driveshaft and its housing because the securing clamp for the watertight rubber boot had not been adequately secured by the maintenance mechanic.

2. The *Miss Majestic* sank because the DUKW had no watertight bulkheads and no reserve buoyancy and because its Higgins pump, which had been designed for significant dewatering capacity, did not operate.

3. The canopy on the *Miss Majestic* was a major impediment to the survival of the passengers.

4. Land and Lakes Tours, Inc.'s long-term vessel maintenance was inadequate and directly compromised the safety of the *Miss Majestic* and its passengers.

5. The Coast Guard's inspection program for the *Miss Majestic* was inadequate and cursory.

6. The lack of Coast Guard guidance and training for the inspection of DUKWs contributed to the inadequate inspections of the *Miss Majestic*.

7. Industry and Coast Guard inspectors need to become familiar with the general background and unique safety issues of all types of amphibious vehicles to improve the maintenance, inspection, and operation of specialized amphibious vehicles.

8. Flooding from failed boots, open hull plugs, hull damage, collisions, groundings, mechanical failures, improperly performed maintenance, and other scenarios continue to present serious risks of rapid flooding and sinking in amphibious vehicles lacking reserve buoyancy.

9. On amphibious passenger vehicles that cannot remain afloat when flooded, canopies can represent an unacceptable risk to passenger safety.

10. Wearing lifejackets before the vehicle enters the water would enhance the safety of passengers on board DUKWs without adequate reserve buoyancy where canopies have been removed

11. Weather, drug and alcohol use, and operator fatigue were not factors in the sinking of the *Miss Majestic*.

12. Given the circumstances of this accident, the operator could not have taken any action to avert or mitigate its fatal outcome.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the uncontrolled flooding and sinking of the *Miss Majestic* was the failure of Land and Lakes Tours, Inc., to adequately repair and maintain the DUKW. Contributing to the sinking was a flaw in the design of DUKWs as converted for passenger service, that is, the lack of adequate reserve buoyancy that would have allowed the vehicle to remain afloat in a flooded condition. Contributing to the unsafe condition of the *Miss Majestic* was the lack of adequate oversight by the Coast Guard. Contributing to the high loss of life was a continuous canopy roof that entrapped passengers within the sinking vehicle.

Recommendations

New Recommendations

To the U.S. Coast Guard and the Governors of the States of New York and Wisconsin:

Require that amphibious passenger vehicle operators provide reserve buoyancy through passive means, such as watertight compartmentalization, built-in flotation, or equivalent measures, so that the vehicles will remain afloat and upright in the event of flooding, even when carrying a full complement of passengers and crew. (M-02-1)

Until such time that owners provide sufficient reserve buoyancy in their amphibious passenger vehicles so that they will remain upright and afloat in a fully flooded condition (by M-02-1), require the following:

removal of canopies for waterborne operations or installation of a Coast Guard-approved canopy that does not restrict either horizontal or vertical escape by passengers in the event of sinking,

reengineering of each amphibious vehicle to permanently close all unnecessary access plugs and to reduce all necessary through-hull penetrations to the minimum size necessary for operation,

installation of independently powered electric bilge pumps that are capable of dewatering the craft at the volume of the largest remaining penetration to supplement either an operable Higgins pump or a dewatering pump of equivalent or greater capacity,

installation of four independently powered bilge alarms,

inspection of the vehicle in water after each time a through-hull penetration has been removed or uncovered,

verification of a vehicle's watertight condition in the water at the outset of each waterborne departure, and

compliance with all remaining provisions of *Navigation and Vessel Inspection Circular1-01*. (M-02-2)

Where canopies have been removed on amphibious passenger vehicles for which there is not adequate reserve buoyancy, require that all passengers don lifejackets before the onset of waterborne operations. (M-02-3)

To the U.S. Coast Guard

Develop and promulgate guidance for all amphibious passenger vehicles similar in purpose to the Navigation and Vessel Inspection Circular 1-01. (M-02-4)

Previously Issued Recommendation Classified in this Report

The following Safety Recommendation was issued to 30 operators and refurbishers of amphibious passenger vehicles in the United States:

M-00-5

Without delay, alter your amphibious passenger vessels to provide reserve buoyancy through passive means, such as watertight compartmentalization, built-in flotation, or equivalent measures, so that they will remain afloat and upright in the event of flooding, even when carrying a full complement of passengers and crew.

Based on information received, the Safety Board classifies, in this report, Safety Recommendation M-00-5 (previously classified "Open—Acceptable Response") "Closed—Acceptable Action" for the following company: Cool Stuff.

Based on the lack of response to its February 18, 2000, initial letter and its August 17, 2000, follow-up letter, the Safety Board classifies Safety Recommendation M-00-5 "Open—Unacceptable Response" to the following companies: Aqua Traks, Inc; Austin Ducks; Buffalo Point; Chattanooga Ducks; Chicago Duck Tours; Ducks Amphibious Renovation/Sales; Land and Sea Tours; Maui Duck Tours; Naples Land and Sea Tours; National Park Duck Tours; Outfitter Kauai; Ozark Mountain Ducks; Sterling Equipment; and South Padre Water Sports/Breakaway.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARION C. BLAKEY
Chairman

CAROL J. CARMODY
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

GEORGE W. BLACK, JR.
Member

Adopted: April 2, 2002

Concurring Statement

John J. Goglia, Member, filed the following concurring statement on April 9, 2002. Member Goglia was joined in the following concurring statement by Members John A. Hammerschmidt and George W. Black, Jr.

Notation 7222B

Member GOGLIA concurring:

The Board makes several important recommendations in its report. However, this accident was initiated by a maintenance failure and the recommendations fail to fully address the maintenance shortcomings that initiated this tragic accident.

More needs to be done to ensure the safety of the public on vessels within the jurisdiction of the Coast Guard. The NTSB report could provide helpful guidance on the maintenance aspects.

There was improper maintenance performed on this vessel. There were no requirements that the technicians were capable or qualified. There was no oversight of the contract maintenance performed on this vessel by the operator. There was no supervision to ensure that the maintenance was properly performed. There were few or no records of what maintenance was accomplished, or any documentation of proper maintenance procedures and whether such procedures were followed. The Coast Guard has maintenance standards and requirements for maintenance incidental to the operation of its own vessels. The Coast Guard would improve public safety if it required the operators of vessels carrying the pubic for hire to have maintenance standards and requirements similar to what they require of themselves.

It should also be noted that there was disagreement among staff regarding recommendation number 1 to the Coast Guard. Some staff believe it is improbable that the passive measures as proposed in the Board's early recommendation and the report can be readily incorporated into existing DUKW vehicles. These staff point out that the Board previously issued a similar recommendation to the industry and that no company has managed to achieve this goal for existing vehicles to date. Rather, these staff believe the remedial actions proposed by the Coast Guard NVIC such as the installation of restrictor plated and carrier bearings over the drive shaft opening, the use of double clamps on drive shaft boots, and the installation of additional high level bilge alarms, are sufficient to prevent the recurrence of Miss Majestic type accidents in the future.

These same staff do not completely agree with conclusion number 9 and the recommendation to remove canopies. They have requested the conclusion state, "On amphibious passenger vehicles that cannot remain afloat when flooded canopies can represent a grave risk to passenger safety" because they do not agree that canopies represent an unacceptable risk to passenger safety.

Appendix A

Investigation And Public Forum

The National Transportation Safety Board was notified of the *Miss Majestic* accident at 1700, on May 1, 1999. An eight-person investigative team, consisting of an investigator-in-charge, the technical branch chief, and human performance and survival factors investigators, arrived in Hot Springs at 0130, May 2, 1999, and began the investigation later that morning. Representatives from the Safety Board's Office of Government, Public, and Family Affairs supported the team. A Board Member arrived with the team on scene the same day.

The Safety Board investigated the accident under the authority of the Independent Safety Board Act of 1997, according to the Safety Board's rules. Team members conducted witness interviews and examined the vessel after it was raised from the bottom of Lake Hamilton. On December 8–9, 1999, in Memphis, Tennessee, the Safety Board sponsored a public forum on amphibious passenger vessel safety, which brought together representatives of the U.S. Coast Guard, State governments, amphibious passenger vessel operators, other private sector organizations, and the public to explore safety matters relating to the design, regulation, maintenance, and operation of these vessels.

The designated parties to the Safety Board's on-scene investigation were the Garland County Sheriff Department and Land and Lakes Tours, the owner of the *Miss Majestic.* Although offered party status, the U.S. Coast Guard declined to participate in the Safety Board's investigation.

Appendix B

Minnow and *DUKW No. 1* Accident Briefs

National Transportation Safety Board

Washington, DC 20594

Marine Accident Brief

Sinking of the Alvis Stalwart M/V *Minnow* in Milwaukee Harbor on September 18, 2000

Accident No.	DCA-00-MM-042
Vessel:	20-foot 10-inch long, 8-foot 7-inch wide, steel-hull amphibious passenger vehicle of Alvis Stalwart design, built in 1967 in the United Kingdom
Accident Type:	Flooding and sinking
Location:	Milwaukee Harbor, Lake Michigan
Date:	September 18, 2000
Time:	11:55 a.m. Central Daylight Time
Owner:	Minnow Tours LLC, 3775 S. Packard Avenue, St. Francis, Wisconsin
Property Damage:	$ 170,000 (approximate)
Complement:	Nineteen people, including a licensed operator,[1] and an unlicensed deckhand. The *Minnow* was certificated by the U.S. Coast Guard to carry 1 operator, 1 deckhand, and up to 28 passengers.
Injuries:	None

Vessel History

The previous owner of the M/V *Minnow*, a 21-foot-long Alvis Stalwart amphibious passenger vehicle, contracted with Land and Sea Tours of Apopka, Florida, to refurbish and to sell the vehicle on his behalf. To prepare the Stalwart for sale, the refurbisher did some topside finishing work, such as replacing the canopy and seats, painting the vehicle, and making other aesthetic changes. He also rebuilt the main engine.

The vehicle remained on the market and was not operated for about a year, when the owner of Minnow Tours, based in St. Francis, Wisconsin, bought it in May 2000. Before taking possession of the vehicle, the Minnow Tours owner visited the refurbisher to obtain a set of manuals and information about Stalwart operations and maintenance. The refurbisher did not

[1] The operator, age 26, held a Coast Guard license for "Master of not more than 50 Gross Tons upon Great Lakes and Inland Waters" that was issued June 5, 1998, and that expired on June 5, 2003.

provide formal training or an orientation program about the Stalwart; rather, he answered questions that the owner posed.

Accident Narrative

About 1130 on September 18, 2000, the *Minnow* departed on a tour of Milwaukee, Wisconsin, with 19 people on board, including an operator, a deckhand, and 17 passengers. After an 8-minute road trip, the *Minnow* entered the waters of Milwaukee Harbor from a boat launch at the South Shore Yacht Club. The deckhand gave the passengers a safety orientation that included instructions on how to don lifejackets and what actions to take in the event of an emergency. The deckhand's other duties included narrating the sightseeing tour.

The *Minnow* followed its normal water tour route, hugging the shoreward side of the harbor breakwater. The operator said that, as he cruised at a speed of about 3 knots, he heard no unusual mechanical noises and had no operational problems. About 15 minutes after the water tour began, however, he heard a sudden "mechanical" noise on the port side of the vessel and felt the vessel "shudder." The operator said that the engine speed then dropped 400 rpm. After a few seconds, the shuddering lessened somewhat but did not cease. The operator said that, at this time, the jet wash appeared normal, the gage readings were normal, and no alarms sounded. He said that, at the time, he thought a foreign object had been sucked in and out of the jet.

About 1200, the high-water bilge alarm sounded. The operator said that he immediately turned on the two bilge pumps and headed the vessel back toward the dock. He said that he saw water issuing from the forward bilge pump discharge point on the starboard bow. From the driver's position, he could not see whether water was issuing from the stern bilge pump discharge point. To avoid panic among the passengers, the operator silenced the bilge alarm.

About 1202, the operator noted that the engine temperature was dropping and wondered whether the gage had an electrical problem.[2] He said the vessel was handling normally. When the mechanical noise and mild shuddering suddenly ceased, the operator observed in the rearview mirror that the left propulsion jet wash was mixed with air while the right jet wash was normal.

As the *Minnow* came into view of the Coast Guard base, the vessel's engine began to sputter. The operator steered the *Minnow* toward the concrete pier embankment. About 1206, the engine stopped just as the operator reached the last ladder on the embankment. The operator then observed that, from the vessel's deck, the ladder was too high for the passengers to grasp. About this time, the deckhand pointed out to the operator that the vessel's stern was low in the water, with a freeboard of 1 to 1 ½ feet.[3]

Meanwhile, two marine police officers and a Coast Guardsman were eating lunch in the Coast Guard base mess when one of the police officers noticed a tour boat (the *Minnow*) heading toward the embankment and its operator reaching out toward a ladder on the embankment. The

[2] At the time, the operator did not realize that water was flooding the vessel and that the engine was becoming submerged.

[3] The *Minnow* normally had a freeboard of 4 feet.

Coast Guardsman immediately left to notify the Coast Guard Station of the situation. The police officers immediately proceeded to their boat, which was moored at the pier outside the mess. At 1207, as they were casting off, they overheard the *Minnow*'s operator radio the Coast Guard, whereupon the marine police radioed the Stalwart operator, advising him that they were en route. The *Minnow*'s operator told the police that the *Minnow* was taking on water and needed assistance. The police relayed the information about the *Minnow*'s distress situation to the Coast Guard, which immediately dispatched response personnel in a rigid hull inflatable boat (RHIB).

The operator stated that, upon receiving an immediate response from the marine police and observing that a police boat was within 200 yards of the *Minnow*, he did not think it necessary to ask the passengers to don lifejackets. Rather, he told passengers that they would have to board the police boat when it came alongside.

Soon after the police boat had moored port to port with the *Minnow*, the Coast Guard RHIB arrived and moored on the *Minnow*'s starboard side. According to the responders, no problems occurred during the evacuation. The marine policemen described the passengers as "very calm" and characterized their demeanor as "almost festive" during the transfer. Twelve people from the *Minnow* evacuated to the police boat. The remaining 7 people originally evacuated to the RHIB but subsequently transferred to the police boat, which took all the passengers and crew of the *Minnow* back to shore. No injuries requiring medical treatment occurred during the transfers.

The marine police reported that the operator's behavior seemed normal and that he did not seem to be impaired from drugs or alcohol. Within 2 hours of the accident, the Coast Guard gave the *Minnow* operator a Breathalyzer test; the test results were negative.

After dropping off the *Minnow*'s passengers and crew, the Coast Guard crewmen returned in a 41-foot UTB with a dewatering pump to prevent the Stalwart from sinking. The effort was unsuccessful; the *Minnow* drifted around the embankment and sank in 25 feet of water.

Postaccident On-Scene Examination

After the *Minnow* was salvaged, Safety Board investigators found no evidence of blockage from debris in the intake and discharges for the port and starboard waterjets and no abnormalities in the starboard waterjet tunnel. They observed that the blade of the port waterjet impeller had cut through the waterjet tunnel housing the impeller, leaving a 1/8-inch-wide circumferential gap through which water from the port waterjet tunnel could enter the amphibious vehicle.

When the port and starboard waterjets were disassembled, investigators observed that the port impeller shaft inside the stator bearing was severely damaged, and that the bearings inside the port stator were broken into fragments and discolored. Neither the stator bearing nor the conical fairwater at the end of the port stator had any lubricant. Investigators found that the lubricating fitting (spigot) for the port stator had broken off. The bearing's retaining nut on the port impeller shaft was severely corroded.

The underwater area of the hull was in good condition and showed no evidence of leaks. The three drain plugs on the hull were secured in place. No other sources that potentially could have resulted in a significant flooding of the hull were identified. Investigators tested the Stalwart's two 12-volt positive-displacement bilge pumps and found that one of the pumps was inoperative. Two of the six impeller vanes were broken and were blocking the suction and discharge openings inside the pump casing.

Laboratory Tests

The on-scene investigators sent components to the Safety Board's Materials Laboratory in Washington, D.C., for further examination and analysis. The laboratory report states that the high temperature deformation of the bearing rollers indicated inadequate lubrication, which caused the failure of the aft shaft bearing, which, in turn, resulted in the failure of the port propulsion unit. Severe corrosion on the shaft bearing retaining nut indicated that the integrity of the bearing and oil cavity had been compromised for a significant period before the accident, allowing water to enter the oil chamber, corrode the nut, and degrade the lubricating oil. Over a period of time, water had entered through either a bad shaft seal or the fractured spigot. Laboratory analysis could not conclusively determine when the spigot had fractured.

The report found that, although the final breakup of the bearing occurred during the *Minnow*'s final voyage, severe degradation of the bearing had occurred for a long time before the accident voyage.

Follow-up Interviews

The owner stated he could not remember whether the refurbisher had told him about servicing recommendations for the rear bearing that malfunctioned in this accident. The refurbisher said he could not recall whether the oil level or the condition of the bearing that broke had been checked before the sale. Both the owner and refurbisher stated that the refurbisher had repaired the main bearing forward of the propulsion plenum because water had entered the bearing and caused it to seize.

According to the owner of Minnow Tours, he and the vehicle operator had performed the maintenance on the Stalwart. Both men had previous experience with automobile repairs. The company owner provided Safety Board investigators with a maintenance guide, *Servicing Schedule Condensed Summary*, which outlined daily, weekly, monthly, bimonthly, and annual maintenance schedules for the vehicle. Item 12 A under "weekly inspection and servicing" recommended that the rear hub bearing oil level be checked for the propulsion shafts. According to the company owner, the oil level for the rear bearings for the propulsion shafts had not been checked since he purchased the Stalwart. He had repaired the bevel gearing on the port power transmission shaft when mechanical problems occurred soon after purchase. He had made other minor repairs in the 4 months between purchase and the accident, including changing the lubricant in the wheel hubs because water in the lubricant had resulted in the hubs' overheating. He had changed the distributor points "because of problems" and had had to replenish the engine oil frequently because the vehicle "blows a little engine oil."

Coast Guard Inspections

At the refurbisher's *Minnow* was being modified for sale, a Coast Guard inspector from MSO Jacksonville, Florida, examined the vehicle. The Coast Guard inspector did not conduct a detailed plan review of the refurbished Stalwart; he approved the design of the *Minnow* based on the Coast Guard's be successful in 5 years of service.

The Coast Guard inspector in Milwaukee, who was tasked with certificating the *Minnow*, had never inspected a Stalwart. He said that, after receiving 2 years of training, he had been qualified in 1990 to inspect small passenger vessels, oceangoing ships, large passenger ferries, and tank barges. He was qualified as both a machinery and hull inspector. He said that he had inspected two DUKWs in 1988; however, he considered a Stalwart more complex mechanically than a DUKW. He stated that MSO Jacksonville provided him with very limited background information on the *Minnow*, merely an electrical diagram and stability information. He was not provided with manuals or other Coast Guard guidance for inspecting Stalwarts. He had never inspected waterjet propulsors before and, based on his lack of experience with Stalwarts, stated that he would likely not have thought of inspecting the area where the mechanical failure occurred. He stated that he considered checking the grease and oil levels in bearings a servicing and maintenance procedure that was the responsibility of the owner.

Before issuing the COI, the inspector checked the operation of the bilge alarm, the bilge pumps, and the firefighting system. He also examined the hull condition and took the vessel for a test ride in the water. Based on his inspection, he required that repairs be made to the electrical wiring.

As part of the requirements for issuing the COI, the Coast Guard inspector observed the crew while they conducted man-overboard drills. He explained the responsibilities for distributing lifejackets, firefighting, briefing passengers, and posting emergency placards. He gave the company a mannequin for practicing man-overboard drills and made several suggestions on how to improve passenger briefings. He stated he visited the company several times to ensure that it satisfactorily completed these requirements. During the COI inspection, the company owner and the operator of the *Minnow* were present. The deckhand who was on board the *Minnow* on the day of the accident was a new employee who had not been present at the COI inspection. The company is required to train its new employees in safety procedures and log its crew training. The Coast Guard witnesses drills only during its annual inspections.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the flooding and sinking of the *Minnow* was the inadequate prepurchase mechanical evaluation and subsequent inadequate maintenance by Minnow Tours before placing the vessel in passenger service.

National Transportation Safety Board

Washington, DC 20594

Marine Accident Brief

Sinking of the *DUKW No. 1*
Lake Union, Seattle, Washington, December 8, 2001

Accident No.:	DCA-02-MM-002
Vessel:	33-foot long, 8-foot 2-inch wide, steel-hulled amphibious passenger vehicle *DUKW No. 1*, built in 1945 for the U.S. Army[1]
Accident Type:	Flooding and sinking
Location:	Lake Union, Seattle, Washington
Date:	December 8, 2001
Time:	1430 Pacific Standard Time
Owner:	Ride the Ducks of Seattle, Seattle, Washington
Property Damage:	$100,000 (approximate)
Complement:	1 operator, 11 passengers. Certificated for 36 passengers maximum
Injuries:	None

Preaccident Events

On December 8, 2001, the junior mechanic for Ride the Ducks of Seattle, Washington, arrived at the company's garage about 0730 to perform maintenance on the DUKW that was to be used for the tours that day. For the winter months, the company had cut back operations, conducting tours only on weekends using one of its four DUKWs. In case problems arose with the first DUKW, the company maintained another DUKW on standby. The work hours of the company's staff had been reduced commensurate with the operating demand. The senior mechanic and supervisor of the junior mechanic did not come into the garage that week. The junior mechanic worked part time between 0700 and 1000.

[1] During the DUKW's modification from Army cargo vehicle to civilian passenger vehicle, *DUKW No. 1* was lengthened.

About 1000, the operator arrived, checked *DUKW No. 2*, which had been scheduled for use that day, and departed to pick up passengers at the 1100 tour. The junior mechanic then left for the day.

According to the operator, the 1100 tour was completed without incident. During a walk-around inspection of the DUKW after the tour, however, the operator noted that a tire was low. He drove the DUKW to a nearby automotive service station to inflate the tire where, coincidentally, he met the junior mechanic who had stopped there on his way home. The tire would not hold air and, rather than undertake the time-consuming process of changing the DUKW's tire, the operator asked mechanic told him that *DUKW No. 1* had been serviced. The senior mechanic later advised the Safety Board that *DUKW No. 1* was not originally scheduled to be the standby vehicle. *DUKW No. 4*, the standby DUKW, had developed engine problems about a week before this accident. As a result, about December 5, the company transferred its insurance to *DUKW No. 1* and placed it in a standby status.

The junior mechanic said that he last changed the oil and completed a maintenance checklist for *DUKW No. 1* on November 28; however, the Safety Board investigators were not provided a copy of the checklist.

The Accident

Company procedures required that, before a tour is conducted, both the mechanic and the operator sign the daily maintenance checklist attesting that they have checked 55 items, including engine fluid levels, tires, brakes, driveshaft rubber boots and clamps, and hull plugs.

On the day of the accident, the operator said that he arrived at the company garage about 1300 and spent about 5 to 10 minutes inspecting *DUKW No. 1*. He said that because he was in a hurry to pick up waiting passengers, he was unable to examine all the items listed on the safety checksheet; however, he told Safety Board investigators that he thought the maintenance access plug had been in place. A review of the daily maintenance checklist for *DUKW No. 1* shows all items were checked.

The operator arrived about 1320 at the ticket booth, where 11 passengers boarded. The operator stated that he gave a safety briefing, which included information about the location of and donning procedures for lifejackets as well as procedures for exiting the vehicle in the event of an emergency.

After completing the land portion of the tour, the *DUKW No. 1* entered the water and proceeded on its normal route across Lake Union. The operator said that, about half way across the lake, he felt the boat vibrating and thought that, because all the passengers were seated in the forward area of the DUKW, the propeller was not completely immersed. He therefore asked several passengers to move aft in the vehicle.

The *DUKW No. 1* had been in the water about 5 minutes when the bilge alarm sounded briefly. About a minute later, the bilge alarm began sounding steadily, and the Higgins pump began discharging water. In accordance with company safety procedures, which stipulated that an operator proceed to the nearest open beach area if the Higgins pump discharged water, the

DUKW No. 1 operator headed towards Good Turn Park. The *DUKW No. 1* operator later stated that he did not order the passengers to don lifejackets[2] because the vehicle was so close to the park.

The operator of a nearby boat noticed the Higgins pump discharge and followed the *DUKW No. 1* to see if it needed assistance.

About 2-3 minutes elapsed from the time that the bilge alarm began sounding steadily to the time that the DUKW's wheels loose gravel bottom, and the vehicle's onto the beach. The *DUKW No. 1* operator then asked the operator of the Good Samaritan boat to shuttle the *DUKW No. 1*'s passengers had to enter the water or were injured during the transfer.

The *DUKW No. 1* operator contacted the tour company, which arranged for taxis to pick up the passengers from Good Turn Park and return them to the ticket booth. The operator also contacted the Seattle Harbor Patrol, which dispatched a patrol vessel that arrived on the scene after all the passengers had safely disembarked. The Harbor Patrol vessel attempted to tow the stalled *DUKW No. 1* back across the lake; however, before reaching its destination, the *DUKW No. 1* sank by the bow in 27 feet of water.

Postaccident Findings

Divers sent down to the vehicle found that a 4 ½-inch hull access plug [3] was missing, which had allowed water to flood the hull and sink the *DUKW No. 1*.[4] The company initially could not find the spare access plug. To close the hole in the *DUKW No. 1* before salvaging the vehicle, the company installed a plug from another vehicle. The company later accounted for the access plugs and the single spare plug for all four DUKWs. The company's stated that, before the accident, the company had moved to apresident and larger garage. The *DUKW No. 1* plug and the spare plug were found in a vehicle used for the garage move; thus, the plug had not become loose in the vehicle but had been previously removed and not replaced by a mechanic.

After the accident, the junior mechanic stated that he was puzzled by the absence of the plug in *DUKW No. 1* because he thought he had replaced the access plug when he had last changed the oil. He said that, as an obvious reminder to himself, he had placed the plug on the nose of the DUKW during the oil change. He stated,

> Something apparently went wrong with this reminder system. While I had believed I had put the plug back in, I do also believe that the DUKW left the shop

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[2] The *DUKW No. 1* was equipped with 36 adult lifejackets, which were stored in the overhead above the passenger seats and near the operator's station. Ten child-size lifejackets were stowed under the seats.

[3] The access plug is located under the engine, forward of the front axle, on the centerline of the vessel. When removed, the plug provides access to the engine's oil filter and drain plug from below the hull.

[4] Safety Board investigators calculated that the DUKW's dewatering pumps would not have had sufficient capacity to keep up with the ingress of water through the missing access plug hole.

on December 8, 2001, without the drain plug in place. It is not likely that someone took the plug out after I had put it in.

DUKW No. 1 had a fixed overhead canopy made of solid sheet metal. Each side of the DUKW had a roller side curtain assembly that extended the length of the vehicle. In normal operation, the curtain on each side was moved up or down on a roller mounted on the canopy. In an emergency, the operator could use a lever at his station to release the entire roller assembly, allowing it fall away from the vehicle to facilitate emergency egress. The vehicle's windshield was also hinged at the bottom, allowing it to open outward for egress.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the flooding and sinking of the *DUKW No.1* was a missing access plug, which, in turn, was caused by inadequate supervision of company personnel and inadequate management oversight of amphibious passenger vehicle maintenance. Contributing to the sinking was a flaw in the design of DUKWs, that is, the lack of adequate reserve buoyancy that would have allowed the vehicle to remain afloat in a flooded condition.