National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 2, 2002

In reply refer to: M-02-1 through -4

Admiral James M. Loy
Commandant
U.S. Coast Guard
Washington, D.C. 20593-0001

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. Shortly 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. The remaining 13 passengers, including 3 children, lost their lives. The vehicle damage was estimated at $100,000.[1]

The National Transportation Safety Board (Safety Board) determined 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.[2] Contributing to the sinking was a flaw in the design of DUKWs converted to 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 U.S. Coast Guard. Contributing to the high loss of life was a continuous canopy roof that entrapped passengers within the sinking vehicle. Based on its investigation of this accident, the Safety Board identified the following issues in the following safety areas: vehicle maintenance, Coast Guard inspections of the *Miss Majestic,* Coast Guard inspection guidance, reserve buoyancy, and survivability.

[1] For further information, read: National Transportation Safety Board, S*inking of the Amphibious Passenger Vehicle Miss Majestic, Lake Hamilton, Near Hot Springs, Arkansas, May 1, 1999*, Marine Accident Report NTSB/MAR-02/01 (Washington, DC: NTSB, 2002).

[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. After the war, many DUKWs were sold as surplus and, like the *Miss Majestic*, were converted to commercial excursion passenger vehicles.

The *Miss Majestic* was inspected and certificated by the Coast Guard as a small passenger vessel[3] meeting the requirements of 46 *Code of Federal Regulations* (CFR) Parts 175-185 (Subchapter T). Based on its length and its anticipated passenger load, the vehicle 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* was equipped with three electric pumps. In addition, the vehicle had a Higgins pump, which had been part of the original Army design but 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 and operated only when the driveshaft was engaged. While it operated, the pump discharged bilge water straight upward and overboard, creating a readily observable stream of water.

During postaccident interviews, the operator stated that, during the tour, she had not observed discharges from either the Higgins pump or the forward electric bilge pump.[4] The discharge pipes for the pumps had been to her left, and she had 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.

When the *Miss Majestic* 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*. Detailed examination of the vehicle's hull and plugs did not reveal a structural failure through which massive flooding could have occurred.

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. Each end of the aft shaft housing had an accordion rubber boot. The two rubber boots together with the shaft housing were to provide a watertight barrier where the driveshaft penetrated the hull. Postaccident examination revealed that the aft boot had separated from the housing at one end, creating a gap between the driveshaft and its housing that allowed water to freely enter the vehicle's hull. 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.

When Safety Board investigators fit the rubber boot back on the housing, they found that the clamp used to attach the boot to the housing was loose. They determined that, before the accident, a maintenance mechanic had replaced the aft boot because the original boot had a tear. His supervisor 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.

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

[4] 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.

Postaccident testing and examination determined that the Higgins pump and one of the electric bilge pumps were inoperable. The Safety Board calculated that the rate of water inflow through the annular opening was at least 170 GPM. Although two electric pumps were operating, their combined pumping capacity was not enough to prevent the water buildup. At the rate of water 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.

Revisions to Subchapter T required that existing vessels at least 26 feet long, which included the *Miss Majestic*, be equipped with high-level bilge alarms no later than March 11, 1999. Postaccident examination revealed the vehicle did not have a bilge alarm. Thus, the *Miss Majestic* had neither an active means of dewatering the vehicle nor a means of alerting the operator to the condition of the vehicle before it sank.

The Coast Guard had last inspected the *Miss Majestic* on February 23, 1999, a little more than 2 months before the accident. The inspector had reminded the owner's representative of the regulatory requirement. However, the Coast Guard inspector did not follow up to ensure the bilge alarm was installed. His report states that he examined the hull interior and exterior; however, he testified that he inspected the bottom of the vehicle by looking underneath it from the side. He did not get under the vehicle. 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 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, no inspection record indicates 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. Based on its findings in the *Miss Majestic* accident, the Safety Board concluded that the Coast Guard's inspections of the vehicle were inadequate and cursory.

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 Marine Safety Offices (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 the hull, 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.

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 Officer-in-Charge, Marine Investigation nor the supervisor of inspectors at MSO Memphis had ever inspected a DUKW or was aware of any Coast Guard inspection procedures for DUKWs. The Safety Board concluded that the lack of Coast Guard guidance and training for the inspection of DUKWs contributed to the inadequate inspections of the *Miss Majestic*.

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.

About the time that 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.

The Safety Board's amphibious passenger vehicle 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, a naval architect company contracted by the Safety Board, had 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 had 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. At the forum, a JMS representative made a presentation on the flooding characteristics of DUKWs and stated that the estimated 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, on February 18, 2000, the Safety Board issued the following safety recommendation to 30 operators and refurbishers of amphibious passenger vehicles:

> M-00-5
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> 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.

In the Safety Board's opinion, 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. Consider the Higgins pump, which 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 contrast, a passive safety system requires no deliberate action or operation to deploy and generally facilitates fail-safe performance of the vehicle. 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.

As of the date of the Safety Board's report on the *Miss Majestic* accident, only three owners of amphibious passenger vehicle companies have indicated that they were trying to install reserve buoyancy into their vehicles as requested by Safety Recommendation M-00-5. Other companies have 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 additional high-water bilge alarms.

Despite the negative responses 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. It is clear, however, from the responses received from the industry, that with the exception of a few owners, the industry will not take voluntary action 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. The Safety Board notes that the Coast Guard's report of the *Miss Majestic* sinking concluded, and the Coast Guard Commandant concurred, the following:

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

Because the industry has, by and large, refused to take voluntary action to address this risk, the Safety Board considers it imperative that a regulatory authority takes steps to ensure that all amphibious passenger vehicles will not sink in the event of an uncontrolled flooding event. The Safety Board, therefore, believes that the Coast Guard should 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.

Following its investigation of the *Miss Majestic* accident and after participating at the Safety Board's forum, the Coast Guard met with representatives of the amphibious passenger vehicle industry to develop comprehensive guidelines containing best practices on the inspection and operation of these vehicles. The Coast Guard subsequently issued Navigation and Vessel Inspection Circular (NVIC) 1-01, *Inspection of Amphibious Passenger Carrying Vehicles*, to provide its inspectors and industry with necessary background information and guidance about DUKWs.

NVIC 1-01 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 and provides inspectors with a list of 19 modifications that might have been made to a DUKW when it was converted to passenger service. The NVIC offers sample calculations for flooding, as well as expected scantlings. The circular is very well done as far as it goes; however, it is only an advisory document. Whether all amphibious passenger vehicle operators have incorporated the circular's advice into their vehicles or vehicle operations is not certain. Moreover, NVIC 1-01 does not adequately address important safety concerns, namely passenger egress and survivability.

For example, NVIC 1-01 recognizes canopies as an impediment to passenger egress. The circular 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. During postaccident interviews with the survivors of the *Miss Majestic* accident, all but one person stated that the canopy was an impediment to 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. 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 drowned. The Safety Board found that on amphibious passenger vehicles such as the *Miss Majestic* that cannot remain afloat when flooded canopies are a major impediment to survival and can represent an unacceptable risk to safety. Therefore, a more realistic approach to ensure passenger safety would be to afford passengers a reasonable opportunity to escape by removing the canopy for waterborne operations or by installing a Coast Guard-approved canopy does not restrict either horizontal or vertical escape by passengers in the event of sinking.

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 a sinking vessel that did not have a canopy, 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. The Safety Board, therefore, 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 the onset of 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. As noted earlier, the canopy should be removed before water operations so that passengers will float clear of the vehicle in the event of sinking, and passengers should be required to don lifejackets.

In addition, owners should be required to reduce through-hull penetrations and to install adequate dewatering capability to keep the vehicle afloat longer. The sinking of the *DUKW No. 1* on December 8, 2001,[5] clearly demonstrates what can happen to an amphibious passenger vehicle without sufficient reserve buoyancy if it experiences flooding and if it relies on the Higgins pump for dewatering. In that accident, *DUKW No. 1*, with 12 people on board, began flooding during a tour of Lake Union in Seattle, Washington. When the bilge alarm sounded repeatedly and the vehicle's Higgins pump

[5] Sinking of the *DUKW No.* 1, Lake Union, Seattle, Washington, December 8, 2001; Brief report in Appendix B of footnote 1.

began discharging water, the operator headed for shore. All passengers were transferred to a passing boat and taken ashore. The local harbor patrol, not knowing that an access plug was missing, 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 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 the 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, *DUKW No. 1* sank because of a simple human error that occurred during routine maintenance.

In the case of the *DUKW No. 1*, company procedures required that, before a tour was conducted, both the mechanic and the operator sign the daily maintenance checklist attesting that they had checked 55 items, including engine fluid levels, tires, brakes, driveshaft rubber boots and clamps, and hull plugs. On the day of the accident, however, the operator was in a hurry to pick up waiting passengers and did not take the time to examine all the items listed on the safety checksheet. 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.

Following the *DUKW No. 1* accident, the owner of the vehicle decided to permanently seal the larger access plugs in all his DUKWs to reduce the likelihood of flooding. The change required some reengineering. Other amphibious passenger vehicle owners should be able to modify their vehicles to permanently close unnecessary access plugs, thus reducing the risk of flooding.

As discussed earlier in this letter, Higgins pumps are subject to multiple failure modes. If a Higgins pump malfunctions and the DUKW vehicle lacks sufficient reserve buoyancy to remain afloat, it could rapidly sink, risking serious injury or death to passengers. Further, the operation of the pump is contingent upon the operation of the engine. 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 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. Therefore,

until such time as reserve buoyancy requirements come into effect for amphibious passenger vehicles, a provision for dewatering capacity should be made mandatory.

Thus, the Safety Board believes that 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), the Coast Guard should 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 the 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 Circular 1-01*.

Following the *Miss Majestic* accident, the Safety Board investigated another amphibious passenger vehicle accident that resulted from inadequate maintenance. On September 18, 2000, the *Minnow*, a 21-foot-long Alvis Stalwart-type (Stalwart) 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 when the engine 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.[6]

During postaccident examination, the Safety Board Materials Laboratory in Washington, D.C. determined that the port propulsion unit had 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.

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. 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,

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[6] Sinking of the Alvis Stalwart M/V *Minnow* in Milwaukee Harbor on September 18, 2000; Brief report in Appendix B of footnote 1.

and inspectors. In the Safety Board's opinion, industry and Coast Guard inspectors need to become familiar with the general background of and unique safety issues for all types of amphibious vehicles, such as 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 NVIC 1-01.

In summary, the National Transportation Safety Board makes the following safety recommendations to the U.S. Coast Guard:

> 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:

> (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 the 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 *Navigation and Vessel Inspection Circular1-01*. (M-02-2)

Where canopies have been removed on amphibious passenger vehicles for which there is no adequate reserve buoyancy, require that all passengers don lifejackets before the onset of waterborne operations. (M-02-3)

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

As a result of this investigation, the Safety Board has issued three safety recommendations to the States of New York and Wisconsin. In your response to the recommendations in this letter, please refer to M-02-1 through -4. If you need additional information, you may call (202) 314-6607.

Chairman BLAKEY, Vice Chairman CARMODY and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

Original Signed

By: Marion C. Blakey
Chairman