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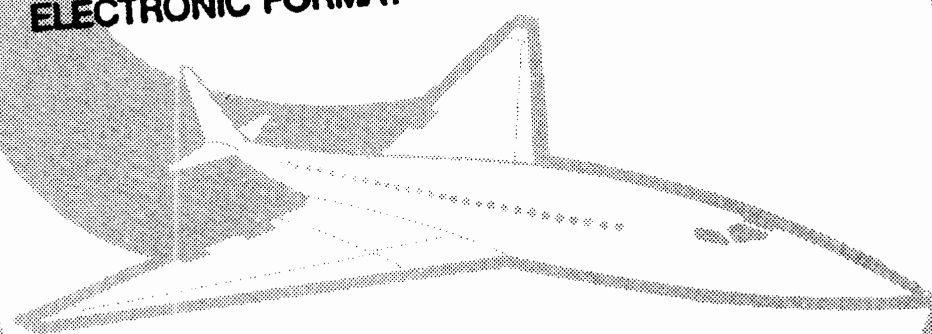
FAA Technical Center
Atlantic City International Airport,
N.J. 08405

Commuter/Air Taxi Ditchings and Water-Related Impacts that Occurred from 1979 to 1989



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16. Abstract

This report documents an investigation of ditchings and water-related impacts for commuter-category aircraft that occurred during the years 1979 through 1989. The main source of accident data was the National Transportation Safety Board (NTSB). Data were also sought from the International Civil Aviation Organization and the U.S. Navy Safety Center. A total of 46 accidents was obtained and examined for this study. Of these, 40 cases satisfied the criteria for inclusion into the database. Impact and post-impact conditions were categorized to assess aircraft behavior and occupant survivability. Two impact scenarios and two post-impact scenarios were established. Special emphasis was placed on examining aircraft flotation behavior and post-impact survivability. In addition, five representative case studies are presented to demonstrate aspects peculiar to the commuter-category aircraft water impact and post-impact sequence that could not be adequately covered by the statistical categorizations alone.

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PREFACE

This report was prepared by Galaxy Scientific Corporation under Contract No. DTFA03-89-C-00043 with the Federal Aviation Administration (FAA) Technical Center. Mr. Bill Broyles of the Navy Safety Center provided valuable assistance in searching for applicable U.S. Navy data for this study. Kevin Fogarty of Galaxy Scientific Corporation participated in the accident reconstruction and database design performed for this study.

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EXECUTIVE SUMMARY

This report documents an investigation of ditchings and water-related impacts of commuter/air taxi aircraft that occurred during the years 1979-1989. The objective was to provide an assessment of aircraft behavior in ditchings and water-related impacts, personal flotation equipment behavior, and occupant survivability in the water impact and post-impact environments. The approach used in achieving this goal was to collect and examine accident/incident data from a variety of sources on water impacts that occurred during the target time period. Behavioral trends were determined and scenarios for impact and post-impact conditions were established.

The main source of accident data was the National Transportation Safety Board. Data also was sought from the International Civil Aviation Organization and the U.S. Navy Safety Center. A total of 46 accidents was obtained and examined . Of those, 40 cases met the criteria necessary for inclusion in this study. The nature of the information available for these water impacts included factual reports generated by the investigator, witness statements, and photographic documentation of aircraft damage.

The impact parameters, injury types, and injury causes were categorized based on the information drawn from reconstructions of the accident cases. This information was placed into a computerized database which facilitated categorization and analysis. Special emphasis was placed on examining aircraft flotation behavior and post-impact survivability. The structural damage documented in these accident cases was also addressed. The results of these categorizations are analyzed. Two impact scenarios and two post-impact scenarios were established for commuter aircraft ditching and water-related impacts. Six representative case studies are presented to demonstrate aspects peculiar to the commuter water impact and post-impact sequence that could not be adequately covered by the statistical categorizations alone.

Analysis indicates that longitudinal and vertical-velocity components were the most significant contributors to the resultant velocity. Flailing and drowning were the most significant hazards to occupants. Noseovers of amphibious aircraft attempting water landings present significant problems to occupant survivability.

1. INTRODUCTION.

This study attempts to characterize trends that affected occupant survivability in commuter/air taxi airplane ditchings and water-related impacts that occurred during 1979 through 1989. These impacts were characterized and then analyzed. By correlating impact conditions with occupant injury and fatality data, design requirements can be produced which improve the crashworthiness of the commuter/air taxi aircraft in water impacts.

The aircraft in this study were those operating in accordance with Code of Federal Regulations, Title 14, part 135, "Air Taxi Operators and Commercial Operators" (reference 1). This effort consisted of four main tasks:

a. Task I – Accident Reconstruction. Identify sources of commuter/air taxi airplane water impact data for accidents that occurred between 1979 and 1989, obtain the data, and assess its suitability for the study. Use accident reconstruction techniques to determine the sequence of events, impact velocities and attitudes, occupant injuries, impact structural damage, flotation performance, and post-impact survival aspects.

b. Task II – Data Categorization. Generate statistics characterizing parameters such as impact velocities and attitudes; injury cause, frequency, and severity; and flotation availability and behavior.

c. Task III – Scenario Establishment. Establish water impact scenarios that are representative of survivable impacts encountered in the data sample.

d. Task IV – Structural Damage. Summarize and assess the impact structural damage and how it contributed to occupant injury.

This report describes the data acquisition and selection methodology, the accident reconstruction methodology, and the categorization approach. Trends that can be ascribed to the water impact and post-impact environments, including injury causes and flotation equipment performance, are developed and discussed. Scenarios for water impact and post-water impact situations are also defined. The significance and interrelationships of the trends are discussed. Conclusions regarding occupant survivability in commuter/air taxi airplane water impacts are offered. The appendices provide supplementary documentation of the collection, reconstruction, and analysis of the accidents.

1.1 BACKGROUND.

Past improvements in occupant survivability have been supported by investigations that characterized the accident environment. Definition of the accident conditions to which an occupant is subjected make it possible to reduce or eliminate those hazards. Typical impact scenarios are developed so that assessments of the aircraft structure may be made. Occupant injury types, causes and severity, and the damage incurred to the aircraft structure are also examined. A water impact involves not only the impact threat to the occupants but the threat of a hazardous post-impact environment as well, with risks such as exposure and drowning. Therefore there is a need to examine the water impact and post-impact sequence to determine the current level of occupant survivability.

In addition to the post-crash survivability hazards discussed above, the conditions in a water impact are different than those experienced in a ground impact. In a water impact the landing gear of the aircraft may not absorb significant impact energy and the impact load may be distributed over a wider contact area (reference 2). Therefore, there is a need to specifically examine the effects of a water impact on the structure of the aircraft and how the resulting damage affects occupant injury and survivability. This investigation focuses on characterizing the commuter/air taxi airplane water impact and post-water impact sequences and establishing the current trends in survivability for the occupants involved in these impacts. A glossary defining terms used in this report is contained in section 7.

In instances of in-flight emergencies such as engine failure, the pilot often must perform a controlled landing on the water. The definition used in this report to define commuter/air taxi ditching is "an emergency landing on the water, deliberately executed, with the intent of abandoning the (aircraft) as soon as practical. The (aircraft) is assumed to be intact prior to water entry with all controls and essential systems, except engines, functioning properly."

In addition to controlled ditchings, commuter/air taxi airplanes often hit the water surface when the pilot has varying degrees of mechanical control of the aircraft, and these situations are called water impacts. For example, malfunction of a control surface followed by a pilot-guided descent to the water is not a ditching by definition, but rather a water impact. Another relatively common example is a sudden, unexpected flight into the water. This often occurs in poor visibility conditions such as in bad weather or darkness and is a result of the pilot losing altitude reference. Several cases noted in this sample involved amphibious aircraft whose wheels were extended during water landings which caused the aircraft to noseover.

2. TECHNICAL APPROACH.

The objective of this investigation was to provide for the years 1979 through 1989 an assessment of:

a. Current commuter/air taxi aircraft behavior in both ditchings and water impacts.
b. Ditching equipment and personal flotation equipment behavior.
c. Factors affecting occupant survivability in the water impact and post-impact environment.

The main approach used in achieving this objective was to collect and examine data documenting specific accidents involving water impacts that occurred during the target time period. From this body of data, behavioral trends were determined and water impact and post-impact scenarios were developed.

2.1 DATA ACQUISITION AND SELECTION.

The accident data sample was required to contain a significant representation of survivable water impacts experienced by the civilian commuter/air taxi airplane fleet during the years 1979 to 1989. The sample had to contain a significant number of severe accidents. Based on similar investigations a target number of 60 to 80 accidents was established. However, only a total of 46 accident cases with supporting documentation was obtained. This number does not fall within the target range. However, the accident data obtained did contain a representation of both survivable and nonsurvivable accidents.

The main source of accident data was the National Transportation Safety Board (NTSB) in Washington, D.C. The Accident/Incident Data System (AIDS), maintained by the Federal Aviation Administration, was also used as a search cross-reference and proved valuable in identifying accidents in the NTSB database that were not located by the initial NTSB searches. Inquiries were made to the U.S. Navy Safety Center and the U.S. Coast Guard for water impact accident data involving commuter airplanes. No water impacts were identified through the U.S. Navy and only amphibious aircraft landings were identified through the U.S. Coast Guard. Accident data was also identified by the International Civil Aviation Organization (ICAO); however, only U.S. accidents were obtained. Appendix A contains a listing of the civilian sources for accident data and the number of accidents obtained from each. It also illustrates the variable results encountered for different inquiries to the same body of data. Figure 2.1 summarizes the number of accidents by data sources.

The selected reports were judged on the quality and depth of their documentation to assess their usefulness in supporting accident reconstruction. Not all accident reports found in the data search were obtained for further examination. The method used to collect the data reports creates an inherent bias towards higher severity accidents and the trends presented in this report should be reviewed with this in mind. Unfortunately, less severe accidents are often not documented in terms of detailed aircraft damage or occupant injuries. This weights the accident trends presented in this report towards the partially survivable and nonsurvivable range. However, this is where most injuries occur.

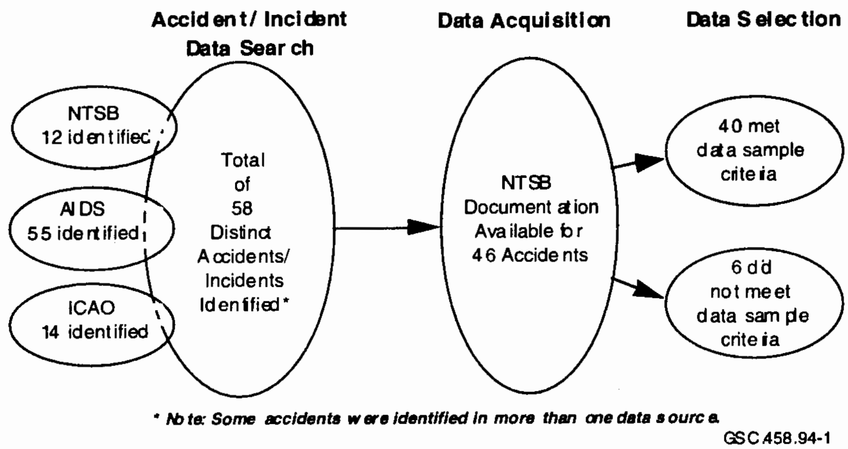


FIGURE 2.1. SUMMARY OF DATA SEARCH, ACQUISITION, AND SELECTION PROCESS

The criteria used to determine the inclusion of an accident report into the database were as follows:

a. The impact terrain was water.
b. The impact occurred between the years 1979-1989 inclusive.
c. The aircraft involved was representative of the civilian and commuter/air taxi/airplane fleet.

Several aircraft which were float-equipped and experienced landing difficulties were included for examination of their post-impact survivability aspects. In all, 40 of 46 accident reports obtained met the selection criteria and were included in the database.

2.2 ACCIDENT RECONSTRUCTION.

Figure 2.2 outlines the accident reconstruction process used in this study. Documentation for the 40 accidents was obtained and/or examined for this study. The information available for these water impacts included factual reports generated by the investigator(s), witness statements, and photographic documentation of aircraft damage. The impact velocities and attitudes, aircraft impact damage, and personal injury data were drawn from each accident report and summarized on a water impact reconstruction form developed for this study. These water impact reconstruction forms facilitated collection, categorization, and analysis of the necessary information. Appendix B contains a sample water impact reconstruction form and complete documentation of the formats used to summarize the data taken from the accident reports. Special emphasis was placed on examining commuter/air taxi airplane flotation equipment performance and post-impact occupant survivability. Environmental conditions, such as wave height and water temperature, and their effects on occupant survivability were recorded.

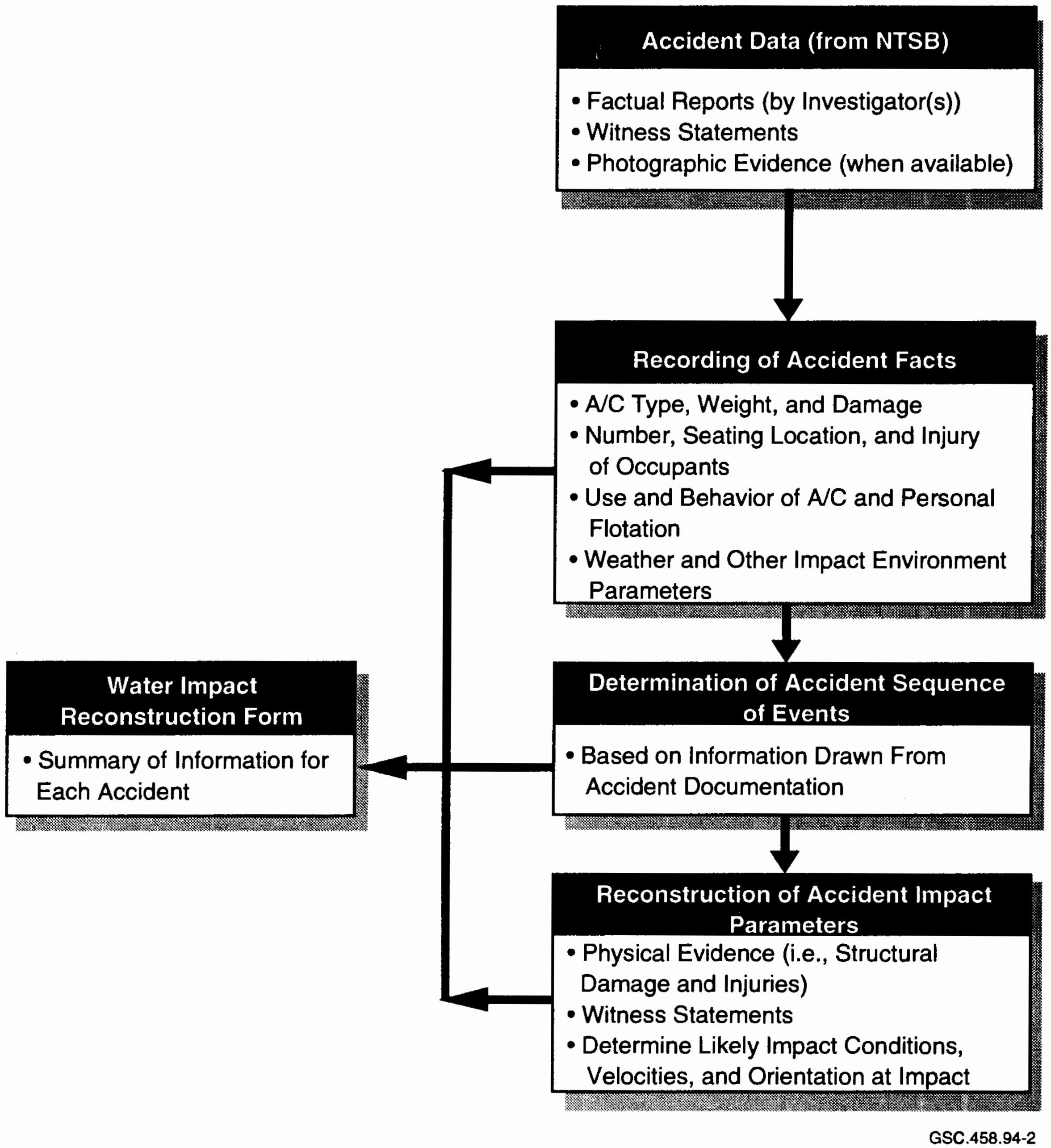


FIGURE 2.2. WATER IMPACT ACCIDENT RECONSTRUCTION PROCESS

It should be noted that reconstruction of water impacts entails unique challenges. In ground impacts, the impacted surface may provide evidence in the form of gouges, broken tree limbs, and similar physical traces. This information is not as available in water impacts. Also, in a ground impact the aircraft is more easily examined to determine impact attitude, accelerations, and structural damage. An aircraft involved in a water impact may not be recovered or may be further damaged by post-impact wave action or recovery efforts, thereby masking damage caused by the impact. Witness statements describing the impact were used in conjunction with narrative documentation of the structural damage to assess which damage was caused by the impact. Photographic evidence of recovered aircraft structural damage facilitated this process, when available, by providing a visual reference. The nature of the evidence available for this study was not comprehensive enough to establish the crash pulses with a reasonable degree of certainty in all cases and therefore they are not presented. A sample of the accident reconstruction methodology can be found in appendix C.

2.3 ACCIDENT CATEGORIZATION.

The crash parameters, injury types, and injury causes were categorized to define survivable water impact conditions and support the establishment of typical water impact and post-water impact scenarios. The categorization effort was organized into seven main areas:

a. Accident Sample Summary—This area examines the sample according to yearly number of occurrences, aircraft weight class, first accident event, occupant injuries relative to aircraft weight class, and injury level relative to accident survivability.

b. Crash Parameters—This area examines the distribution of impact attitudes and velocities for all levels of survivability, the 95th percentile velocities for survivable/partially survivable and significant survivable groups, and compares the 95th percentile significant survivable impact velocities in the current sample with values for U.S. Navy water impacts and all commuter/air taxi impact results.

c. Injury Causes and Severity—This area examines the frequency of occurrence of impact injury types and causes, impact injury occurrence relative to occupant restraint, the frequency of occurrence of post-impact injuries and causes, and the frequency of occurrence and severity of impact and post-impact injuries relative to aircraft weight class.

d. Aircraft Flotation—This area examines the wave heights encountered, the number of aircraft equipped with flotation gear, the number of aircraft with deployed flotation gear, and the effect of flotation gear on aircraft water stability and occupant injury.

e. Personal Flotation—This area examines occupant egress, personal flotation equipment availability, use and performance, and occupant exposure to the post-impact environment.

f. Scenario Establishment—This area uses trends identified in the accident data to establish "typical" survivable impact and post-impact scenarios for this sample.

g. Structural Damage—This area examines and discusses descriptions of structural damage that were taken from the accident data.

3. RESULTS AND DISCUSSION.

This section presents the results of the categorization tasks performed for this investigation. It presents summary statistics on the entire accident sample regarding the sample size, aircraft weight class, injuries, and survivability. Also documented are the impact velocities and attitudes. It examines the types, causes, and frequencies of injuries and trauma suffered by occupants due to impact and post-impact conditions. This section also explores occurrences of injury relative to aircraft weight class and restraint type. The findings on the availability, use, and performance of personal flotation equipment are discussed. The establishment of and the supporting data in the scenarios defined in this study are presented. Finally, the effects of structural damage on occupant survivability is discussed.

3.1 ACCIDENT SAMPLE SUMMARY.

In this current investigation, which covers water impacts from 1979 to 1989, the sample contains a total of 40 accidents which yields an average of 3.6 accidents per year. The yearly distribution of accidents for this study is shown in figure 3.1.

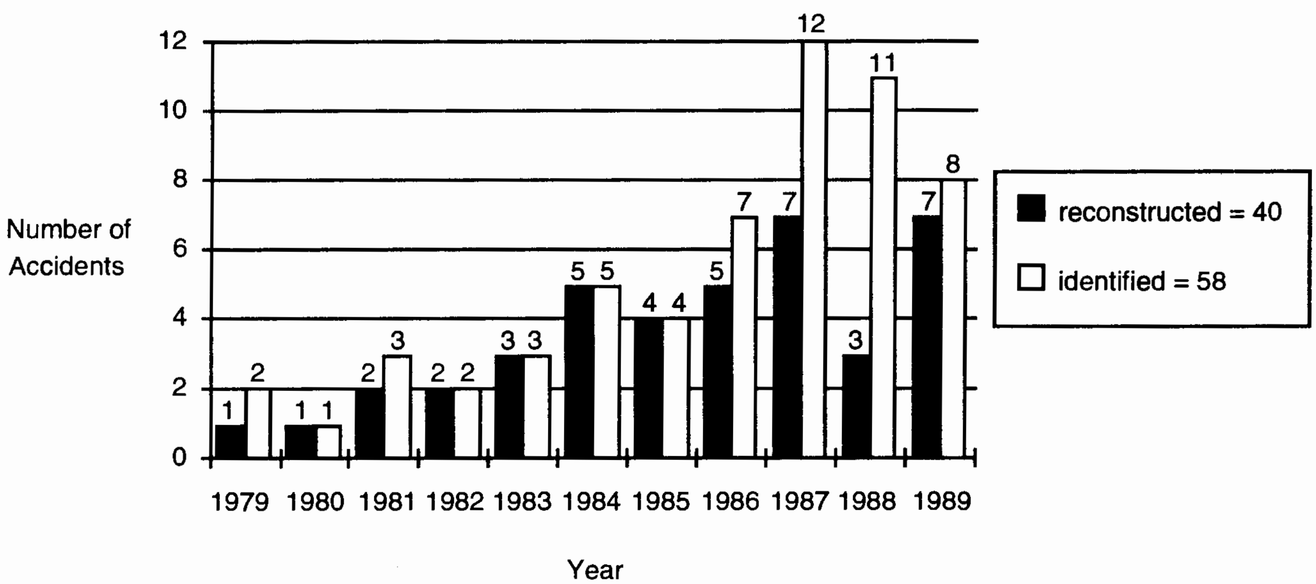


FIGURE 3.1. YEARLY DISTRIBUTION OF ACCIDENTS IDENTIFIED AND RECONSTRUCTED

3.1.1 Sample Distribution of Aircraft by Weight Class.

The distribution of aircraft by weight class provides a useful piece of information when examining other trends in the accident sample. For this study, aircraft weight classes were categorized according to the following definitions:

a. Weight Class A - $\leq$ 10,000 pounds.
b. Weight Class B - > 10,000 pounds and $\leq$ 20,000 pounds.

c. Weight Class C - ≥ 20,000 pounds.

Table 3.1 contains the sample distribution by aircraft weight class and shows that weight class A was by far the most frequently occurring weight class in the sample, representing 77 percent of the aircraft in this investigation. Table 3.1 also shows that a total of 65 percent of the occupants were onboard weight class A aircraft.

TABLE 3.1. DISTRIBUTION OF WATER IMPACTS BY WEIGHT CLASS AND OCCUPANTS ON BOARD

Weight Class	Number of Aircraft		Occupants On Board	
	Number	Percent	Number	Percent
A	31	77	93	65
B	5	13	41	29
C	4	10	9	6
Total	40	100	143	100

3.1.2 Sample Distribution by Aircraft Configuration.

Aircraft were categorized by wing, engine, and landing gear configuration to better characterize the content of the sample. Table 3.2 contains the results of these categorizations. It can be seen that for wing configuration, the distribution between high- and low-wing configurations was approximately equal. For landing gear configuration, tricycle-type landing gear represents 57 percent of the sample. Another significant landing gear configuration was described as amphibious. This category includes both float planes and those aircraft with amphibious hulls and represented 33 percent of the accident population.

TABLE 3.2. DISTRIBUTION OF WING, ENGINE, AND LANDING GEAR CONFIGURATION, TOTAL SAMPLE

Wing and Engine Configurations	Number	Percent
High wing with nose-mounted engines	16	40
High wing with wing-mounted engines	4	10
Low wing with nose-mounted engines	4	10
Low wing with wing-mounted engines	14	35
Unknown	2	5
Total	40	100
Landing Gear Configurations	Number	Percent
Amphibian	13	33
Tailwheel	4	10
Tricycle	23	57
Total	40	100

3.1.3 Sample Distribution by First Accident Event.

A distribution of the first accident event, defined as the first occurrence in the accident sequence, gives an indication of the typical accident causes. The distribution of first event occurrence for this sample is presented in table 3.3. This table shows that the first events involving loss of power comprise 45 percent of the sample. Another significant group, dragged float, represents 17.5 percent of the sample. This group of accidents were float planes that were attempting water landings and nosed over at touchdown. All of these accidents occurred with no occupant injury and were assessed to be survivable. In-flight collision with terrain represented 15 percent of the sample.

TABLE 3.3. FREQUENCY OF FIRST-EVENT OCCURRENCE FOR THE TOTAL SAMPLE

Type of First Event	Number of Occurrences	Percentage
Abrupt Maneuver	1	2.5
Airframe/Component/System Failure or Malfunction	3	7.5
Altitude Deviation, Uncontrolled	1	2.5
Dragged Float	7	17.5
In-Flight Collision With Terrain	6	15.0
In-Flight Encounter with Weather	1	2.5
Nose Down	1	2.5
Loss of Control - In-Flight	2	5.0
Loss of Power (Unspecified Cause)	9	22.5
Loss of Power (Total) Mech. Failure/Malfunction	6	15.0
Loss of Power (Total) Non-mechanical	3	7.5
Total	40	100.0

3.1.4 Injury Distribution by Weight Class.

The injury severity distribution by weight class is shown in table 3.4 and it demonstrates the effect of aircraft weight on injury. A total of 42 percent of occupants onboard weight class A aircraft received fatal or serious injury compared with 29 percent for weight class B and 22 percent for weight class C. It is expected that injury severity and frequency will increase as aircraft weight/size decreases. Figure 3.2 illustrates this trend more clearly.

3.1.5 Injury Distribution by Accident Survivability.

Distributions of accident survivability relative to degree of occupant injury and aircraft weight class were made for this sample. Figure 3.3 presents the distribution of injury degree relative to accident survivability. The level of survivability could not be assessed for three of the

TABLE 3.4. OCCUPANT INJURY SEVERITY DISTRIBUTION BY AIRCRAFT WEIGHT CLASS

Occupant Injury Level	Aircraft Weight Class			Totals
	Class A	Class B	Class C	
Fatal	36	7	1	44
Serious	3	5	1	9
Minor	14	9	4	27
None	40	20	3	63
TOTALS	93	41	9	143
TOTAL NUMBER OF OCCUPANTS = 143				

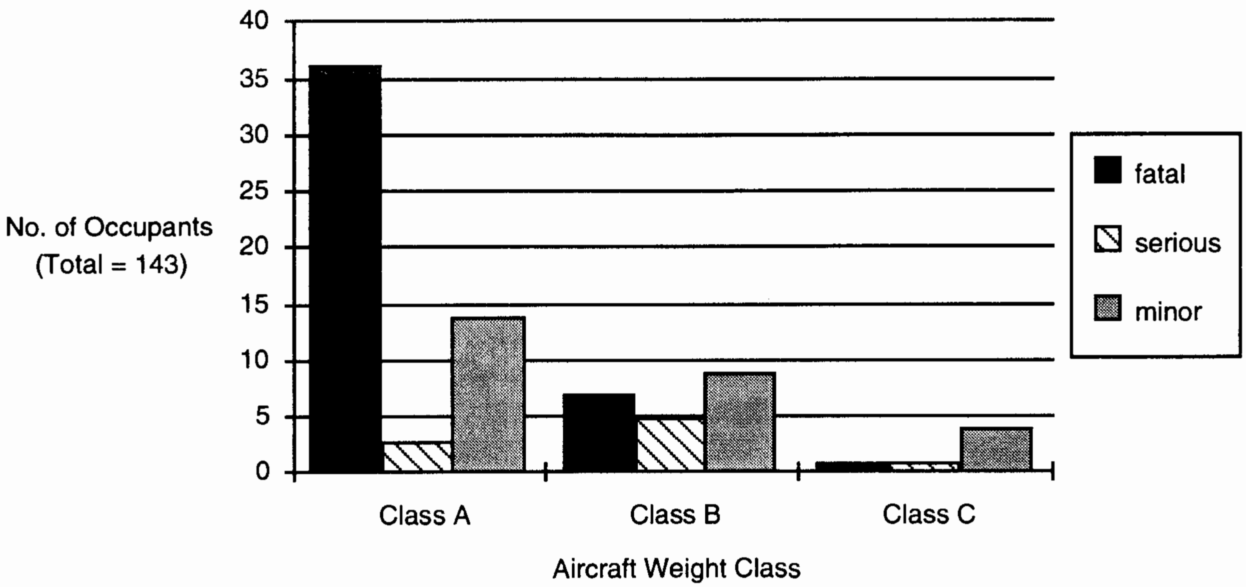


FIGURE 3.2. INJURY SEVERITY DISTRIBUTION BY AIRCRAFT WEIGHT CLASS

unknown. For those accidents assessed as either survivable or partially survivable there were occurrences of injury, which points to a population of significant survivable accidents. A total of 11 accidents in this sample satisfied the definition of significant survivable. The injury frequency for these significant survivable accidents is presented in table 3.5.

Examination of the distribution of accident survivability relative to aircraft weight class, presented in table 3.6, shows that accident severity was relatively uniform for aircraft weight classes A and B. A total of 22.5 percent of all weight class A accidents were nonsurvivable, compared to 20 percent for weight class B and 0 percent for weight class C (which only had 4 total accidents).

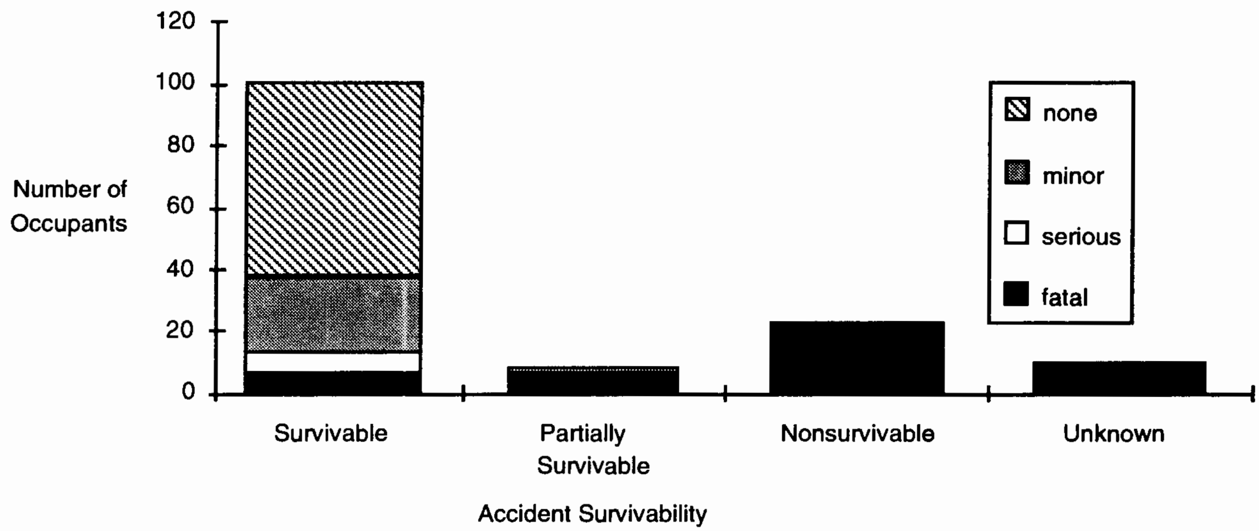


FIGURE 3.3. DISTRIBUTION OF INJURY DEGREE BY ACCIDENT SURVIVABILITY

TABLE 3.5. INJURY FREQUENCY FOR SIGNIFICANT SURVIVABLE ACCIDENTS

Injury Percentage			Total on Board	Number Fatally or Seriously Injured
Fatal	Serious	Minor		
20	16	27	55	20

11 cases were significant survivable

TABLE 3.6. ACCIDENT SURVIVABILITY BY WEIGHT CLASS, TOTAL SAMPLE

Weight Class	Survivable	Partially Survivable	Nonsurvivable	Unknown	Totals
A	20	1	7	3	31
B	4	0	1	0	5
C	3	1	0	0	4
Totals	27	2	8	3	40

3.2 IMPACT PARAMETERS.

The impact parameters and the impact attitudes and velocities of the aircraft are an indicator of accident severity and survivability. Trends found in the frequency and magnitude of these parameters are significant because they help to characterize what conditions the aircraft and its occupants are typically subjected to in a water-related event. In addition, such a characterization can support establishment of design requirements.

3.2.1 Impact Attitude.

The impact pitch angle distribution for this sample relative to accident survivability is presented in figure 3.4. A total of 57 percent of all known pitch angles for survivable and partially survivable accidents occurred between ± 10 degrees. It should be noted that the 7 pitch angles indicated for survivable accidents in the 85 to 90 degree range were for the seaplane noseover incidents mentioned earlier and do not indicate a vertical impact from a significant height. The principal impact for these noseover incidents was determined to be the contact of the aircraft nose with the water.

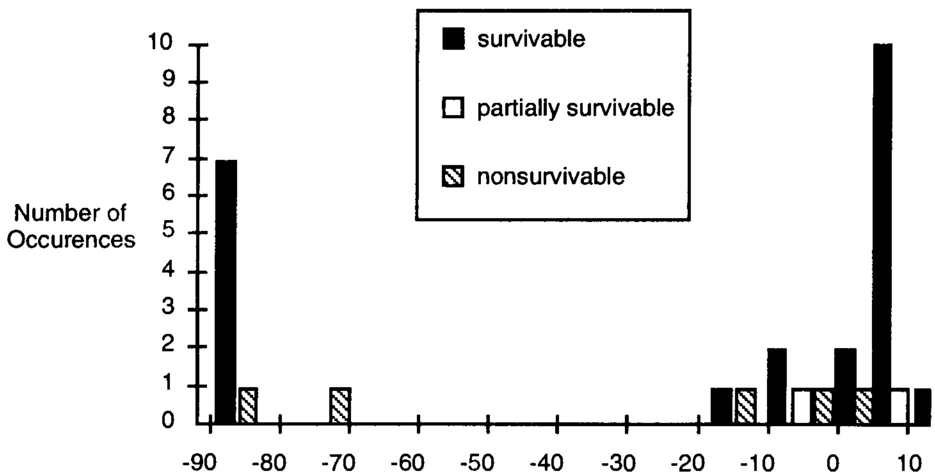


FIGURE 3.4. DISTRIBUTION OF IMPACT PITCH ANGLE RELATIVE TO ACCIDENT SURVIVABILITY, TOTAL SAMPLE

The impact roll angle distribution for this sample relative to accident survivability is presented in figure 3.5. A total of 84 percent of all known roll angles for survivable and partially survivable accidents were determined to be 0 degrees. The three extreme impact roll angles, 85 degrees and greater, were for one partially survivable and two nonsurvivable accidents.

The impact yaw angle distribution for this sample relative to accident survivability is presented in figure 3.6. All known yaw angles for survivable and partially survivable accidents were determined to be 0 degrees.

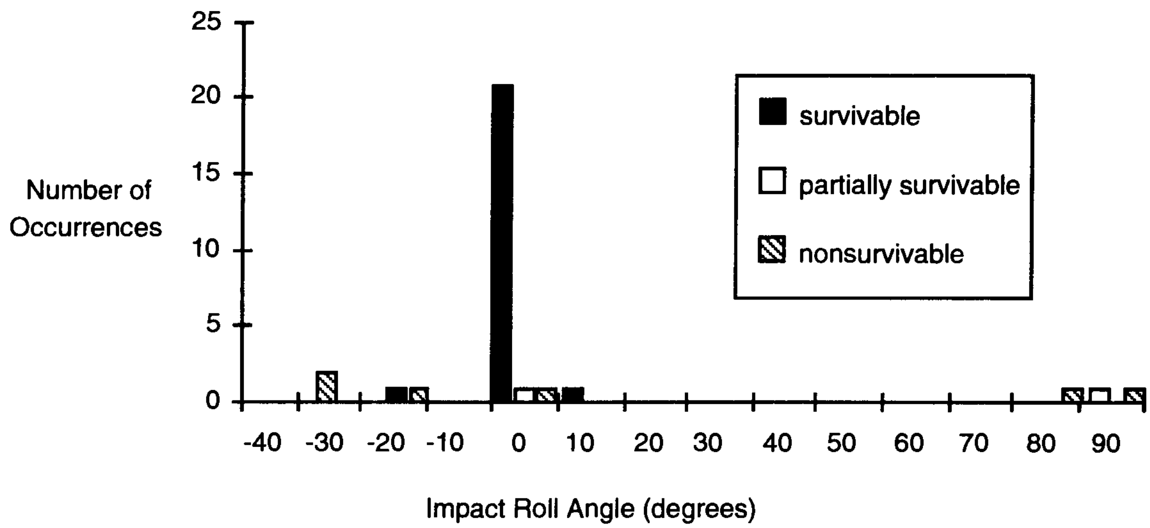


FIGURE 3.5. DISTRIBUTION OF IMPACT ROLL ANGLE RELATIVE TO ACCIDENT SURVIVABILITY, TOTAL SAMPLE

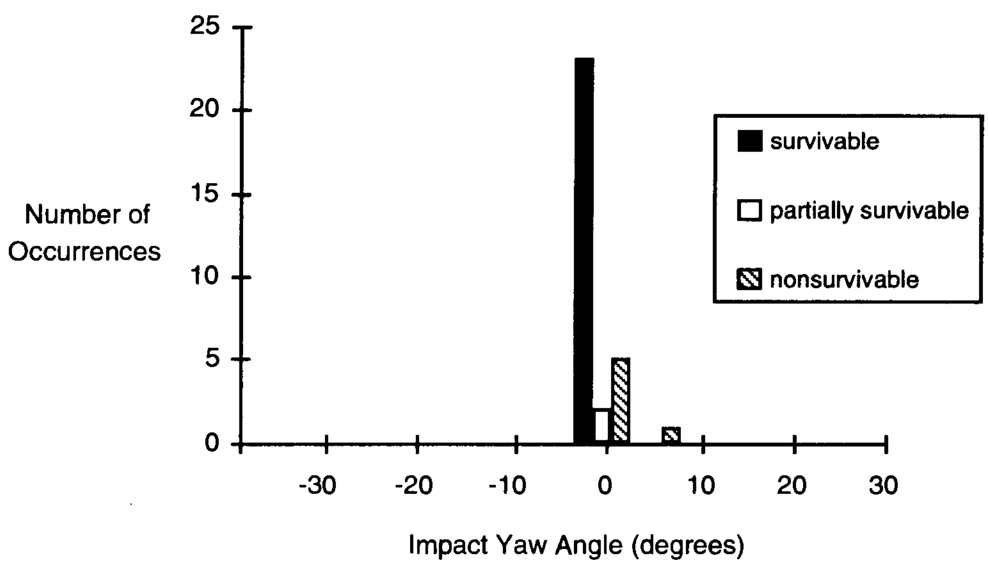


FIGURE 3.6. DISTRIBUTION OF IMPACT YAW ANGLE RELATIVE TO ACCIDENT SURVIVABILITY, TOTAL SAMPLE

3.2.2 Impact Velocities.

The distribution of vertical impact velocities relative to impact survivability is presented in figure 3.7. The cumulative frequency of occurrence of vertical impact velocities for survivable and partially survivable accidents is shown in figure 3.8. It can be seen in figure 3.8 that the 95th percentile vertical impact velocity is 22 ft/sec for survivable and partially survivable accidents. The velocities for the seven float plane noseover incidents are not included in either the plots of the distribution or the cumulative frequency. The vertical velocities for these incidents were determined to be upward, relative to the aircraft, because of the overturning pitching action of the aircraft. Therefore they were not consistent in direction with the rest of the sample. The estimates of the vertical velocities for these noseovers ranged from 4 to 6 ft/sec.

The distribution of longitudinal impact velocities relative to accident survivability is shown in figure 3.9. It should be noted that the two velocities in the 200 to 205 ft/sec area are for nonsurvivable accidents and that the remaining velocities are less than or equal to 145 ft/sec. The cumulative frequency of occurrence of longitudinal impact velocities for survivable and partially survivable accidents is presented in figure 3.10. Figure 3.10 shows the 95th percentile longitudinal velocity is 143 ft/sec for survivable and partially survivable accidents.

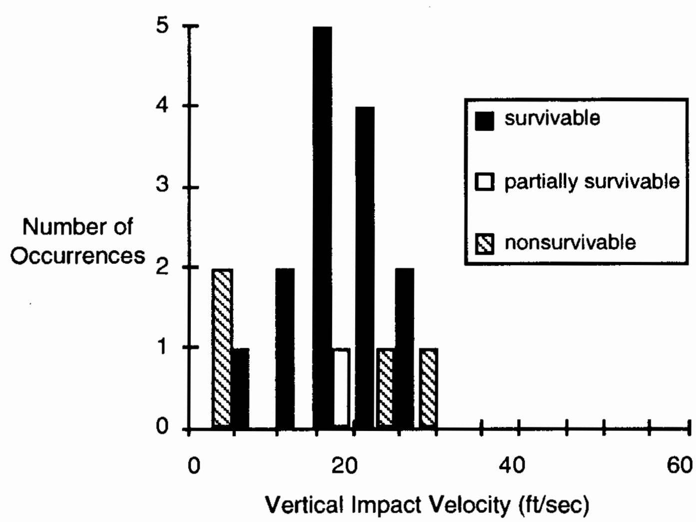


FIGURE 3.7. DISTRIBUTION OF VERTICAL IMPACT VELOCITY RELATIVE TO ACCIDENT SURVIVABILITY

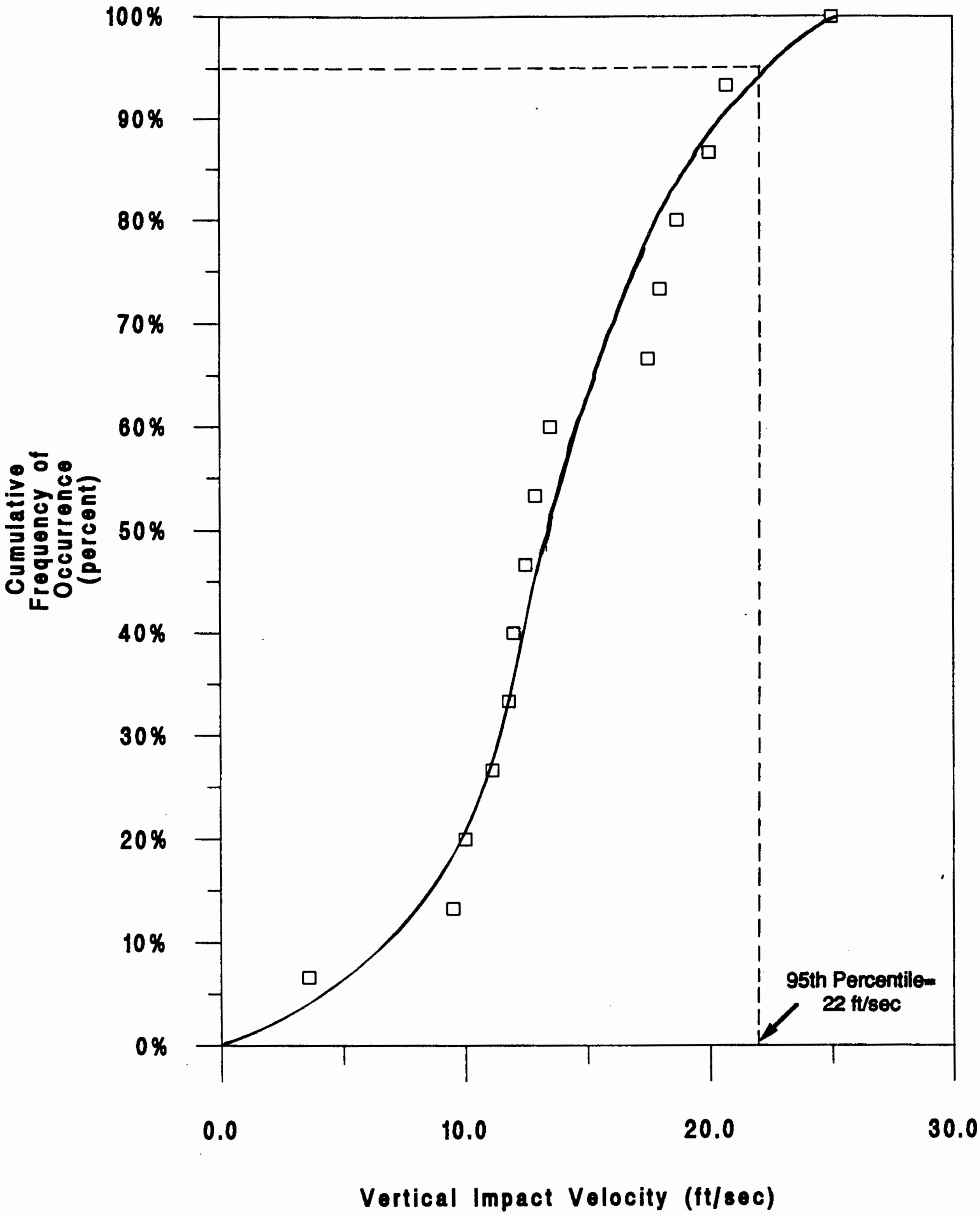


FIGURE 3.8. CUMULATIVE FREQUENCY OF OCCURRENCE OF VERTICAL IMPACT VELOCITIES, SURVIVABLE AND PARTIALLY SURVIVABLE ACCIDENTS

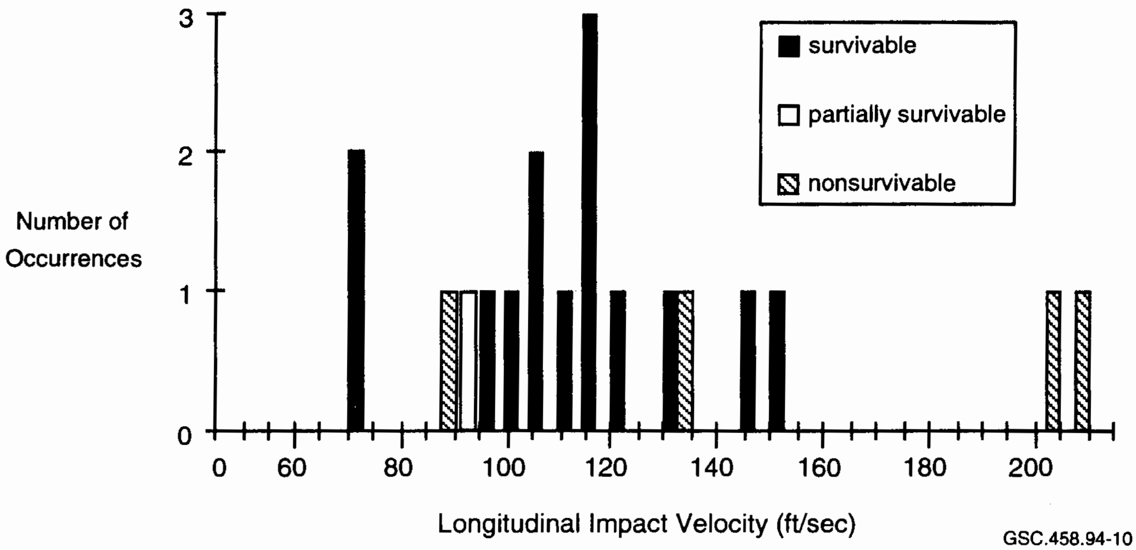


FIGURE 3.9. DISTRIBUTION OF LONGITUDINAL IMPACT VELOCITY RELATIVE TO ACCIDENT SURVIVABILITY

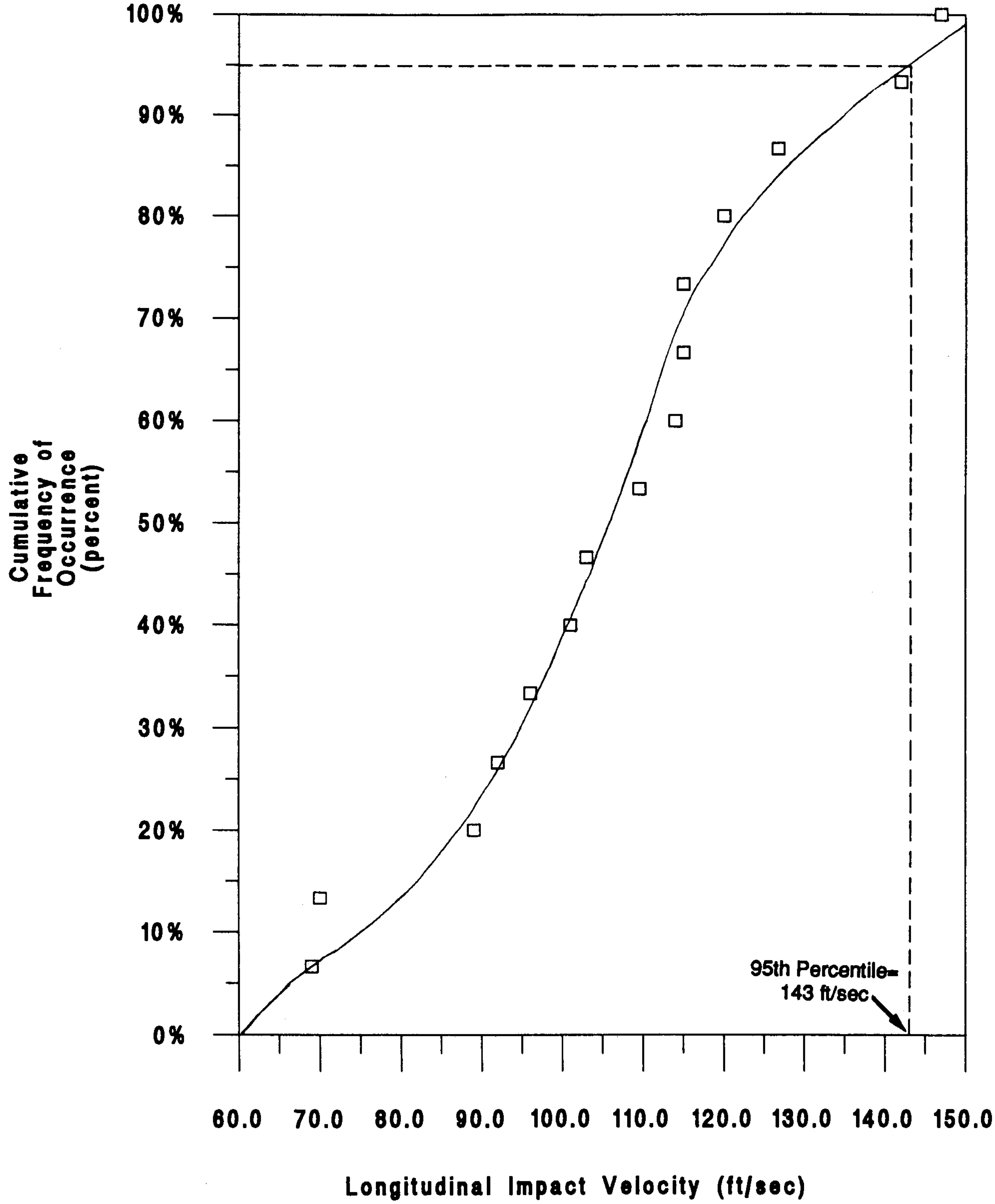


FIGURE 3.10. CUMULATIVE FREQUENCY OF OCCURRENCE OF LONGITUDINAL IMPACT VELOCITIES, SURVIVABLE AND PARTIALLY SURVIVABLE ACCIDENTS

The distribution of lateral impact velocities relative to accident survivability is shown in figure 3.11. From this plot of the lateral impact velocity distribution it can be seen that there was no lateral velocity in the majority of the sample. The cumulative frequency of occurrence of lateral impact velocities for survivable and partially survivable accidents is shown in figure 3.12. The 95th percentile lateral impact velocity is 4 ft/sec for survivable and partially survivable accidents.

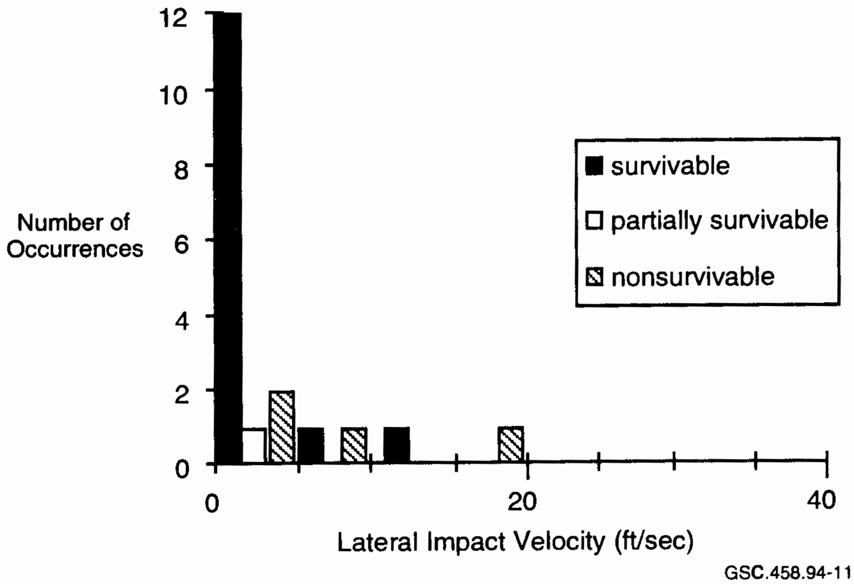


FIGURE 3.11. DISTRIBUTION OF LATERAL IMPACT VELOCITY RELATIVE TO ACCIDENT SURVIVABILITY

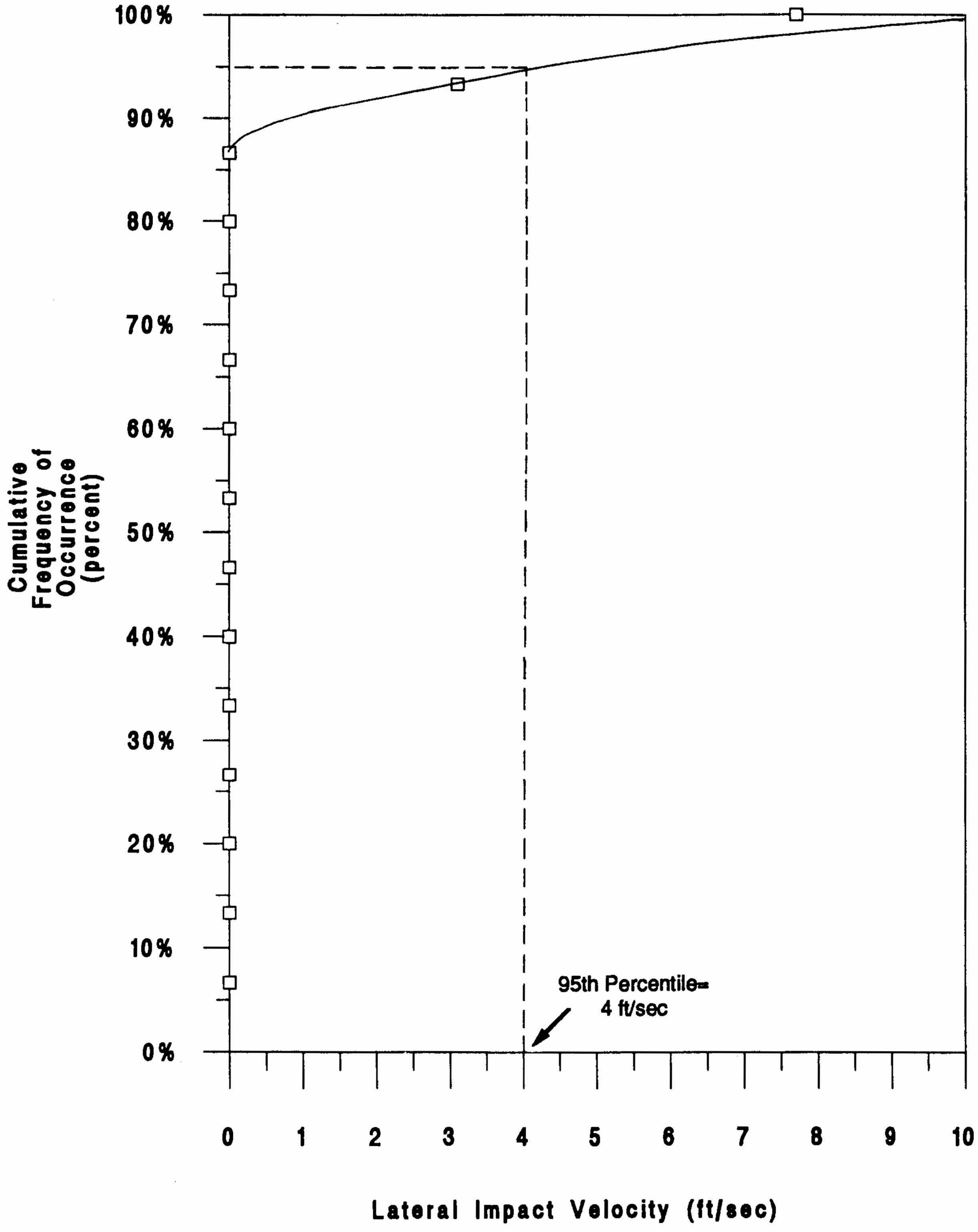


FIGURE 3.12. CUMULATIVE FREQUENCY OF OCCURRENCE OF LATERAL IMPACT VELOCITIES, SURVIVABLE AND PARTIALLY SURVIVABLE ACCIDENTS

The 95th percentile velocities can be used to establish an envelope relative to the longitudinal, vertical, and lateral velocity components. Figure 3.13 shows the 95th percentile envelope for vertical versus longitudinal impact velocity. Plotted in this figure are data points coded for level of survivability that represent accident occurrences from the sample. It can be seen that the majority of the nonsurvivable accidents lie outside the envelope. Figures 3.14 and 3.15 provide similar representations of the data for vertical versus lateral and lateral versus longitudinal respectively.

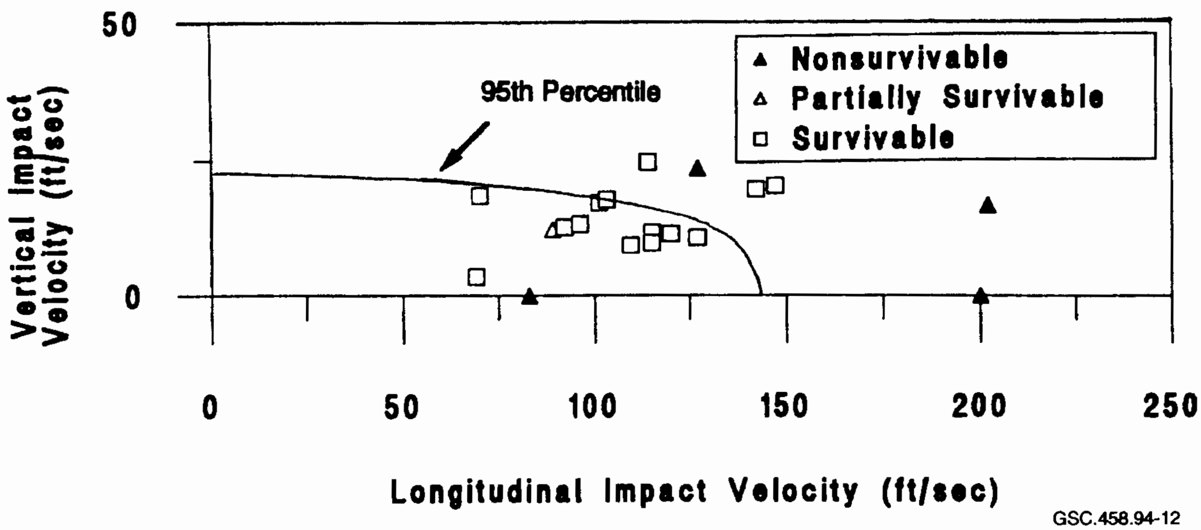


FIGURE 3.13. SURVIVABILITY FOR VERTICAL VS. LONGITUDINAL IMPACT VELOCITY COMPONENTS

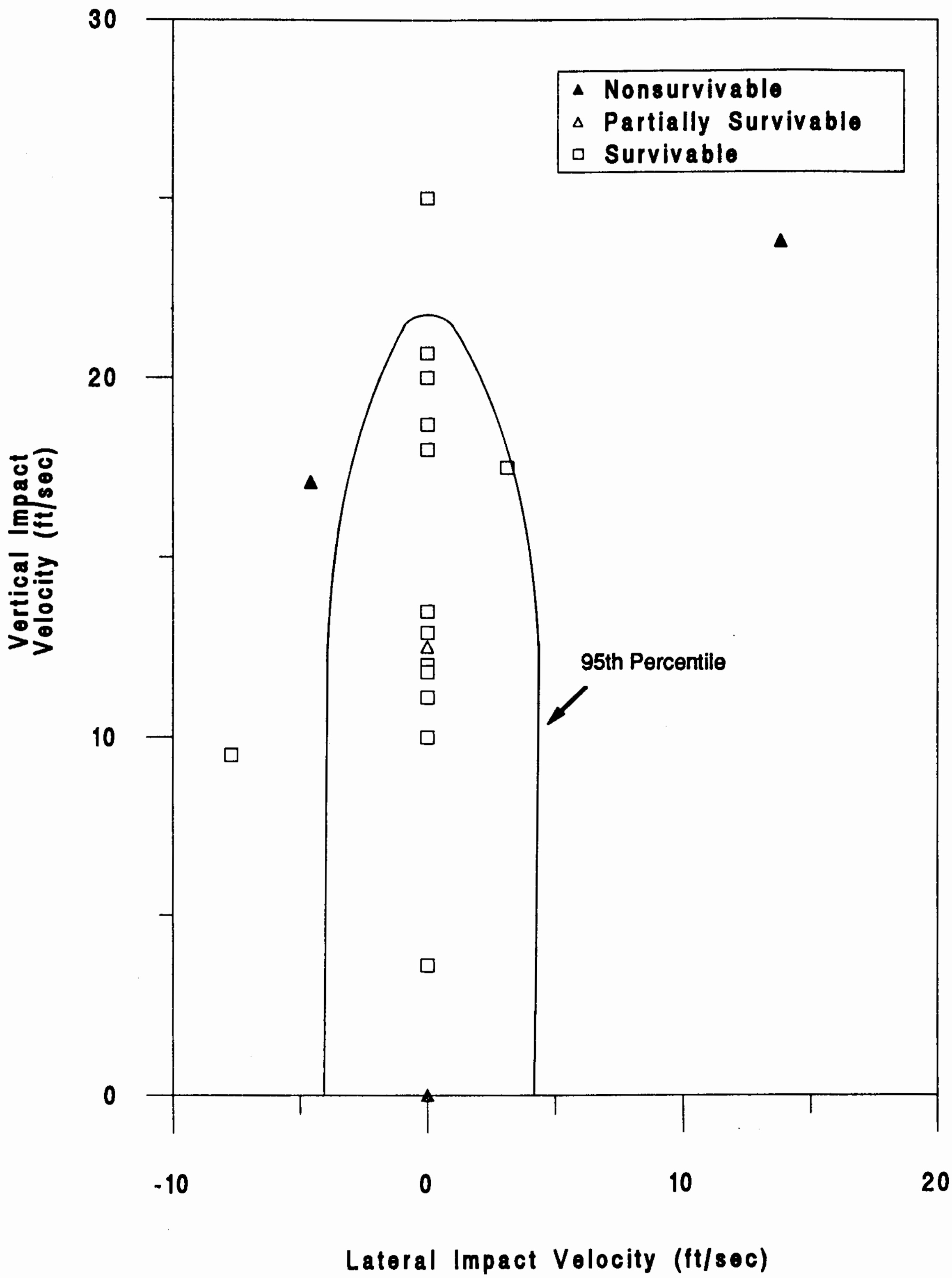


FIGURE 3.14. SURVIVABILITY FOR VERTICAL VS. LATERAL IMPACT VELOCITY COMPONENTS

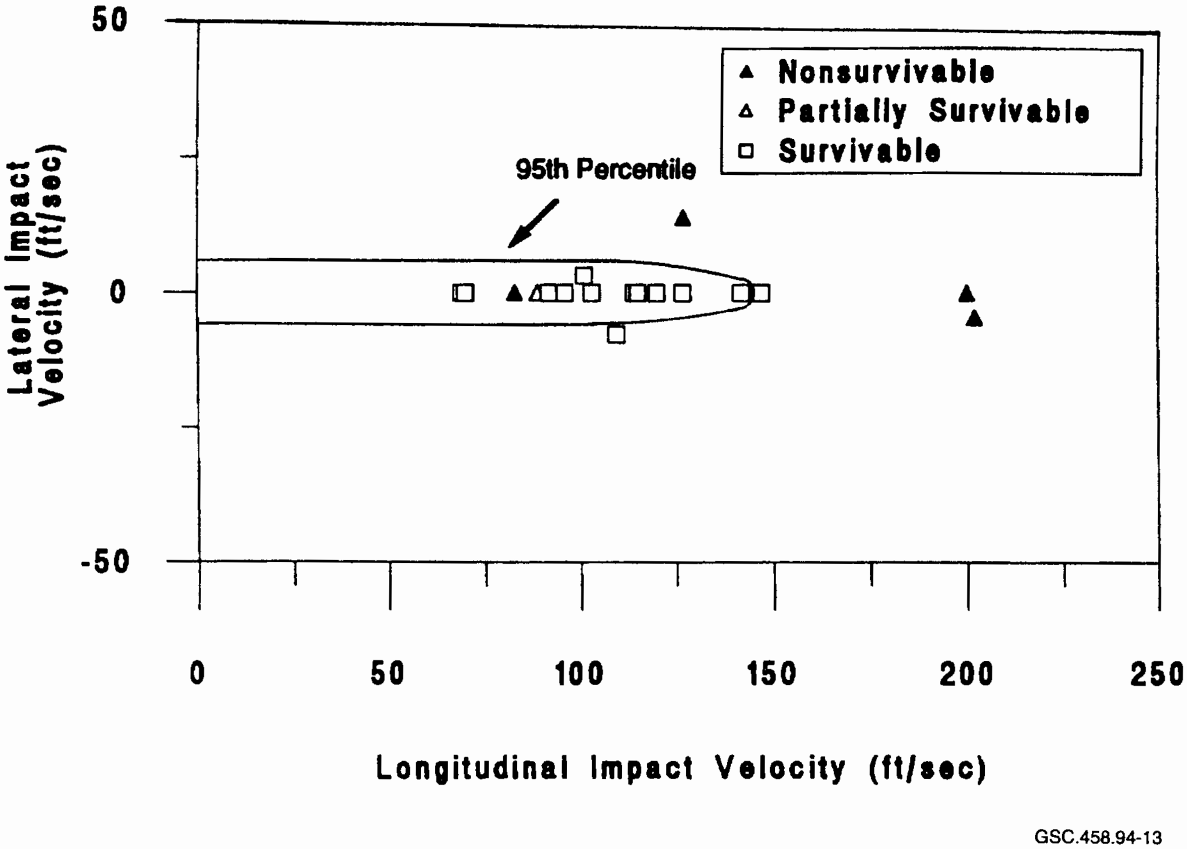


FIGURE 3.15. SURVIVABILITY FOR LATERAL VS. LONGITUDINAL IMPACT VELOCITY COMPONENTS

3.3 INJURIES: TYPES, CAUSES, AND SEVERITY.

The types, causes, and severity of injuries received by occupants help to define the hazards that exist to occupant survivability. When examining water-related impacts a distinction must be made between those injuries received from the impact and those received after the impact. Even after an injury-free touchdown, the occupants face hazards such as drowning and exposure presented by the water environment. Several of the case studies presented in section 4 demonstrate this point. The injury types, causes, and severity as they relate to impact conditions, including restraint use, and post-impact conditions were examined.

3.3.1 Impact Injuries.

The frequency of occurrence of impact injury causes is presented in table 3.7. The ten occurrences of a propeller causing injury resulted from a single accident in which two occupants received multiple injuries when a wing-mounted engine was dislodged and the propeller penetrated the cabin. The percentage of injuries with unknown cause was very high at 81 percent. The frequency of occurrence for impact injury type, given in table 3.8, is more informative. Injuries that can be attributed to flailing, laceration, contusion, and fracture, together represent a total of 64 percent of all impact injury types.

TABLE 3.7. FREQUENCY OF OCCURANCE — IMPACT INJURY CAUSES

Impact Injury Cause	Number of Occurrences	Percentage
Whole-Body Acceleration Forces	1	1
Instrument Panel	2	2
Propeller	10	10
Window	2	2
Unknown	80	81
Other	4	4
Total	99	100

An examination of impact injury severity relative to restraint use presents several interesting points regarding restraint use. Figure 3.16 shows the distribution of Accident Injury Severity (AIS) for impact injuries relative to the type of occupant restraint worn, while table 3.9 defines the AIS severity codes. To provide a basis for comparison, table 3.10 shows the number of occupants that used each restraint type. Of note is the large percentage of occupants for whom restraint use is unknown. Although the number of occupants that used a lap belt only was 1.6 times the number that used lap belts and shoulder harnesses, the number of documented injuries suffered by occupants wearing a lap belt only was 18 times that for occupants who wore a lap belt and shoulder harness.

TABLE 3.8. FREQUENCY OF OCCURRENCE — IMPACT INJURY TYPES

Impact Injury Type	Number of Occurrences	Percentage
Avulsion	1	1
Concussion	2	2
Contusion	8	8
Dislocation	1	1
Fracture	29	29
Fracture and Dislocation	1	1
Laceration	26	26
Perforation (Puncture)	1	1
Severance	2	2
Transection	1	1
Injury, Unknown Type	21	21
Other	7	7
Total	100	100

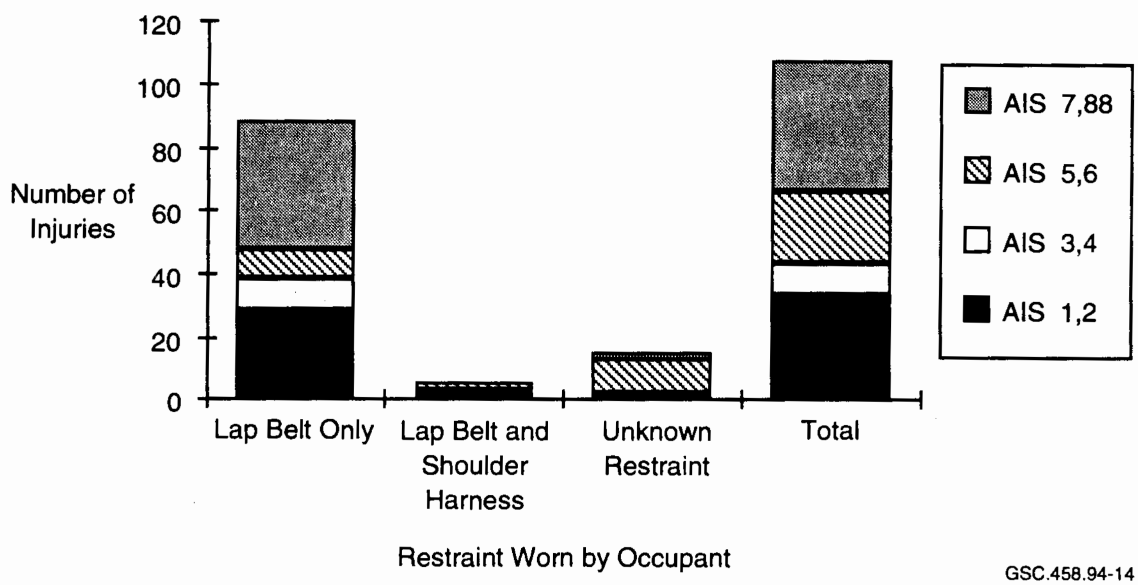


FIGURE 3.16. DISTRIBUTION OF AIS IMPACT INJURY SEVERITY RELATIVE TO OCCUPANT RESTRAINT

TABLE 3.9. DEFINITION OF AIS SEVERITY CODES

AIS Code	Definition
0	Not injured
1	Minor injury
2	Moderate injury
3	Serious injury (not life-threatening)
4	Severe injury (life-threatening, survival probable)
5	Critical injury (survival uncertain)
6	Maximum (untreatable - fatal)
7	Injured (unknown severity)
88	Unknown if injured

TABLE 3.10. OCCUPANT USE OF RESTRAINT

Use of Restraint	
Restraint Type	Number of Occupants
Lap belt only	49
Lap belt and shoulder harness	30
Unknown	64
Total	143

3.3.2 Post-Impact Injuries.

The frequency of occurrence of post-impact occupant injury causes is shown in table 3.11. This table shows that there were two main causes of post-impact injury: exposure and drowning. Inhalation of water occurred more frequently than exposure and caused 67 percent of the post-impact hazard to the occupants. Table 3.12 presents the frequency of occurrence for post-impact injury types. This table shows that suffocation from inhalation of water was the predominant injury type. In all, the suffocation experienced by 15 of these 16 occupants was fatal and resulted in death by drowning. The remaining eight post-impact injuries were of unknown type but were known to be caused by exposure.

TABLE 3.11. FREQUENCY OF OCCURRENCE – POST-IMPACT INJURY CAUSES

Post-Impact Injury Cause	Number of Occurrences	Percentage
Exposure	8	33
Inhalation of Water	16	67
Total	24	100

TABLE 3.12. FREQUENCY OF OCCURRENCE – POST-IMPACT INJURY TYPES

Post-Impact Injury Type	Number of Occurrences	Percentage
Suffocation	16	67
Injury, Unknown Type	8	33
Total	24	100

3.4 AIRCRAFT FLOTATION.

Aircraft flotation behavior establishes the adequacy of current aircraft flotation devices to provide for occupant egress and survivability. As noted previously in section 3.1.2, a total of 13 of the 40 aircraft in the sample either had floats or amphibious hulls and were intended for water landings. The remaining portion of the sample were land-based planes. The investigations made into their flotation behavior reflect this distinction.

3.4.1 Water Impact Conditions.

The sea state that the aircraft encounters upon impact can directly influence its time upright and afloat. The distribution of sea states encountered by the aircraft in this sample is shown in figure 3.17 The classifications used to categorize the wave heights are those from the World Meteorological Organization as used by the FAA to regulate rotorcraft ditching performance (reference 4). All but one of the aircraft for which wave height could be determined encountered sea states of three or less. The wave height could not be determined in 30 percent of the cases.

3.4.2 Aircraft Flotation Behavior.

As will be seen in section 3.5, most aircraft were generally afloat or partially afloat at the time of occupant egress. A distribution of the aircraft's time afloat is shown in figure 3.18 The time upright indicates the aircraft time in the upright position prior to overturning after the impact. The overturning may have been caused by the impact as in the several cases documented as noseover incidents or by flooding of the aircraft with water. Figure 3.19 shows the distribution of time upright for the sample. Note the large proportion of aircraft that remained upright for an extended period of time. The causes for aircraft overturning in the water is important because it may indicate areas for improvements that can be made in either aircraft design, performance, or emergency landing procedures. Figure 3.20 shows the distribution of causes of aircraft overturning as assessed during accident reconstruction. Significantly, a large proportion of aircraft remained upright in the water. Float problems (i.e., seaplane noseovers) and impact parameters were the main reasons known to have caused aircraft to overturn.

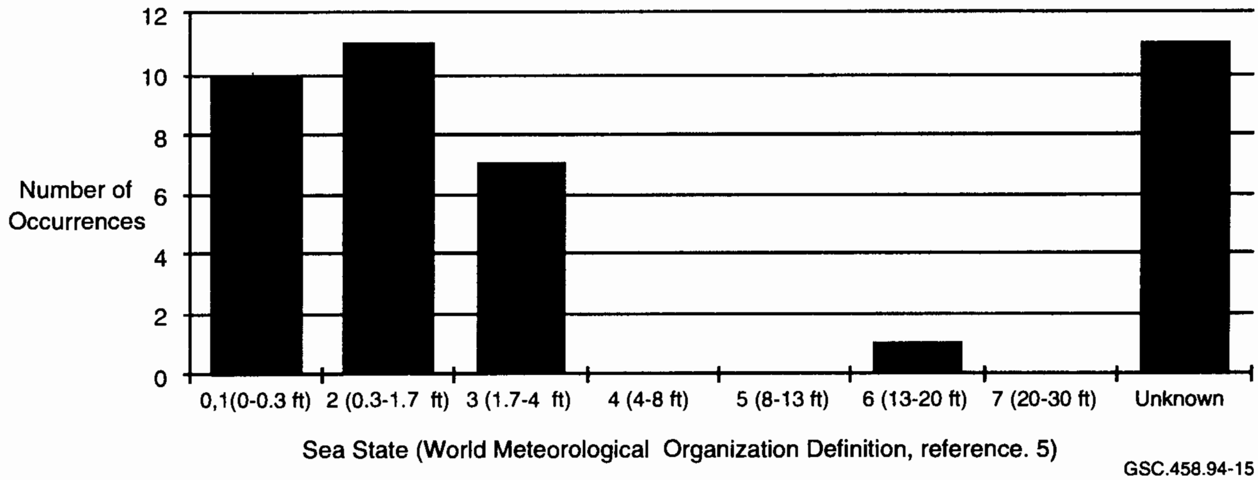


FIGURE 3.17 SEA STATES ENCOUNTERED BY AIRCRAFT, TOTAL SAMPLE

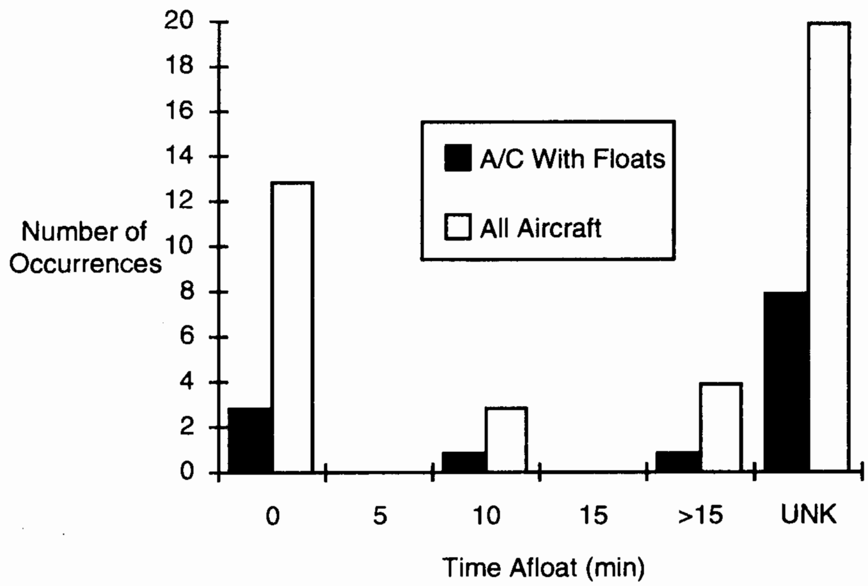


FIGURE 3.18. AIRCRAFT TIME AFLOAT RELATIVE TO AIRCRAFT FLOAT CONFIGURATION

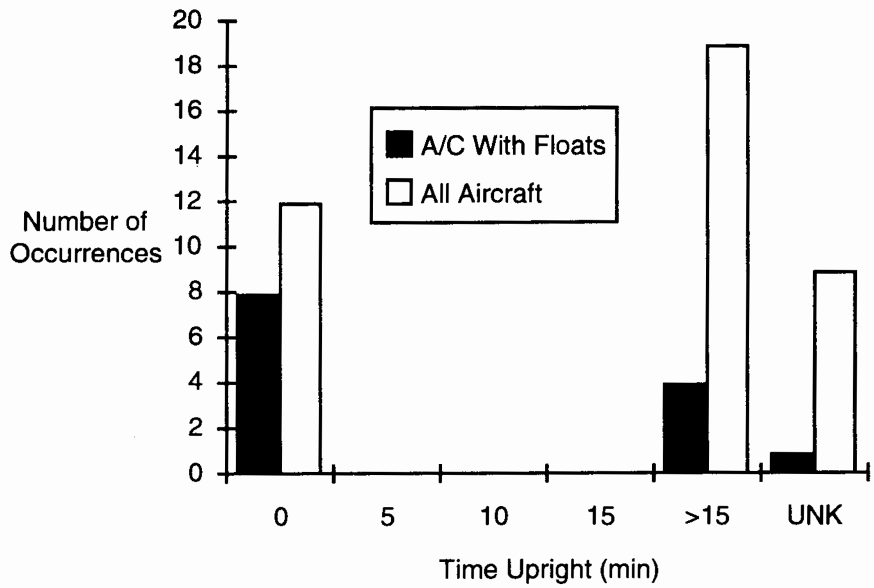


FIGURE 3.19. AIRCRAFT TIME UPRIGHT RELATIVE TO AIRCRAFT FLOAT CONFIGURATION

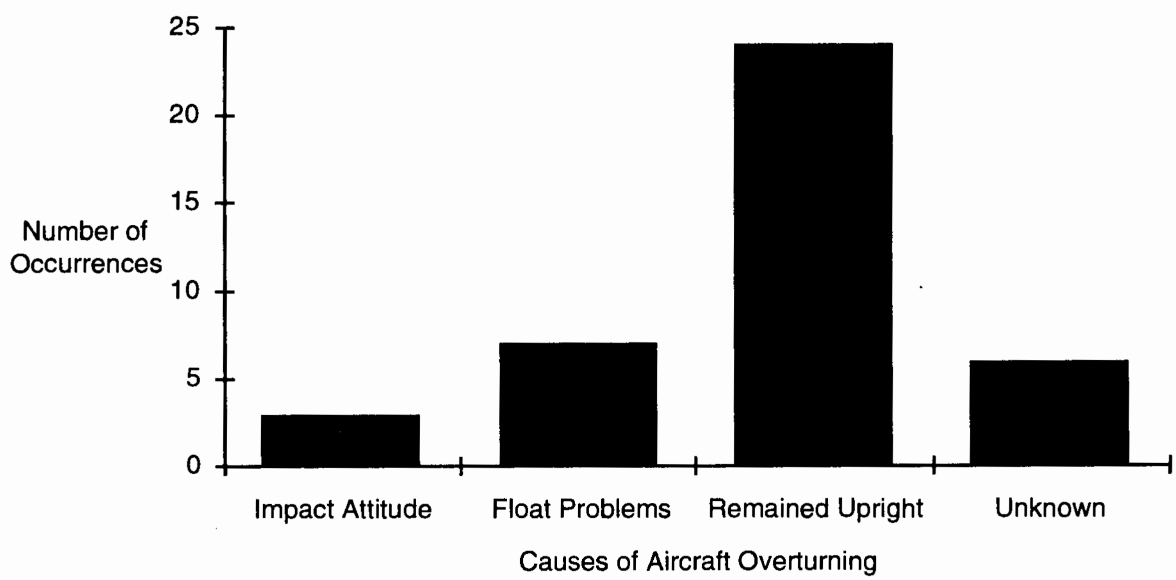


FIGURE 3.20. DISTRIBUTION OF CAUSES OF AIRCRAFT OVERTURNING

3.5 OCCUPANT FLOTATION AND EGRESS.

Two important factors in post-impact survivability in the water impact environment are: (1) successful occupant egress from the downed aircraft; and (2) effective personal flotation equipment for survival after egress. Successful occupant egress from the downed aircraft is greatly affected by the following factors:

a. Aircraft flotation attitude (upright or inverted).
b. Aircraft status at egress (e.g., floating, submerged).
c. Aircraft time afloat.

Additionally, personal flotation devices should be available to all and they should maintain effectiveness for an extended period of time.

3.5.1 Occupant Egress.

For cases in which the aircraft's status at egress was known, the number of aircraft that were floating was approximately equal to the number that were partially submerged. These were the two main conditions that occupants faced when exiting the downed aircraft. Figure 3.21 shows the distribution of aircraft status as occupant egressed, and it shows that only one occupant egressed when the aircraft was fully submerged.

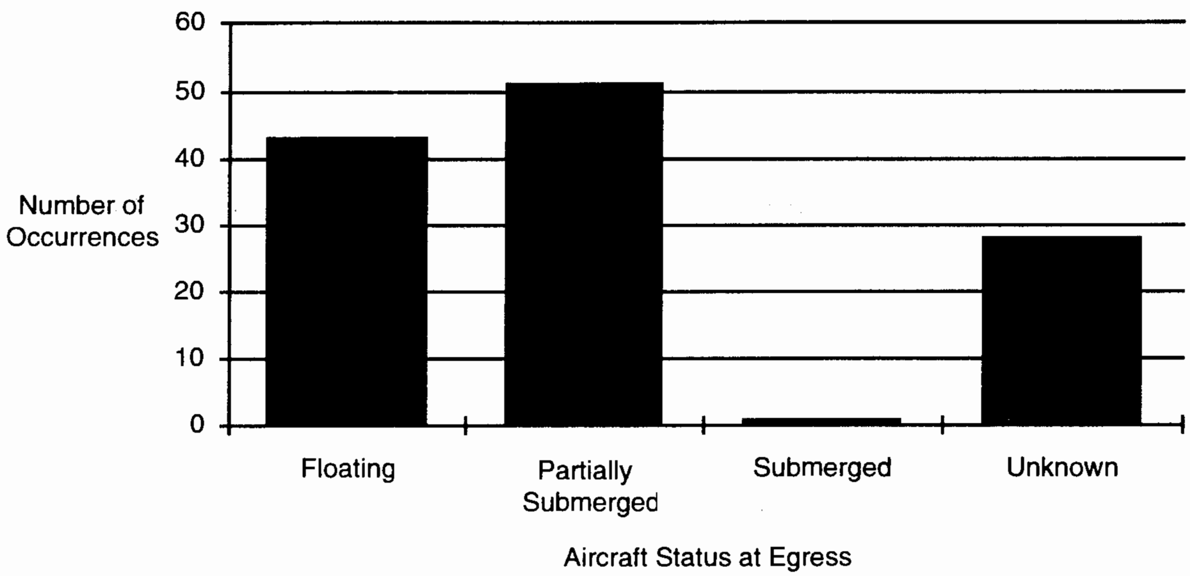


FIGURE 3.21. DISTRIBUTION OF AIRCRAFT STATUS AT TIME OF OCCUPANT EGRESS

3.5.2 Personal Flotation Equipment Availability, Use, and Performance.

The availability, use, and performance of personal flotation equipment in the accident cases examined in this investigation can be summarized as follows:

a. A total of 55 of the 143 occupants in the sample had personal flotation equipment available.

b. Of the 55 who had personal flotation equipment available, 23 people used it.

c. There were no noted cases of personal flotation equipment not functioning properly.

By correlating use of personal flotation equipment with the 15 drownings that occurred, the usefulness of personal flotation devices may be evaluated. Specifically, of the 15 occupants that drowned, 6 had no personal flotation device available, 6 had personal flotation device available but did not use it, and the use of personal flotation equipment is unknown for 3 occupants.

<u>3.5.3 Occupant Exposure to the Post-Impact Water Environment</u>.

Another important factor in assessing the post-impact survivability requirements of aircraft occupants exposed to water impacts is the length of time that they are in the water environment. Figure 3.22 presents the distribution of occupant time in the water for the total sample. The distribution falls into three main groups: 0 to 10 minutes, 30 to 40 minutes, and 60 and above minutes. The occupants who were recorded as being in the water for 60 minutes and longer were all determined to have been impact fatalities, therefore, the first two distributions are the only ones that need to be considered to meet this effort's objectives.

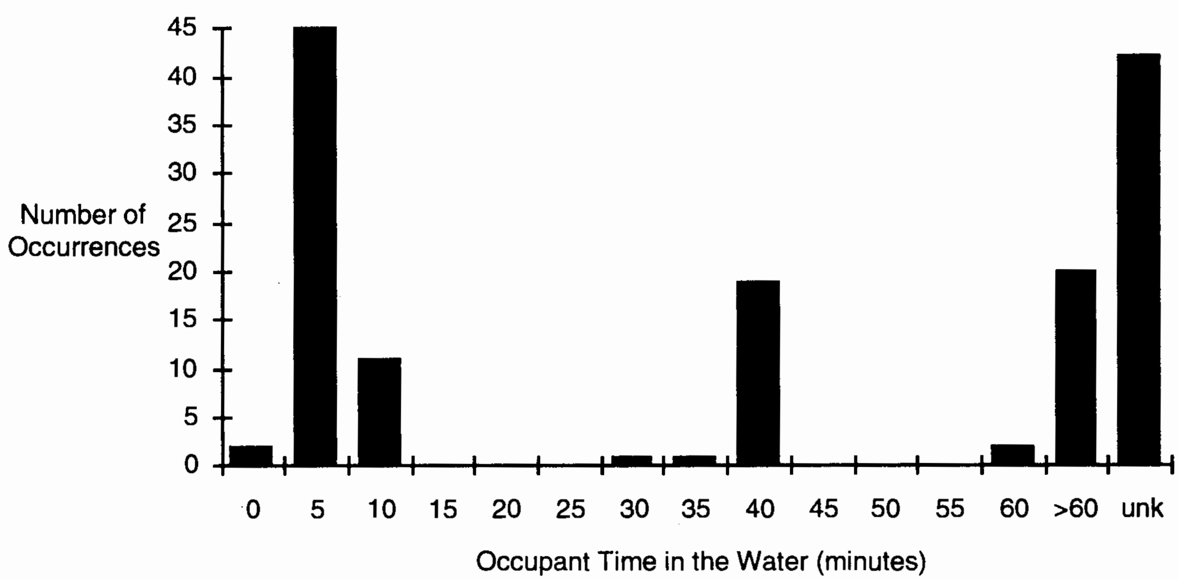


FIGURE 3.22. DISTRIBUTION OF OCCUPANT TIME IN WATER

3.6 SCENARIO ESTABLISHMENT.

An effective means of summarizing the results of this investigation was to establish scenarios that described the ways aircraft were typically found to impact the water surface in survivable and partially survivable accidents. These scenarios provide the velocities and orientations of the aircraft at impact as well as the resulting occupant injury levels. Drawing upon the results of the accident reconstruction task, patterns in impact sequences were observed and two impact scenarios established. Also the impact parameters, including flight path angle, and the accident narratives were used to support the aforementioned scenarios development. The scenarios are:

a. Forced Landing – Normal.
b. Landing – Noseover.

An added complication in this study, however, was that for the occupants, hazards to survivability did not cease at impact but continued as new hazards appeared after impact. Therefore two post-impact scenarios were established. These scenarios were:

a. Immediate sinking of the aircraft (< 90 sec.).
b. Delayed sinking of the aircraft (> 90 sec.).

3.6.1 Water Impact Scenarios.

The impact scenarios were defined by the reconstructed sequence of events that led to impact. The definitions used for the water impact scenarios are as follows:

a. Forced Landing – Normal — A controlled aircraft landing on the water. Impact attitude — pitch, roll, and yaw $\leq \pm 20$ degrees.

b. Landing – Noseover — An aircraft that nosed over after dragging a float or other protruding structure when attempting a water landing.

In a total of 14 accident cases, 48 percent of the survivable and partially survivable accidents, satisfied the definition for the first water impact scenario. A total of 9 cases, 31 percent of the survivable and partially survivable accidents, satisfied the second scenario definition. The noseovers that occurred upon landing represented 23 percent of the total sample and thus were a significant part of the accidents studied.

Table 3.13 presents the results of this scenario development task by showing the numbers and percentages of accident cases that were in each impact scenario category. It can be seen that the most frequently occurring water impact scenario was that defined as a normal forced landing. Table 3.13 shows that 79 percent of all survivable and partially survivable accidents satisfied the impact scenario definitions.

TABLE 3.13. ACCIDENT FREQUENCY ACCORDING TO IMPACT SCENARIO TYPE, SURVIVABLE AND PARTIALLY SURVIVABLE ACCIDENTS

Scenario Type	Description	No. of Accidents	Percentage
1	Forced Landing – Normal	14	48
2	Landing – Noseover	9	31
Total Number of Survivable or Partially Survivable Accidents with Known Scenario Type		23	79
All Other Survivable or Partially Survivable Accidents		6	21
TOTAL		29	100

Injury frequency and severity by impact scenario type is presented by table 3.14. As can be seen from this table, in scenario two only 6 percent of the occupants involved in this type accident received serious or fatal injuries. By comparison, 27 percent of those in a scenario one accident received a serious or fatal injury. It should be emphasized again that these scenarios were based on survivable and partially survivable accidents.

Distributions of the resultant velocity relative to the flight path angle were made to characterize the impact for each scenario. These distributions are presented in figure 3.23. From these distributions it can be seen that data points for the first impact scenario accidents are mainly between a 100 to 150 ft/sec resultant velocity and 0 to 15 degrees flight path angle. The data points for the second impact scenario are clustered around 50 ft/sec resultant velocity and 85 degrees flight path angle. The number of accidents in each scenario was not sufficient to determine meaningful 95th percentile values for the velocity components.

TABLE 3.14. INJURY FREQUENCY FOR IMPACT SCENARIO TYPES FOR SURVIVABLE AND PARTIALLY SURVIVABLE ACCIDENTS

Scenario Type	Description	Injury Percentage			Total on Board	Number of Occupants with Fatal/Serious Injuries
		Fatal	Serious	Minor		
1	Forced Landing – Normal	14	13	18	65	11
2	Landing - Noseover	0	6	28	18	1
TOTAL					83	12

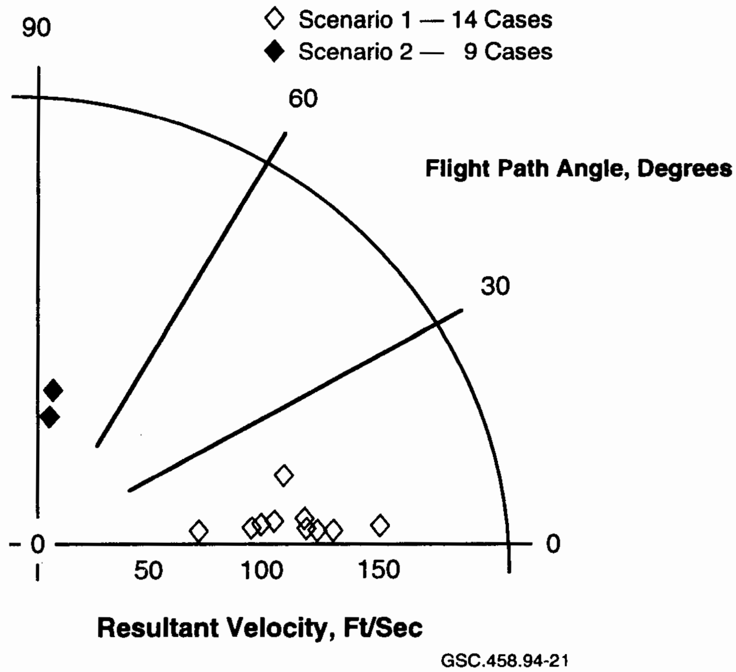


FIGURE 3.23. RESULTANT VELOCITY VS. FLIGHT PATH ANGLE RELATIVE TO IMPACT SCENARIO

3.6.2 Post Water Impact Scenarios

The criteria on which the two post-impact scenarios were based was the time the aircraft remained afloat after impact. The definitions used were as follows:

a. Immediate Sinking—Total submerging of the aircraft within 90 seconds of touchdown.

b. Delayed Sinking—Total submerging of the aircraft after 90 seconds had elapsed since touchdown.

A definition of "immediate" was chosen as 90 seconds for evacuation because it is the upper limit defined by 14 CFR 23.803 (reference 6) for emergency evacuation in a crash landing. It must be recognized that this regulation is defining evacuation time for ground impacts and does not necessarily refer to ditching situations. Table 3.15 shows that 7 percent of the survivable and partially survivable sample were cases of the aircraft sinking in 90 seconds or less, fulfilling post-impact scenario one. Although this scenario consists of only two accidents, it is important for comparison purposes with the delayed sinking scenario. A total of 41 percent were delayed sinking accidents. For 15 accidents, or 52 percent of the total sample, the time between touchdown and sinking could not be determined.

TABLE 3.15. ACCIDENT FREQUENCY ACCORDING TO POST-IMPACT SCENARIO TYPE

Scenario Type	Description	No. of Accidents	Percentage
1	Immediate Sinking	2	7
2	Delayed Sinking	12	41
Total Number. of Accidents with Known Scenario Type		14	48
Time to Overturning Undetermined		15	52
TOTAL		29	100

Injury frequency by post-impact scenario is presented in table 3.16. This table shows that the frequency of injury is much higher for cases of immediate sinking than it is for delayed sinking. A total of 30 percent of occupants involved in immediate sinkings received serious or fatal injuries compared to only 14 percent receiving such injuries in delayed sinkings. It should be noted that the higher frequency of serious and fatal injury for immediate aircraft sinkings as demonstrated by table 3.16 includes both impact and post-impact injury effects. However, the number of accidents for immediate sinking is small and, therefore, skews the data.

TABLE 3.16. INJURY FREQUENCY FOR POST-IMPACT SCENARIO TYPES FOR SURVIVABLE AND PARTIALLY SURVIVABLE ACCIDENTS

Scenario Type	Description	Injury Percentage			Total on Board	Number of Occupants with Fatal/Serious Injuries
		Fatal	Serious	Minor		
1	Immediate Sinking	14	16	32	37	11
2	Delayed Sinking	9	5	35	43	6
TOTAL					80	17

3.7 STRUCTURAL DAMAGE.

The behavior of the aircraft structure during an impact sequence is a significant factor in occupant survivability. The structure should:

a. Maintain a protective structural envelope around the occupants.

b. Help to attenuate the impact forces to maintain survivable acceleration conditions for the occupants.

An examination of the structural damage data obtained in this investigation focused on the damage that particular sections of the aircraft received and the effects of that damage on occupant injury.

A total of 15 cases in the accident sample had descriptions containing some detail of the structural damage incurred by the involved aircraft . These 15 accident cases included all levels of survivability. For discussion purposes structural damage has been organized according to aircraft section. It should be noted that this information is descriptive only and is an attempt to present and discuss those structural damage details that were found to occur in the water impact cases examined. Table 3.17 summarizes this damage data.

The nose section of the aircraft can serve an important role in absorbing energy in impacts with significant longitudinal velocities such as those typical of the two impact scenarios defined in section 3.6. In several instances noted in table 3.17, crush damage and airframe separation were observed. Separation of the nose does absorb impact energy but it may expose the remaining forward sections of the aircraft, such as the cockpit, to greater impact forces. In one case it was noted that the upper engine mount pads were broken and as a result the engine was tilted downward several degrees. The retention of high mass components such as an engine is important to prevent it from becoming a missile during a crash. Poor engine retention did contribute to occupant injury as will be seen later. It should be noted that large-mass items can be designed to safely separate from the aircraft on impact, thereby reducing their hazard to the airframe and occupants.

The fuselage damage types (table 3.17) are significant because the fuselage is the part of the aircraft that contains the occupants. In one case a fuselage split was noted. This airframe damage was potentially hazardous because such damage can not only expose the occupant to external hazards but may cause aircraft fragments or torn surfaces to contact the occupants and produce injury. In this accident, however, the fuselage split did not cause injury because the occupants were seated well forward of the split.

In another case a cabin was penetrated by a propeller. This damage was caused by rotation of the wing-mounted engine towards the fuselage. This propeller caused fatal injuries to two occupants seated in its path. This event illustrates the need for proper retention or properly designed release of large-mass components and the potential hazard posed by a rotating propeller that shifts from its original position.

Peeling of the cabin roof was observed in two of the cases examined. This damage type demonstrates the effect that hydrodynamic forces can exert on aircraft structure and the resultant damage to the occupiable volume. One case was a high speed longitudinal impact with a forward velocity estimated at approximately 200 ft/sec in which both occupants were

TABLE 3.17. SUMMARY OF IMPACT STRUCTURAL DAMAGE

Aircraft Component	Damage
Nose	• crush damage - lower nose • crush damage - longitudinal direction • buckling - top of nose • twisting - entire nose to one side • separation - entire nose • upper engine mount pads broken
Fuselage	• wrinkling of fuselage sides • fuselage indentation matching wing tip • fuselage bottom crushed upward and rearward • fuselage split behind wing • cabin roof peeled back by water • cabin penetrated by propeller
Tail	• separation of tail assembly • buckling of top of tailcone • peeling of fuselage side attached to separated tail
Wings	• wing tips separated • outer length of high wing deformed down • outer length of wing separated • leading edge of wing deformed • separation of entire wing • heavy crush of bottom side of inboard wings
Landing Gear	• deformed up from lowered position • separated from aircraft

ejected while still strapped in their seats. The other case was an aircraft that struck trees, struck the water, then came to rest inverted on the river bottom. The loss of upper cabin structure in this accident meant that the pilot was pinned against the river bottom by the inverted aircraft and drowned.

Damage to the tail cone and/or the empennage was noted in several cases. Such loss of aircraft structure is potentially hazardous if the motion of the separated tail section causes it to strike and compromise the occupied section of the aircraft during the impact sequence. The loss of the tail section may contribute to accelerated flooding of the downed aircraft.

The wings are a major structural component of the aircraft and the damage they experience can influence occupant survivability. There were cases of the wing separating from the aircraft in part or in whole. As noted for the tail section, the separation of large-mass items during the impact sequence is a potential hazard. There were, however, no noted instances of separated wing structure causing injury. Low-mounted wings represent a significant structural element located between the impact surface and the occupants. The wing box rigidity and the impact conditions determine whether this structure will absorb impact energy or transmit the impact forces directly to the floor above it. High-mounted wings represent an overhead mass that experiences downward acceleration from vertical impact forces. Downward bending of an outer-wing section was noted in one case.

Landing gear serve to absorb impact energy in ground impacts but their effect in water impacts is inconclusive. It was noted in one accident that the pilot lowered the landing gear prior to making a primarily longitudinal velocity forced landing. The pilot's stated intention was for the lowered gear to absorb some of the impact. The resulting impact was survivable and the pilot did not suffer any injuries. It is not known, however, to what extent the landing gear attenuated the impact forces.

4. REPRESENTATIVE CASE STUDIES.

Several case studies were included to characterize the commuter/air taxi water impact sequence. It was felt that a narrative format would be effective in bringing out peculiar aspects that could not be adequately covered in the statistical categorizations. The case studies presented herein describe a variety of crash sequences that highlight unique findings of this study. Photographic documentation is presented when available, especially of the occupiable volume and any damage experienced, to better convey the effects of water impact on the aircraft structure and its occupants. It is felt that the following case studies demonstrate the unique aspects of the commuter/air taxi water impact sequence as defined by this investigation.

4.1 CASE STUDY 1.

4.1.1 Background.

This case study documents an accident involving an aircraft from weight class A with a low wing and two wing-mounted engines impacting onto a salt water surface. The accident occurred in daylight. The wind speed was recorded at five kts., air temperature at 87°F, and water temperature at 82°F. The impact surface was recorded as calm with the wave height estimated to be one foot.

This accident satisfies impact scenario 1 (forced landing–normal). This accident also falls within the definition of post-impact scenario 2 (delayed overturn). In this accident, there were three people on board and no one was injured.

4.1.2 Accident Characteristics.

The accident began when the aircraft experienced surging of the right engine during an overwater descent. The pilot then shut down the right engine. Shortly after this the left engine began to run unevenly and it became difficult to maintain altitude. The pilot then ditched the aircraft, which was put down "fairly easily with only a couple of bumps", according to one passenger. A mayday call was made during the forced landing and the passengers were instructed to put on their lifejackets. The pilot and two passengers then exited the aircraft through the pilot's hatch onto the left wing and awaited rescue by a nearby fishing boat.

4.1.3 Impact Conditions.

The accident was reconstructed using the methodology presented in appendix C. The impact conditions developed during the reconstruction are given below.

Velocity Vectors:

Vertical	12 ft/sec
Longitudinal	115 ft/sec
Lateral	0

Flight Path Angle: 0 - 5°

Attitude:

Roll	0
Pitch	0 - 5° (noseup)
Yaw	0

4.1.4 Damage.

The aircraft sank approximately five minutes after touchdown in 800 feet of water and was not recovered. No details regarding damage to the aircraft structure were recorded.

4.1.5 Injury and Post-Impact Survivability.

Three occupants were on board this aircraft during the accident. None of the occupants were reported as having sustained any injuries. All of the occupants awaited rescue on the left wing of the floating plane for approximately one minute. Personal flotation equipment was available in the aircraft before the accident and was utilized by the occupants. A detailed description of occupant locations and their injury, egress, and restraint usage follows.

a. Pilot – left front. This occupant was reported to have remained uninjured and his restraint use is unknown. This occupant's path of egress was through the pilot's hatch.

b. Pax – right middle (row three). This occupant was reported to have remained uninjured and his restraint use is also unknown. This occupant's egress was also through the pilot's hatch.

c. Pax – right middle (row four). This occupant was not reported to have sustained any injury nor was his use of restraint documented. This occupant egressed through the pilot's hatch.

4.1.6 Discussion.

This accident is an example of a successful emergency landing on the water. The touchdown was not reported to have caused any injuries and all occupants egressed safely and were rescued shortly afterwards. All occupants used the life jackets that were available, though they were not forced to leave the floating aircraft wing before rescue. An important consideration in this case was the speed of rescue which meant that the occupants were retrieved from the downed aircraft before it sank approximately five minutes later.

4.2 CASE STUDY 2.

4.2.1 Background.

This case study documents an accident involving an aircraft from weight class A with a high wing and nose-mounted engine impacting onto a salt water surface. The accident occurred in daylight with Visual Meteorological Conditions (VMC) prevailing. The wind speed was recorded at 24 kts., gusting to 31 kts. The air temperature was reported at 41°F and the water temperature was reported at 35°F. The impact surface was recorded as choppy with wave heights of two feet.

Because of the nature of the impact, this accident is included in impact scenario 1 (forced landing–normal). This accident also falls within the definition of post-impact scenario 2 (delayed sinking). In this accident, there were six people on board: four received fatal injuries, one received serious injuries, and one received minor injuries.

4.2.2 Accident Characteristics.

The accident initiated as the aircraft made a landing approach. The aircraft experienced an engine failure and the pilot decided to ditch the aircraft in a nearby channel. The aircraft was alighted 50 to 75 feet from shore. The current in the channel, however, caused the aircraft to drift away from the shore. The pilot of another nearby aircraft that heard the disabled aircraft's radio transmission was monitoring the ditching and made several observations. Upon arrival over the channel, the downed aircraft was observed afloat in a level attitude and four people were visible on the aircraft's wings. Within 10 minutes only the tail and antenna were above the water and only two occupants were visible. After an hour the aircraft was no longer visible.

4.2.3 Impact Conditions.

The accident was reconstructed using the methodology presented in appendix C. The impact conditions developed during the reconstruction are given below.

Velocity Vectors:

Vertical	13 ft/sec
Longitudinal	89 ft/sec
Lateral	0

Flight Path Angle: 3 - 5°

Attitude:

Roll	0
Pitch	3 - 5° (noseup)
Yaw	0

4.2.4 Damage.

The aircraft sank and was not recovered.

4.2.5 Injury and Post-Impact Survivability.

Six occupants were onboard this aircraft during the accident. Four of the six were reported as drowning victims; the fifth sustained serious injuries, and the sixth sustained minor injuries. Personal flotation was not available in the aircraft. The specific injuries that the occupants sustained in this accident as well as each occupant's post-crash survivability aspects are discussed below.

a. Pilot – left front. This occupant was reported to have died from drowning with no impact injuries being recorded. The occupant reportedly was wearing both lap belt and shoulder harness restraints. The occupant's path of egress was recorded as through the left front door while the aircraft was floating.

b. Pax – right front. This occupant was reported to have sustained minor injuries resulting from exposure and classified as hypothermia. Again, no impact injuries were reported. A lap belt and shoulder harness were used by this occupant. Egress was aided by another occupant and was through the left front door of the floating aircraft. This occupant was in the water for a reported 35 minutes before rescue.

c. Pax – right front. This occupant was reported to have sustained serious injuries from hypothermia and water inhalation. This occupant was an infant which was held by the preceding occupant throughout the accident sequence. No restraint was worn by this occupant and egress was as for pax – right front. This occupant remained in the water for a reported 30 minutes before rescue.

d. Pax – left middle. This occupant died from drowning. This occupant most likely used the available lap belt because of the advance warning of impact. The likely path of egress was through the right rear door because of the delay in the cockpit caused by the aid required by the second and third occupants to egress.

e. Pax – right middle. This occupant was presumed to have drowned though the body was not recovered. The occupant's use of restraint was most likely a lap belt only. The occupant's probable path of egress was through the right rear passenger door.

f. Pax – right rear. This occupant was presumed to have drowned although the body was not recovered. Restraint use was most likely a lap belt and the probable path of egress was through the right rear passenger door.

4.2.6 Discussion.

The effect of post-impact hazards on occupant survivability is illustrated by this case. There was no record of injuries caused by the impact. The infant who received no impact injuries despite being restrained only by an occupant's arms in the front of the aircraft is a good indication that the impact was mild. The lack of personal flotation equipment contributed to one confirmed and three presumed drownings in this case. In addition, delayed rescue in the absence of cold-weather survival equipment meant that the two surviving occupants were exposed to a water temperature of 35°F for 30 to 35 minutes. This caused hypothermia in these two surviving occupants. The adult that survived expressed difficulty in unfastening the shoulder harness but was able to escape with the aid of another occupant.

4.3 CASE STUDY 3.

4.3.1 Background.

This case study documents an accident involving an aircraft from weight class A with a high wing and a nose-mounted engine, impacting into a river. The accident occurred in daylight with Visual Meteorological Conditions (VMC) prevailing. The wind speed was recorded at 20 kts., gusting to 37 kts. The air temperature was recorded as 41°F. The impact surface was recorded as calm.

This accident is included in impact scenario 1 (forced landing–normal). This accident also falls within the definition of post-impact scenario 2 (delayed sinking). In this accident, there were four people on board and no one was injured.

4.3.2 Accident Characteristics.

While attempting an approach and landing, the aircraft's engine began to run a little rough. The engine then quit while the aircraft was at between 200 to 300 feet altitude. The pilot felt that the altitude was insufficient to attempt an engine restart or to get back to land, therefore the aircraft was ditched in the nearby river. The aircraft was put down approximately 50 to 60 feet from the shoreline. All occupants escaped from the aircraft unaided and without difficulty.

4.3.3 Impact Conditions.

The accident was reconstructed using the methodology presented in appendix C. The impact conditions developed during the reconstruction are given below.

Velocity Vectors:

Vertical	18 ft/sec
Longitudinal	101 ft/sec
Lateral	3 ft/sec
Flight Path Angle:	5°

Attitude:

Roll	10°
Pitch	5° (noseup)
Yaw	0

4.3.4 Damage.

The aircraft in this case was recovered and noted to have sustained substantial damage. Major aircraft damage that was not attributed to recovery efforts is listed below.

a. Right wing substantially damaged (figures 4.1, 4.2).
b. Right wing flap slightly displaced (figure 4.3).
c. Propeller blade bent.

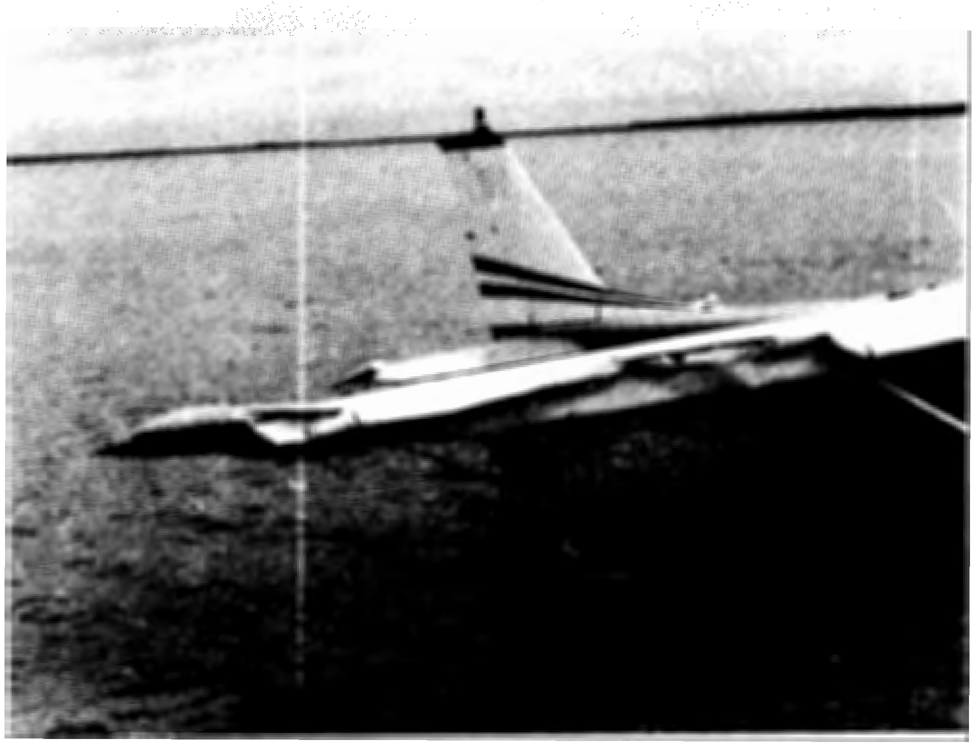


FIGURE 4.1. CASE STUDY 3, DAMAGED LEADING EDGE OF RIGHT WING

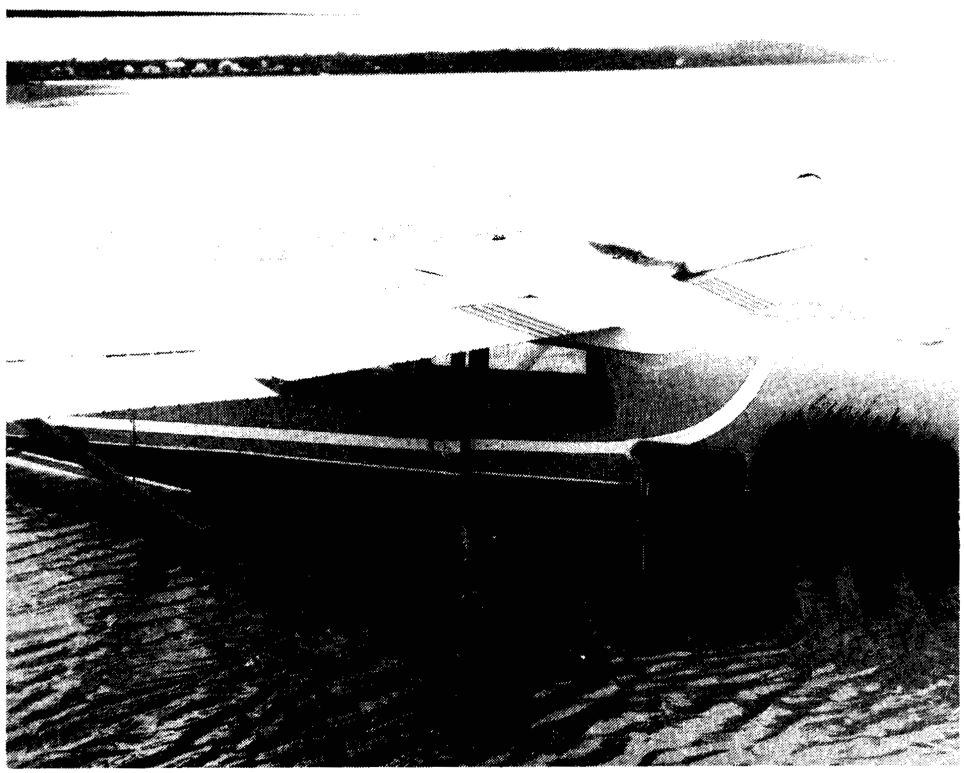


FIGURE 4.2. CASE STUDY 3, MIDSECTION VIEW OF LEFT FUSELAGE

FIGURE 4.3. CASE STUDY 3, FULL VIEW OF RIGHT FUSELAGE

4.3.5 Injury and Post-Impact Survivability.

Four occupants were on board this aircraft during the accident and no one was reported injured. It is unknown how long the occupants were in the water or if personal flotation was available. The specific seating locations and occupant's use of restraints in this accident, as well as each occupant's post-crash survivability aspects, are discussed below.

a. Pilot – left front. The pilot was not injured and was reported as using a lap belt only. Egress for the pilot was unaided through the door located on the left middle of the cabin.

b. Pax – right front. This occupant was reported to have been uninjured and used a lap belt-only restraint. Egress for this occupant was unaided through the door located on the right middle of the cabin.

c. Pax – left rear. This occupant was also uninjured and used a lap belt-only restraint. The occupant egressed unaided through the left middle cabin door.

d. Pax – right rear. The occupant was not injured and used a lap belt-only restraint. The occupant egressed through the right middle cabin door.

4.3.6 Discussion.

This accident was a mild impact based on the lack of reported impact injuries and the pictures that showed no significant damage to the occupiable volume. No occupants expressed any difficulty in egressing from the downed aircraft. No mention was made of any difficulty posed by the water environment after leaving the aircraft. The proximity to the shoreline and the calm sea state may have contributed significantly to the post-crash survivability of this accident (figure 4.4).

4.4 CASE STUDY 4.

4.4.1 Background.

This case study documents an accident involving an aircraft from weight class A with a low wing and a nose-mounted engine impacting onto a salt water surface. The accident occurred in darkness with Visual Meteorological Conditions (VMC) prevailing. The wind speed was recorded at 14 kts. The impact surface was described as choppy and the average wave height was recorded as two feet.

The accident is included in impact scenario 1 (forced landing–normal). In this accident, there was one person on board. This one occupant became a fatality.

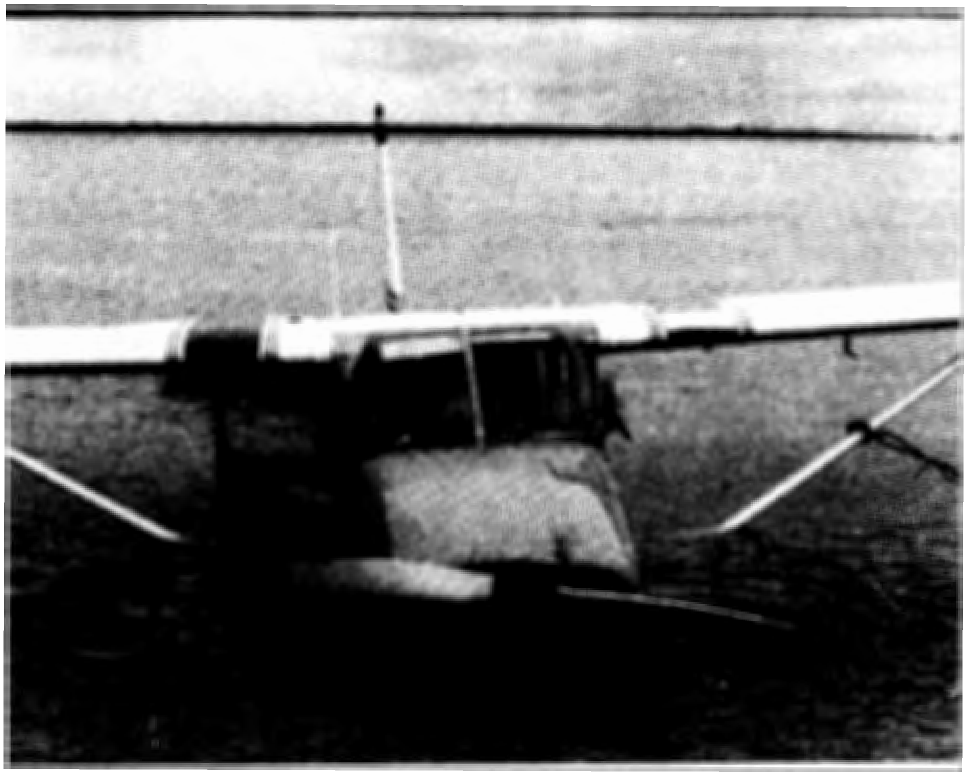


FIGURE 4.4. CASE STUDY 3, FRONT VIEW OF AIRCRAFT

4.4.2 Accident Characteristics.

The aircraft was making a cargo air taxi flight when engine power was lost. The pilot was unable to make it to the emergency landing strip identified to him by air traffic control because of uncontrolled loss of altitude. The last radio transmission from the pilot stated that the aircraft was passing through the 700-foot altitude level. The aircraft was apparently put down under pilot control onto a lake. Underwater examination of the aircraft prior to recovery showed that the pilot had probably escaped the aircraft after touchdown since the cabin door was open and the restraint was unfastened.

4.4.3 Impact Conditions.

The accident was reconstructed using the methodology presented in appendix C. The impact conditions developed during the reconstruction are given below.

Velocity Vectors:

Vertical	11 ft/sec
Longitudinal	127 ft/sec
Lateral	0

Flight Path Angle:	2 - 3°
Attitude:	
Roll	0
Pitch	2 - 3° (noseup)
Yaw	0

4.4.4 Damage.

The aircraft in this case was recovered and noted to have sustained substantial damage. However, there was no evidence of damage in the cockpit or cabin area of the aircraft. Major aircraft damage is listed below.

a. The lower inboard ends of both wings revealed heavy water moulding.

b. A small amount of scratching along the leading edges and wing tips.

c. The upper inboard surface of the right wing displaced upward, enough to interfere with the right cockpit door opening (figure 4.5).

d. Small wrinkling along both sides of the rear portion of the fuselage (figure 4.6.)

e. Separation of the engine cowling (figure 4.7).

f. Upper engine mount pads broken.

g. Both propeller blades bent back (figure 4.8).

4.4.5 Injury and Post-Impact Survivability.

There was only one occupant in this accident and the body was never recovered. The pilot's seat was located in the left front and this was equipped with a lap belt and shoulder harness. It is presumed that the restraint was used. As noted above, there was no evidence of damage to the cockpit or cabin area and the pilot's body was not found near the aircraft. The pilot most probably was able to egress from the downed aircraft and then drowned. No personal flotation equipment was reported onboard the aircraft.

4.4.6 Discussion.

This accident again illustrates the hazards presented by the post water impact environment in an apparently successful ditching. Post-crash examination of the aircraft revealed no significant damage to the occupiable volume. In addition, the open cockpit door and the unfastened pilot restraint seem to indicate that the pilot, the sole occupant, egressed

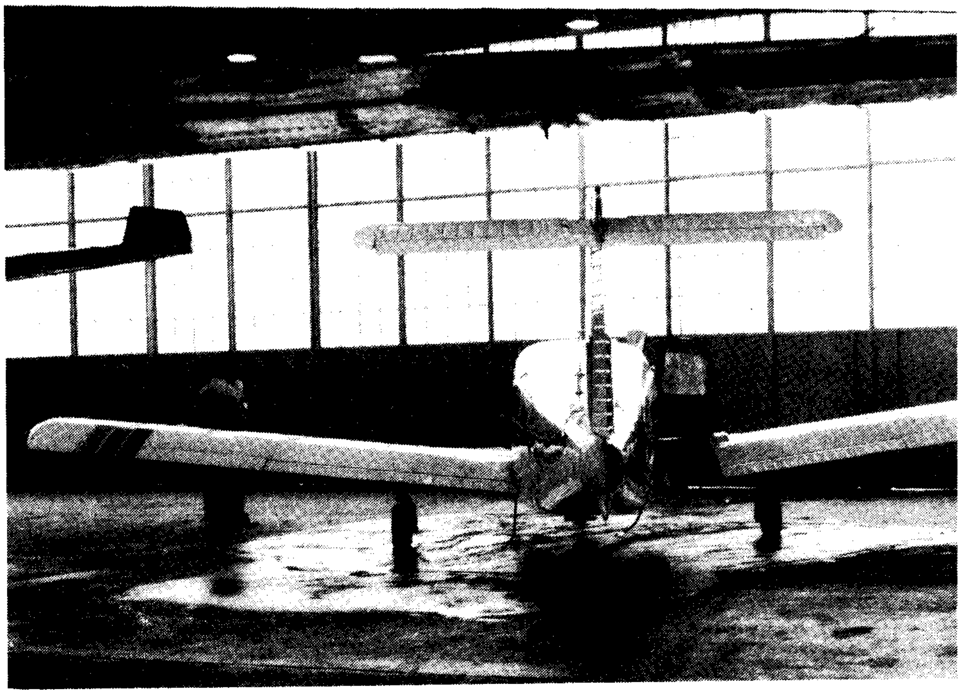


FIGURE 4.5. CASE STUDY 4, REAR VIEW OF AIRCRAFT

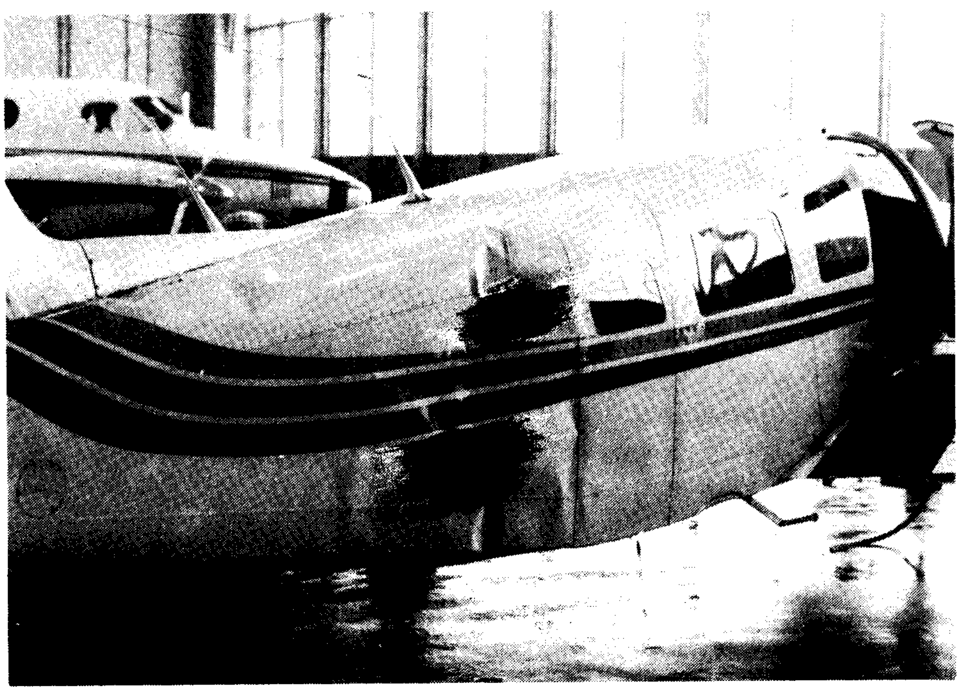


FIGURE 4.6. CASE STUDY 4, RIGHT VIEW OF REAR FUSELAGE DAMAGE

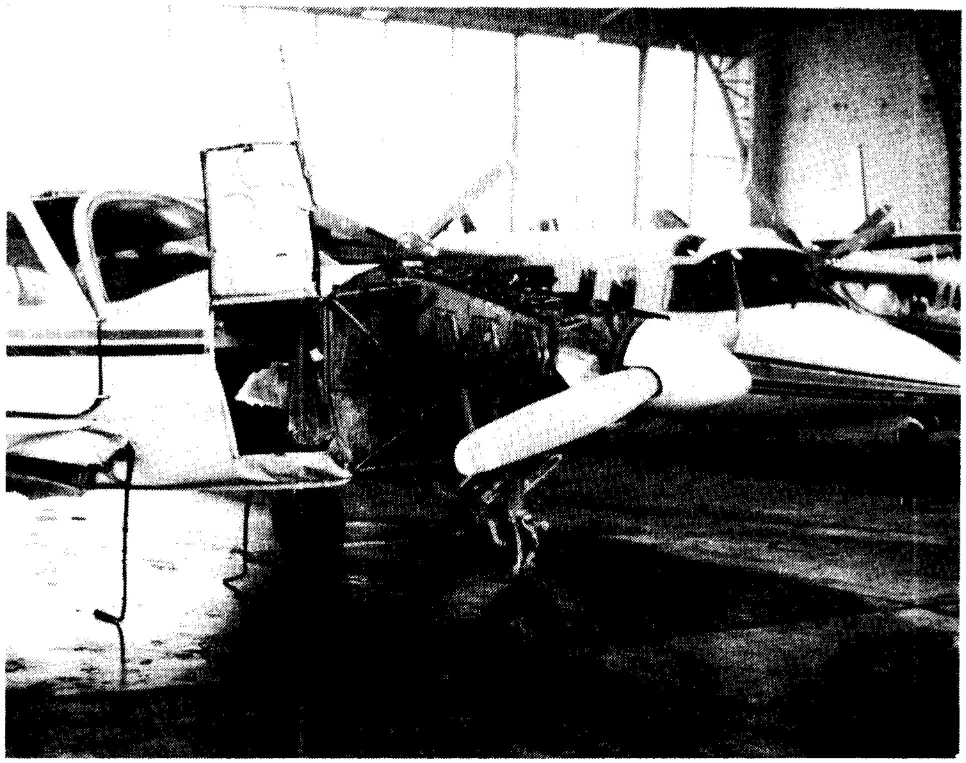


FIGURE 4.7. CASE STUDY 4, RIGHT VIEW OF NOSE DAMAGE

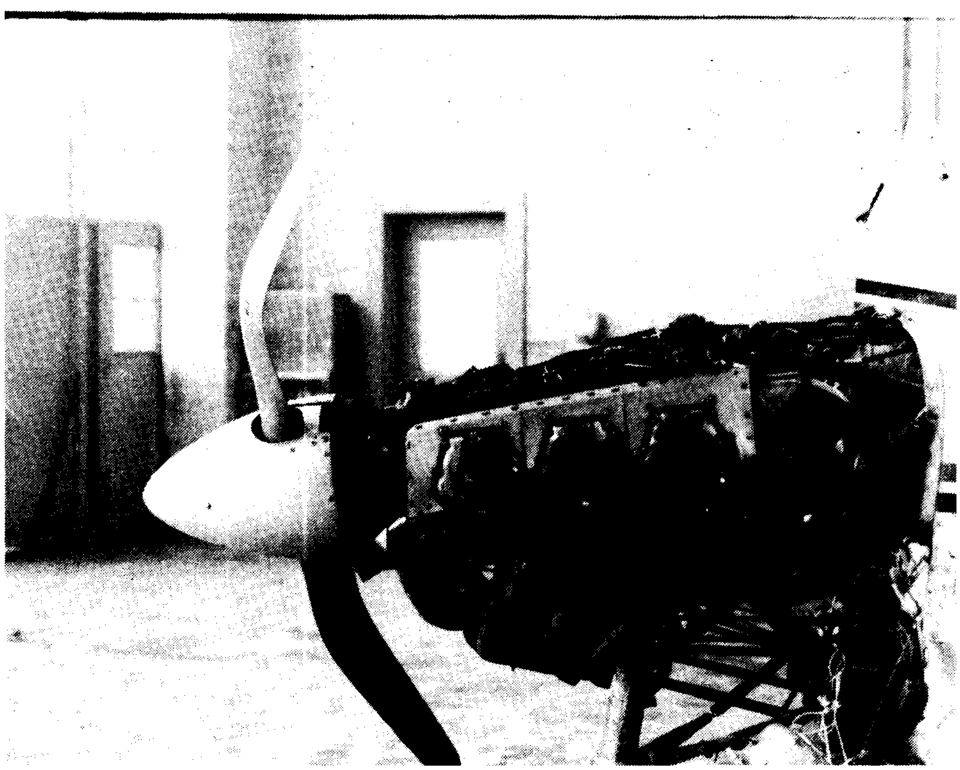


FIGURE 4.8. CASE STUDY 4, LEFT VIEW OF NOSE DAMAGE

successfully. If personal flotation equipment had been available onboard the aircraft it may have aided the presumed drowned occupant.

4.5 CASE STUDY 5.

4.5.1 Background.

This case study documents an accident involving an aircraft from weight class A with a high wing and a nose-mounted engine impacting onto a fresh-water surface. The accident occurred in daylight with Visual Meteorological Conditions (VMC) prevailing. The wind speed was recorded at 3 kts. The impact surface was calm.

This accident is included in impact scenario 2 (landing–noseover). This accident also falls within the definition of post-impact scenario 2 (delayed sinking). In this accident, there was one occupant and the individual was not injured.

4.5.2 Accident Characteristics.

While attempting a water landing, the float-equipped aircraft nosed over during touchdown. It was discovered that landing wheels that were mounted integral with the fixed floats were extended. The downward protruding wheels tripped the aircraft at touchdown and caused the noseover.

4.5.3 Impact Conditions.

The accident was reconstructed using the methodology presented in appendix C. The principal impact for the noseover incident was considered to be the contact of the aircraft nose with the water surface after pivoting forward on the floats. The vertical velocity relative to the aircraft frame of reference was taken to be upwards (negative) to account for the upward pitching of the aircraft center of gravity at impact. The impact conditions developed during the reconstruction are given below.

Velocity Vectors:

Vertical	-5 ft/sec
Longitudinal	54 ft/sec
Lateral	0

Flight Path Angle: 85°

Attitude:

Roll	0
Pitch	-90° (nose down)
Yaw	0

4.5.4 Damage.

The aircraft damage in this case was not described in detail but was recorded as substantial.

4.5.5 Injury and Post-Impact Survivability.

A single occupant was on board this aircraft during the accident and no injuries were reported. The pilot was seated in the left front position, wore a lap belt only, and exited unaided through the left front door. It is unknown if any personal flotation equipment was available but the occupant remained in the water 10 minutes until rescue.

4.5.6 Discussion.

This accident falls under the second impact scenario identified for this study, a noseover upon making a water-landing. The single occupant was restrained only by a lap belt, the aircraft nosed completely over and yet no injuries were reported. This lack of impact injury in such noseover sequences is fairly consistent, as was seen in section 4.6. No mention was made of egress difficulty in this or any similar cases.

4.6 CASE STUDY 6.

4.6.1 Background.

This case study documents an accident involving an aircraft from weight class A with a low wing and with wing-mounted engines impacting onto a salt water surface. The accident occurred in darkness with Instrument Meteorological Conditions (IMC) prevailing. The wind speed was recorded at 21 kts and the air temperature was recorded at 37°F. The impact surface was described as choppy and the average wave height was recorded as two feet.

The accident was an unintentional impact with roll that exceeded 20° and does not satisfy the established impact scenarios. In this accident, there were two people on board and both became fatalities.

4.6.2 Accident Characteristics.

The pilot of this aircraft was attempting an Instrument Flight Rules-landing at night in rain and fog. The aircraft crashed into the water approximately one mile short of the runway.

4.6.3 Impact Conditions.

The accident was reconstructed using the methodology presented in appendix C. The impact conditions developed during the reconstruction are given below.

Velocity Vectors:

Vertical	24 ft/sec
Longitudinal	127 ft/sec
Lateral	14

Flight Path Angle: 2 - 3°

Attitude:

Roll	- 30° (left down)
Pitch	- 15° (nose down)
Yaw	0

4.6.4 Damage.

The aircraft in this case was recovered. Two views of the cockpit interior are given in figures 4.9 and 4.10. Major aircraft damage is listed below:

a. Left wing completely separated from fuselage and inverted (figure 4.11).

b. Forward upper left fuselage side indentation resembling left wing tip (figure 4.11).

c. Fuselage door under the wing (figure 4.11).

d. Left, right, and nose gear in down position (figure 4.12).

e. Nose wheel and lower part of nose strut missing (figure 4.11).

f. Right wing tip missing (figure 4.12).

g. Rudder slightly wrinkled.

h. Nose crush damage (figure 4.11).

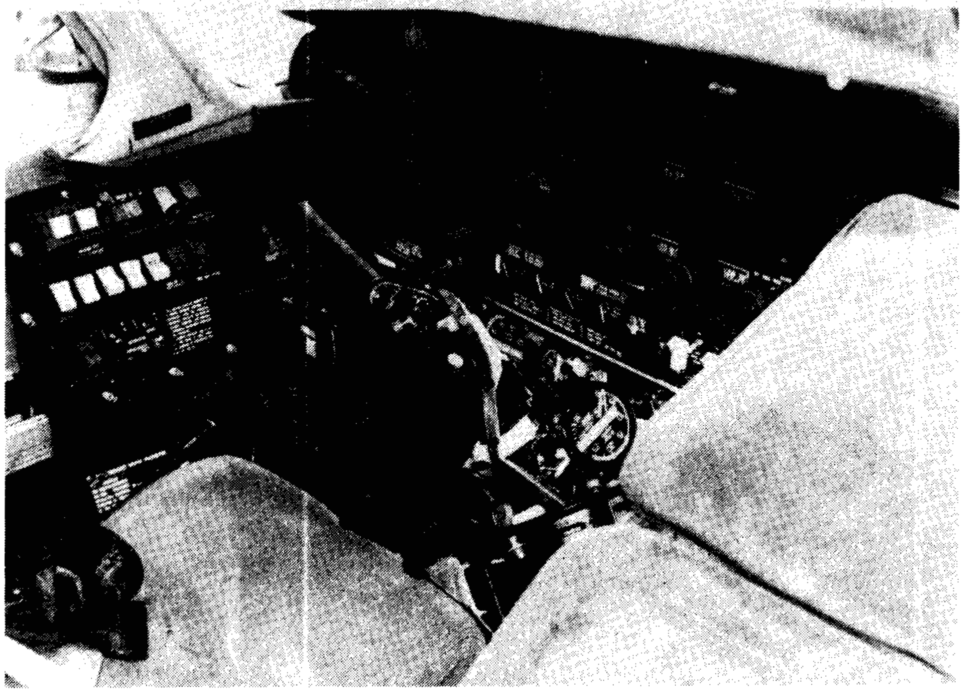


FIGURE 4.9. CASE STUDY 6, FRONT LEFT VIEW OF COCKPIT

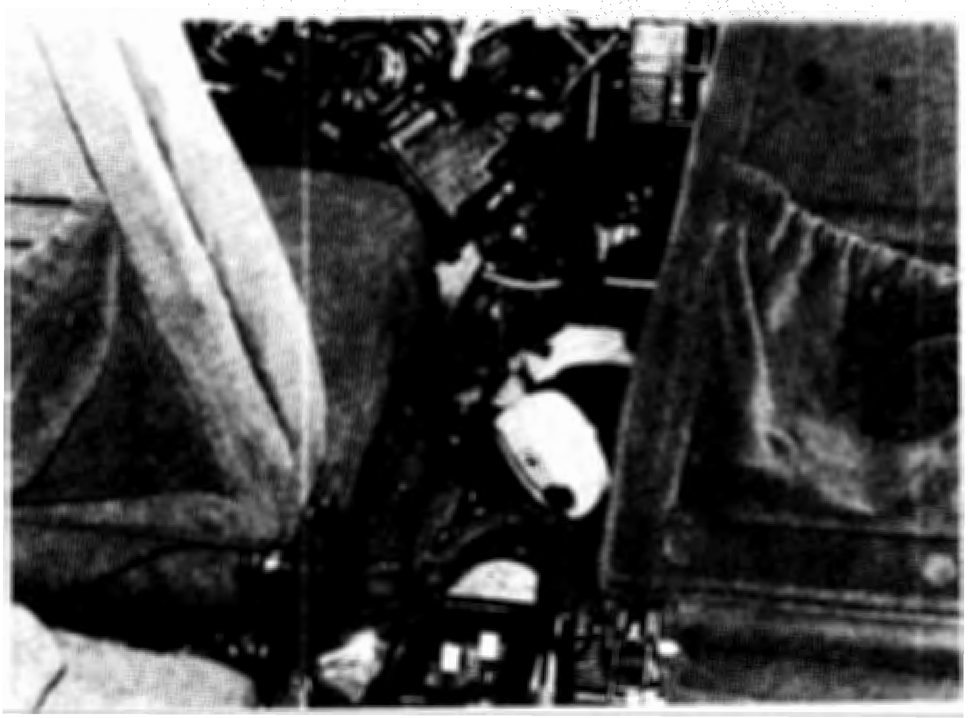


FIGURE 4.10. CASE STUDY 6, FORWARD VIEW OF COCKPIT

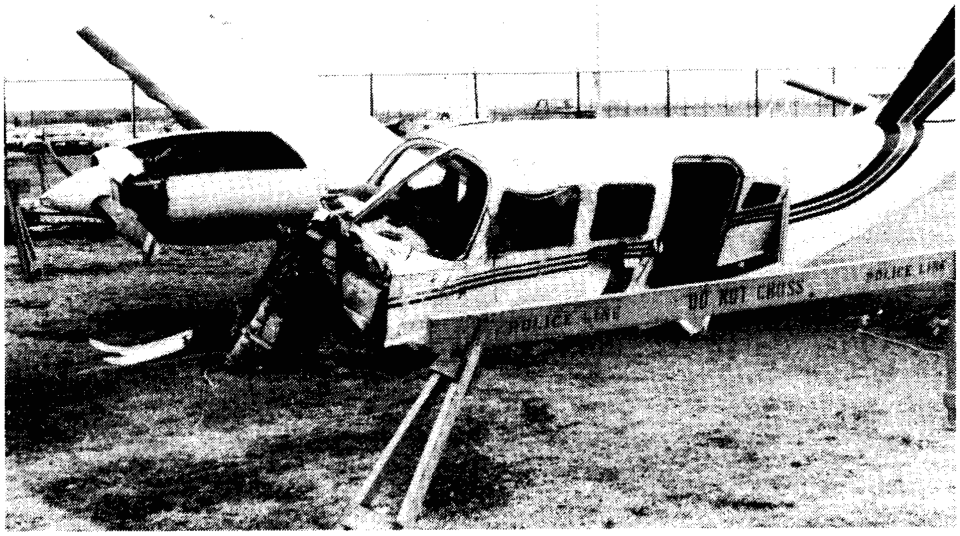


FIGURE 4.11. CASE STUDY 6, FULL VIEW OF LEFT FUSELAGE DAMAGE

FIGURE 4.12. CASE STUDY 6, FULL VIEW OF RIGHT FUSELAGE DAMAGE

4.6.5 Injury and Post-Impact Survivability.

There were two occupants onboard the airplane in this accident. Both occupants used the available lap belts and shoulder harnesses. One occupant was confirmed to have died from drowning and the other occupant was documented as having suffered unknown injuries but survived the impact well enough to egress and died from drowning. Personal flotation equipment was not available to either occupant.

4.6.6 Discussion.

This accident demonstrates the hazards presented by the post water impact environment in an inadvertent water impact. Impact injuries were not recorded for either occupant. Drowning was confirmed for one and strongly suspected for the other. If personal flotation equipment had been available on board the aircraft it may have aided the survivability of these occupants.

5. CONCLUSIONS.

A. Impact Conditions

1. Two impact scenarios were defined to describe how commuter/air taxi aircraft contacted the water in water-related impacts and ditchings. These two impact scenarios are forced landing--normal, and noseover.

2. Two post-impact scenarios were defined to describe post-impact behavior of commuter/air taxi aircraft in water-related impacts and ditchings. These two post-impact scenarios are immediate sinking and delayed sinking.

3. The primary water impact scenario, a normal forced landing, involved accidents where the pilot had control of the aircraft and guided it to a controlled impact. These accidents were primarily longitudinal impacts with insignificant lateral velocity magnitudes.

4. The noseover incidents examined represent a relatively mild impact scenario. Only 1 of the 18 occupants involved in these accidents sustained serious injury.

5. The 95th percentile velocities for survivable accidents were 22 ft/sec vertical, 143 ft/sec longitudinal, and 4 ft/sec lateral.

B. Occupant Survivability Hazards

1. The most prevalent impact hazard was the occurrence of injuries attributed to flailing.

2. The frequency and severity of injury was found to increase as the weight and size of the aircraft decreased.

3. The penetration of a wing-mounted engine into the cabin was found to have directly caused injury to the occupants in one accident.

4. Drowning was the most significant post-impact hazard in this investigation. A total of 15 of the 44 fatalities that occurred in this sample were drownings.

5. Fire was not observed to be a hazard in the water-related impacts examined.

C. Effect of Restraint Use on Occupant Injury

1. Proper use of restraints by occupants helped to reduce the frequency of impact injury in water-related impacts and ditchings.

2. Lower frequency of injury was observed in occupants that used both lap belt and shoulder harness when compared to occupants that used lap belt-only.

D. Occupant Egress and Flotation Equipment

1. Lack of personal flotation equipment can be correlated with the occurrence of drowning fatalities and was probably a contributing factor in these fatalities.

2. Aircraft buoyancy and trim was not found to hinder occupant egress.

E. Aircraft Impact Damage. Water impacts of commuters/air taxis can cause structural damage that is distinctly different from impacts on rigid ground. Peeling of the cabin roof by hydrodynamic forces was observed in two cases.

6. REFERENCES.

1. "Air Taxi Operators and Commercial Operators," Part 135, Chapter I – Federal Aviation Administration, Department of Transportation, Title 14 – Aeronautics and Space, Code of Federal Regulations.

2. Zimmermann, R. E. and Merritt, N. A., "Aircraft Crash Survival Design Guide, Volume I – Design Criteria and Checklists," U.S. Army Aviation Research and Technology Activity (AVSCOM), USAAVSCOM TR 89-D-22A, December 1989.

3. Coltman, J. W., Bolukbasi, A. O., and Laananen, D. H., "Analysis of Rotorcraft Crash Dynamics for Development of Improved Crashworthiness Design Criteria", U.S. Department of Transportation, Federal Aviation Administration, Technical Center, DOT/FAA/CT-85/11, June 1985.

4. Advisory Circular 29-2A, U.S. Department of Transportation, Federal Aviation Administration, September 16, 1987.

5. Coltman J. W. and Arndt, S. M., "The Naval Aircraft Crash Environment: Aircrew Survivability and Aircraft Structural Response", Naval Air Development Center, September 1988.

6. "Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter/Air Taxi Category Airplanes", Part 23, Chapter I – Federal Aviation Administration, Department of Transportation, Title 14 – Aeronautics and Space, Code of Federal Regulations.

7. GLOSSARY.

Attitude – Angles describing the orientation of the aircraft relative to the mutually perpendicular aircraft axes. See figure 7.1.

Ditching – An emergency landing on the water, deliberately executed, with the intent of abandoning the aircraft as soon as practical. The aircraft is assumed to be intact prior to water entry with all controls and essential systems, except engines, functioning properly (reference 4).

Survivable Accident – The acceleration environment was within the limits of human tolerance, and a sufficient occupiable volume remained for properly restrained (lap belt and shoulder harness) occupants, with the effects of fire not considered (reference 3).

Partially Survivable Accident – Some portion of the cockpit or cabin met the definition of survivable (reference 3).

Nonsurvivable Accident – No portion of the cockpit or cabin met the definition of survivable (reference 3).

Significant Survivable Accident – The accident was judged to be either survivable or partially survivable and one or more occupants received impact injuries (reference 3).

Velocity Components – Velocity vectors oriented along the mutually perpendicular longitudinal, vertical, and lateral axes of the aircraft. See figure 7.1.

95th Percentile Velocity – A statistical value indicating the velocity associated with the major impact. Up to 95 percent of the survivable mishaps are attributable to this velocity (reference 5).

Water Impact – Any impact with water in which the pilot may have had varying degrees of mechanical control of the aircraft

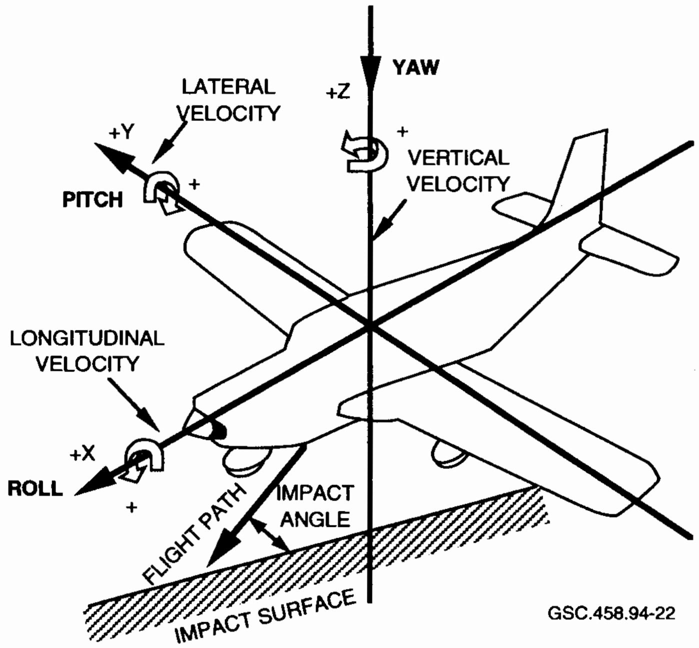


FIGURE 7.1. AIRCRAFT ATTITUDE AND VELOCITY COMPONENT DIRECTIONS

APPENDIX A ACCIDENT DATA SEARCH: SOURCES

The major source of water impact accident/incident reports for this investigation was the National Transportation Safety Board (NTSB). Table A-1 lists the date and location of accidents/incidents from different data search efforts. The target period for the investigation was 1979-1989. The data search was performed on the NTSB data system and the FAA Accident/Incident Data System (AIDS). Four different searches on AIDS were performed: one in Oklahoma City, two at FAA Headquarters, and one at the FAA Technical Center. Search results varied, probably due to the different key words used in performing the searches.

Another data search effort was attempted through the International Civil Aircraft Organization (ICAO). Table A-2 lists the number of water impact accidents/incidents from 10 countries during the years 1979-1989.

TABLE A-1. LIST OF ACCIDENT DATA FROM DIFFERENT SOURCES

	SOURCE OF REPORT - COMMUTER DITCHING AND WATER-RELATED IMPACTS - 5/28/91								
	NTSB	FAA ACCIDENT / INCIDENT DATA SYSTEM (*)						ACCIDENT DATE	ACCIDENT LOCATION
		OKC		TC	HQ2	ACCIDENT	INCIDENT		
		1				A		4/3/79	PHILADELPHIA PA
		1				A		7/13/79	HALIBUT COVE AK
		1				A		12/7/80	MICHIGAN CITY IN
		1				A		6/11/81	NAPASKIAK AK
		1				A		9/16/81	SOUTH TIMBERLAI CA
		1				A		11/11/81	HIDDEN LAKES AK
	1					B		1/17/82	HONOLULU HI
	1	1				A		9/21/82	NEAR KOTZEBUE AK
	1	1				A		3/9/83	FT. LAUDERDALE FL
		1				A		3/27/83	VERMILLION BAY LA
	1					B		9/8/83	KAILUA-KONA HI
	1					B		1/23/84	NEW ORLEANS LA
	1					B		7/17/84	HONOLULU HI
	1							7/21/84	OUZINKIE AK
	1							8/2/84	VIEQUES PR
	1					B		8/29/84	HOWELL MI
		1		1		B		1/15/85	FLORIDANA FL
		1		1		B		4/26/85	SEWARD AK
				1		B		7/19/85	ERIE PA
	1	1		1	1	B		9/23/85	FT LAUDERDALE FL
		1		1		B		3/20/86	MAUNALOA HI
		1				B		6/1/86	HOBART BAN AK

TABLE A-1. LIST OF ACCIDENT DATA FROM DIFFERENT SOURCES (CONTINUED)

	SOURCE OF REPORT - COMMUTER DITCHING AND WATER-RELATED IMPACTS - 5/28/91								
	NTSB	FAA ACCIDENT / INCIDENT DATA SYSTEM (*)						ACCIDENT DATE	ACCIDENT LOCATION
		OKC		TC	HQ2	ACCIDENT	INCIDENT		
		1					C	6/24/86	PORTAGE BAY AK
		1		1		B		7/22/86	SAN JUAN PR
		1					C	8/29/86	NEW YORK NY
		1				B		9/4/86	TALKETEENA AK
		1		1		B		10/28/86	ST CROIX VI
		1				B		4/12/87	BRUNETT INLET AK
		1		1		B		6/21/87	BRIDGEPORT CA
		1					C	7/5/87	KETCHIKAN AK
				1		B		8/8/87	CROOKED CREEK AK
	1							8/8/87	MAMMOTH LAKES CA
		1					C	8/14/87	BIMINI FL
		1					C	8/25/87	TAKO LODGE AK
		1		1		B		10/28/87	ILIAMNA AK
		1					C	11/30/87	CHELAN WA
		1		1		B		12/7/87	MEKLAKATLA AK
		1		1		B		12/18/87	WEDRON IL
		1				B		12/23/87	MANALOA HI
		1		1		B		2/19/88	BRIDGEPORT CT
		1		1		B		2/19/88	RALEIGH-DURHAM NC
		1				B		2/26/88	SABA ISLAND NA
		1					C	3/31/88	ST MARTIN VI
		1					C	5/31/88	KETCHIKAN AK
		1					C	6/23/88	CRESTWOOD IL
		1					C	7/27/88	DILLINGHAM AK
	1	1				B		8/8/88	COOPER LANDING AK
		1					C	8/18/88	LITTLE LAKE LA
		1				B		8/15/88	TOK AK
		1				B		12/14/88	KASAAN AK
		1		1		B		1/15/89	KETCHIKAN AK
		1		1		B		2/9/89	CLEVELAND OH
		1		1		B		3/1/89	SAN JUAN PR
		1					C	3/20/89	KENAI AK
		1				B		5/23/89	GREEN ISLAND AK
		1				B		5/31/89	TOKSOOK BAY
		1					C	6/26/89	MEYERS CHUCK AK
				1		A		11/2/89	APOPKA FL
TOTAL	12	48	0	18	1	42	14		

* A = General Aviation Accident   C = Air Carrier Incident
B = Air Carrier Accident   D = General Aviation Incident

TABLE A-2. COMMUTER WATER IMPACT ACCIDENTS (1982-1989) FROM ICAO

Country	No. of Accidents	Subtotal
United States *	14	14
Australia	1	
Brazil	1	
Canada	10	
Costa Rica	1	
Denmark	1	
Germany	1	19
Japan	1	
New Zealand	1	
United Kingdom	2	
Total		33

* Already obtained from NTSB

APPENDIX B - ACCIDENT RECONSTRUCTION/DATABASE STRUCTURE AND DOCUMENTATION

Water Impact Accident Database for Commuter Aircraft

Reconstruction Form/Database Design and Description of Files

INTRODUCTION

This appendix describes the format of the accident reconstruction forms used to summarize the raw accident data into a format suitable for analysis, as well as the database structure that facilitated this analysis. For each of the three database files created, the appendix first describes the database structure and then presents the data definitions and codes used in both the accident reconstruction forms and the database. The codes used in the accident reconstruction forms were identical to those defined for the database so that they could be used as data entry forms. Examples of the accident reconstruction forms appear at the end of this appendix.

Description of Database Files

Three separate files were created (the '.dbf' file extension denotes database file):

1. ACC-CMD.dbf — stores information specific to each accident in the study. The information stored includes:

    1. Accident Identification Information
    2. Aircraft Identification Information
    3. Aircraft Damage & Accident Severity Summary
    4. Injury Severity Summary
    5. Accident Type/Phase of Operation
    6. Crash Environment: Kinematics Information
    7. Crash Environment: Environmental Conditions
    8. Aircraft Flotation Equipment & Performance

2. OCC-CMD.dbf — stores information about each occupant's relationship to and interaction with the aircraft involved in the accident. The information stored includes:

    1. Occupant Identification Information
    2. Occupant Injury Degree
    3. Occupant/Aircraft Interaction
    4. Occupant Egress Information
    5. Personal Flotation Equipment and Performance

3. INJ-CMD.dbf — stores information on all injuries sustained by each occupant. This includes injury type, location, severity, cause, and the injury's relationship to impact.

The information stored includes:

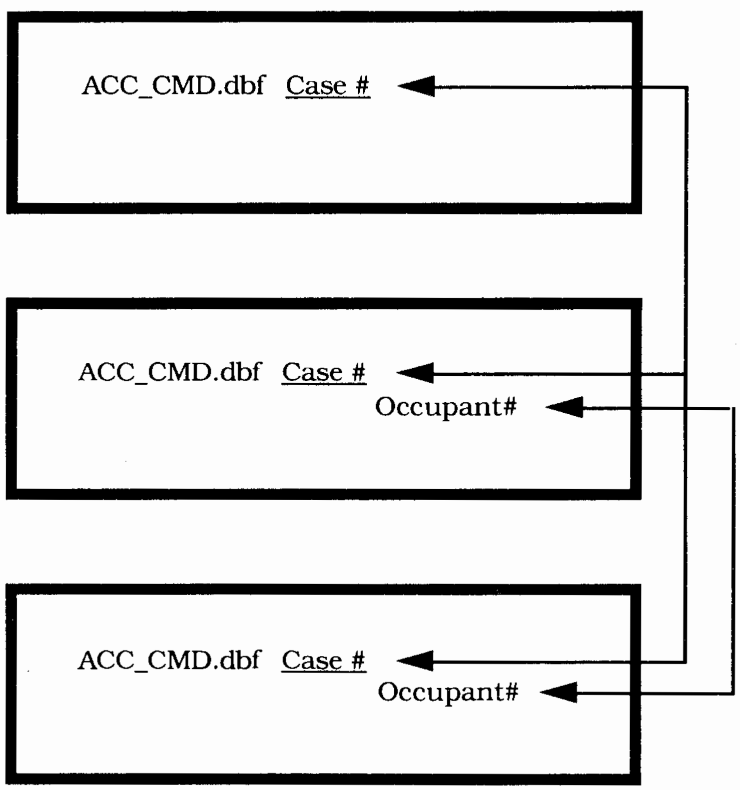
1. Occupant Identification Information
2. Injury Identification Information

Relationship Between Files

1. Accidents to Occupants — This is a one-to-many relationship. For each accident, there exist one or more occupants. These two files are linked by the unique case number assigned to each accident.

2. Occupants to Injuries — This is a one-to-many relationship. For each occupant in a particular accident, there exists none or more injuries. These two files are linked by a combination of the case number and the unique occupant number assigned to each occupant in an accident.

The following diagram shows this relationship.



 Data Dictionary for ACC_CMD.dbf File

03/19/91

Field	Name	Type	Width	Dec	Index?	Range	Default
1	CASE_NO	N	3	0	Y	1 to 999 Cases	Next Case#
2	LOCATION	C	40	0	N	40 Descriptive Characters	
3	DATE	D	8	0	N	MM/DD/YY	00/00/00
4	TIME	C	5	0	N	HH:MM on 24-hr clock	99:99
5	SOURCE	C	20	0	N	20 Descriptive Characters	
6	REG_NO	C	8	0	N	8 Descriptive Characters, N#######	
7	MFR	C	20	0	N	20 Descriptive Characters	
8	MODEL	C	20	0	N	20 Descriptive Characters	
9	WEIGHT	N	6	0	N	0 to 999,999 lbs	0
10	WING_CFG	C	1	0	N	H,L,R,O,U	
11	ENG_CFG	C	2	0	N	NO,TA,WI,OV,OT	
12	LG_TYPE	C	2	0	N	TR,TA,SK,SI,AM,OT	
13	LG_STATUS	C	2	0	N	UP,DO,UK	
14	SEATS	N	3	0	N	1 to 999 seats	0
15	RECOVERED	C	1	0	N	Y,N,U	
16	DAMAGE	C	1	0	N	D,S,M,N,U	
17	FIRE	C	1	0	N	N,P,I,G,U	
18	SURVIVABLE	C	1	0	N	S,P,N,U	
19	ON_BOARD	N	3	0	N	1 to 999 persons on board	0
20	FATAL	N	3	0	N	0 to 999 persons with fatal injuries	0
21	SERIOUS	N	3	0	N	0 to 999 persons with serious injuries	0
22	MINOR	N	3	0	N	0 to 999 persons with minor injuries	0
23	NONE	N	3	0	N	0 to 999 persons with no injuries	0

Field	Name	Type	Width	Dec	Index?	Range	Default
24	ACC_TYPE_A	N	2	0	N	0 to 42, see Accident Type Codes	0
25	ACC_TYPE_B	N	2	0	N	0 to 42, see Accident Type Codes	0
26	ACC_TYPE_C	N	2	0	N	0 to 42, see Accident Type Codes	0
27	ACC_TYPE_D	N	2	0	N	0 to 42, see Accident Type Codes	0
28	ACC_TYPE_E	N	2	0	N	0 to 42, see Accident Type Codes	0
29	VERTICAL	N	6	1	N	-999.9 to 9999.9 ft/sec (-999.9 if unk)	-999.9
30	LONGITUD	N	6	1	N	-999.9 to 9999.9 ft/sec (-999.9 if unk)	-999.9
31	LATERAL	N	6	1	N	-999.9 to 9999.9 ft/sec (-999.9 if unk)	-999.9
32	RESULTANT	N	6	1	N	-999.9 to 9999.9 ft/sec (-999.9 if unk)	-999.9
33	FLT_PATH	N	6	1	N	-360.0 to +360.0 degrees (-999.9 if unk)	-999.9
34	ROLL	N	6	1	N	-180.0 to +180.0 degrees (-999.9 if unk)	-999.9
35	PITCH	N	6	1	N	-180.0 to +180.0 degrees (-999.9 if unk)	-999.9
36	YAW	N	6	1	N	-180.0 to +180.0 degrees (-999.9 if unk)	-999.9
37	TERRAIN	C	1	0	N	A,B,C,D,E,F,G,H,I,J,K,L,M ,P,R,S,Y,Z	K = Water

Field	Name	Type	Width	Dec	Index?	Range	Default
38	WATER_TYPE	C	1	0	N	F,S,O,U	
39	SEA_STATE	N	2	0	N	-1 to 99	-1
40	WIND_SPEED	N	3	0	N	-1 to 999 knots (use -1 if unknown)	-1
41	WIND_GUST	N	3	0	N	-1 to 999 knots (use -1 if unknown)	-1
42	WIND_DIR	N	3	0	N	-1 to 360 degrees (use -1 if unknown)	-1
43	WEATHER	C	1	0	N	V,I,U	
44	WATER_TEMP	N	3	0	N	-99 to 999 deg F, (use -99 if unknown)	-99
45	AIR_TEMP	N	3	0	N	-99 to 999 deg F, (use -99 if unknown)	-99
46	FL_INSTALL	C	1	0	N	Y,N,U	
47	FL_TYPE	C	1	0	N	F,E,O,N,U	
48	FL_LOC	C	1	0	N	L,F,W,O,N,U	
49	FL_ARMED	C	1	0	N	Y,N,U,X	
50	FL_ACT_HOW	C	1	0	N	M,A,N,U,X	
51	FL_INF_WHN	C	1	0	N	B,P,A,U,X	
52	FL_SURVIVE	C	1	0	N	Y,N,U,X	
53	AID_EGRESS	C	1	0	N	Y,N,U,X	
54	AID_SURV	C	1	0	N	Y,N,U,X	
55	TIME_UP	N	3	0	N	-1 to 999 minutes, (use -1 if unknown)	-1
56	TIME_AFLT	N	3	0	N	-1 to 999 minutes, (use -1 if unknown)	-1
57	OVERTURN	C	1	0	N	I,A,W,D,F,X,N,O,U	

37	Undetermined
38	Vortex turbulence encountered
39	Missing aircraft
40	Miscellaneous/other
41	Not reported
42	Other

29-33

Velocity Vectors:

Velocity vectors will be calculated in the aircraft coordinate system. Longitudinal, Vertical, and Lateral Velocities which correspond to the aircraft coordinates' X, Y, and Z axes respectively, will be recorded in feet/second. A resultant velocity vector will also be calculated along with its direction.

34-36

Impact Attitudes:

34 Roll — roll is the aircraft's degree of rotation about its longitudinal X-axis. It ranges from (+)180 degrees to (-)180 degrees. Right roll is designated as positive and left roll is negative.

35 Pitch — pitch is the aircraft's degree of rotation about its' lateral Y-axis. It is measured as the angle between the aircraft's longitudinal X-axis and its flight path. Pitch can be either level, noseup, or nosedown. Pitch can range from (+)180 degrees to (-)180 degrees. Noseup is designated as positive and nose-down is negative.

36 Yaw — yaw is the aircraft's degree of rotation of its nose about its'vertical Z-axis. It ranges from (+)180 degrees to (-)180 degrees. Right yaw is designated as positive and left yaw is negative.

37 Terrain — The type of terrain encountered upon impact. The following table indicates the eighteen possibilities. For this study, all impacts were water (Code K) impacts.

Code	Terrain
A -	Mountainous
B -	Hilly
C -	Rolling
D -	Level, flat
E -	Frozen
F -	Rocky
G -	Sandy

H - Dense with trees
I - City Area
J - Plowed
K - Water
L - Sloped
M - Snow
P - Paved
R - Offshore Rig
S - Soft
Y - Other
Z - Unknown

38 Type of Water — type of water encountered upon impact. Codes are:

F - Fresh
S - Salt
O - Other
U - Unknown

39 Sea State — Classification of water surface by wave height. Enter numerical wave height(ft). (-1 = unknown)

40 Wind Speed — the speed of the wind in knots, as reported by the accident data.

41 Wind Gust — the speed of wind gusts in knots, as reported by the accident data.

42 Wind Direction — the wind direction in degrees, as reported by the accident data.

43 Weather — Indicates basic prevailing weather conditions for aircraft operations. Codes are listed below:

V - Visual Meteorological Conditions (VMC)
I - Instrument Meteorological Conditions (IMC)
U - Unknown

44 Water Temperature — indicated in degrees Fahrenheit.

45 Air Temperature — indicated in degrees Fahrenheit.

46 Floats Installed? — Indicates the presence of floats on the aircraft. Codes are:

Y - Yes
N - No
U - Unknown

47 Float Type — Describes the type of float installed on the aircraft. Codes are listed below:

- F - Fixed
- E - Emergency
- O - Other
- N - None
- U - Unknown

48 Location on Aircraft — Documents the location of floats on the aircraft. Codes are:

- L - Landing Gear
- F - On Fuselage
- W - Wing
- O - Other mounting configuration
- N - None
- U - Unknown

49 Floats Armed? — Indicates whether or not the floats were armed. Codes are:

- Y - Yes
- N - No
- U - Unknown
- X - Not Applicable, X, no floats or fixed floats on aircraft

50 Floats Activated How? — Codes are as follows:

- M - Manually Activated
- A - Automatically Activated
- N - Not Activated
- U - Unknown
- X - Not Applicable, X, no floats or fixed floats on aircraft

51 Floats Inflated When? — Codes are as follows:

- B - Before or Pre-Impact
- P - Post-Impact
- A - At Impact
- U - Unknown
- X - Not Applicable, X, floats never activated, no floats, or fixed floats on aircraft

52 Did Floats Survive Impact? — Codes are as follows:

- Y - Yes
- N - No
- U - Unknown
- X - Not Applicable, X, floats not on aircraft

53 Aided Occupant Egress? —Indicates in general, if the floats assisted in the occupants' egress of the ditched aircraft.

- Y - Yes
- N - No
- U - Unknown
- X - Not Applicable, X, no floats on aircraft, no floats successfully deployed, or occupant(s) didn't egress.

54 Aided Survivability? — Indicates in general, if the floats increased the occupants' chances of survival and reduced the risk of injury.

- Y - Yes
- N - No
- U - Unknown
- X - Not Applicable, X, no floats on aircraft or occupant survivability already fully compromised.

55 Time Aircraft Remained Upright — Indicates the time in minutes that the aircraft remained upright in the water. This duration was rounded to the nearest 5 minutes for values over 5 minutes; otherwise. the time was recorded to the nearest minute.

56 Time Aircraft Remained Afloat — Indicates how long the aircraft remained afloat in minutes. This duration was rounded to the nearest 5 minutes for values over 5 minutes; otherwise, the time was recorded to the nearest minute.

57 Cause of Overturning —Indicates the most probable cause of overturning the aircraft. Codes are as follows:

- I - Intentional
- A - Impact Attitude
- W - Weather (rough seas or high winds)
- D - Uneven Float Deployment
- F - Float Problems other than uneven float deployment.
- X - Not Applicable, X, Did Not Overturn
- N - Not Equipped with Floats
- O - Other
- U - Unknown

WATER IMPACT RECONSTRUCTION FORM

ACCIDENT DATA

Sequence 1

Case No.: __________ Reg. No.: ______ Sheet __1__ of __3__

ACCIDENT IDENTIFICATION

Case No: ____________________
Location: ____________________
____
Date:________/________/________
Time: ____________________
Rep. Source: ____________________

AIRCRAFT IDENTIFICATION

Reg. No: ____________________
Mfr: ____________________
Model:____________________
Weight (DGW):______________lbs.

Wing Configuration:
H High **O** Other
L Low **U** Unknown
R Rotorcraft

Engine Configuration:
NO Nose **OV** Overhead
WI Wing **OT** Other
TA Tail

Landing Gear Type:
TR Tricycle **SI** Skis
TA Tailwheel **AM** Amphibian
SK Skids **OT** Other

Landing Gear Status:
UP Up **DO** Down **UK** Unknown

Number of Seats: __________
(0 = Unknown)

AIRCRAFT DAMAGE AND ACCIDENT SEVERITY

Recovered:
Y Yes **N** No **U** Unknown

Damage:
D Destroyed **U** Unknown
S Substantial **N** None
M Minor

Fire:
I Inflight **G** Groundfire
P Postcrash **N** None
U Unknown

Survivability:
S Survivable **U** Unknown
P Partially Survivable **N** Non-Survivable

INJURY SEVERITY SUMMARY

On Board: __________ (0 = Def)
Fatal: __________ (0 = Def)
Serious: __________ (0 = Def)
Minor: __________ (0 = Def)
None: __________ (0 = Def)
Unknown: __________ (0 = Def)

ACCIDENT TYPE/ PHASE OF OPERATION

A. ____________________
B. ____________________
C. ____________________
D. ____________________
E. ____________________

CRASH ENVIRONMENT: IMPACT KINETICS

Velocities (-999.9 = Unk)
Vertical: ____________ ft/s
Longitudinal: ____________ ft/s
Lateral: ____________ ft/s
Resultant:____________ ft/s

Angles (-999.9 = Unk)
Flight Path: ____________deg.
Roll: ____________deg.
Pitch: ____________deg.
Yaw: ____________deg.

CRASH ENVIRONMENT: ENVIRONMENT CONDITIONS

Terrain: ____________ (K = Water)

Water Type: **F** Fresh **S** Salt
O Other **U** Unknown

Sea State (wave height, feet):
__________feet (-1 = Unk)

Wind Speed (kts): ______ (-1 = Unk)
Wind Gust (kts): ______ (-1 = Unk)
Wind Dir. (°): ______ (-1 = Unk)

Weather:
V Visual **I** Instrument **Uk** Unknown

Water Temp. (°F): ______ (-99=Unk)
Air Temp. (°F): ______ (-99=Unk)

AIRCRAFT FLOTATION

Floats Installed? **Y** Yes **N** No
U Unknown

Float Type:
F Fixed **E** Emerg. **O** Other
N None **U** Unknown

Float Location:
L Landing gear **W** Wing **N** None
F Fuselage **O** Other **U** Unknown

Floats Armed? **Y** Yes **N** No
X N/A **U** Unknown

Float Activated How?
M Manually **N** Not Activated
A Automatically **X** N/A **U** Unknown

Floats Inflated When?
B Before Impact **A** At Impact
P Post Impact **X** N/A **U** Unknown

Floats Survived Impact?
Y Yes **N** No **X** N/A **U** Unknown

Floats Aided Egress?
Y Yes **N** No **X** N/A **U** Unknown

Floats Aided Survivability?
Y Yes **N** No **X** N/A **U** Unknown

Time Aircraft Remained Upright:
__________ Minutes
(-1 = Unknown)

Time Aircraft Remained Afloat:
__________ Minutes
(-1 = Unknown)

Cause of Aircraft Overturning:
I Intentional
A Impact Altitude
W Weather
D Uneven Float Deployment
F Float Problems (other than D)
X Not Applicable (Didn't Overturn)
N Not Equipped with Floats
O Other
U Unknown

WATER IMPACT RECONSTRUCTION FORM

ACCIDENT DATA

Sequence 1

Case No.: __________ Reg. No.: ______ Sheet __2__ of __3__

SEQUENCE OF EVENTS

DAMAGE TO AIRCRAFT

DAMAGE TO A/C FLOTATION EQUIPMENT

WATER IMPACT RECONSTRUCTION FORM
ACCIDENT DATA

Sequence 1

Case No.: __________ Reg. No.: ______ Date: ____ / ____ / ____ Sheet 3 of 3

KINEMATIC RECONSTRUCTION

Page No. 1 Data Dictionary for OCC_CMD.dbf File
03/19/91

Field	Name	Type	Length	Dec	Index?	Range	Default
1	CASE_NO	N	3	0	Y	1 to 999 Cases	Next Case#
2	OCC_NO	N	3	0	Y	1 to 999 Occupants	Next Occ #
3	INJURY_DEG	C	1	0	N	F,S,M,N,U	
4	DROWNING	C	1	0	N	Y,N,U	
5	RESTRAINT	C	1	0	N	2,3,4,5,N,U	
6	POSITION	C	2	0	N	FP,FC,FS,MP,MC,MS,AP, AC,AS,OT,UK	
7	EXIT_TYPE	C	1	0	N	D,W,H,F,U,X	
8	EXIT_LOC	C	2	0	N	FP,FC,FS,MP,MC,MS,AP, AC,AS,OT,UK	
9	AC_STATUS	C	3	0	N	FLO,PSB,SUB,UNK,OTH	
10	EGRESS_MOD	C	2	0	N	UN,AI,EJ,UK,NA	
11	PERS_FLOAT	C	1	0	N	Y,N,U	
12	USED	C	1	0	N	Y,N,U,X	
13	N_INF_VEST	C	1	0	N	Y,N,U,X	
14	INF_VEST	C	1	0	N	Y,N,U,X	
15	LIFERAFT	C	1	0	N	Y,N,U,X	
16	SEAT_CUSH	C	1	0	N	Y,N,U,X	
17	WORKED	C	1	0	N	Y,N,U,X	
18	TIW	N	3	0	N	-1 to 999 minutes	-1

Water Impact Reconstruction Form
Data Definitions and Codes

Sequence 2, Occupant Information

INTRODUCTION

Sequence 2 of the Accident Reconstruction form records information on the occupants in the ditching environment. The purpose is to examine the conditions present when the occupants of an aircraft are put into a water impact situation. Information gathered in this sequence include: occupant identification, the degree of occupant injury, occupant/aircraft interaction, and the availability, use, and performance of personal flotation equipment.

The forms used in accident reconstruction were also used as data entry forms for the computer database. The following describes the information groups/database fields and their appropriate codes. Where character codes are descriptive, the appropriate letters are underlined in the descriptions. The field number is also indicated first in bold. Information is broken into 17 logical areas as follows:

1 Case Number — The number assigned, for record keeping purposes, to each accident report obtained for this study.

2 Occupant Number — The number used to identify the occupant throughout the reconstruction form. Also, the role of the occupant is listed as pilot or passenger and the name is given if available. Recording the name is often useful in facilitating the interpretation of accident report transcriptions of interviews and conversations between occupants.

3 Injury Degree — The overall degree of injury sustained by the occupant in the accident is indicated in the following codes:

F - Fatal
S - Serious
M - Minor
N - None
U - Unknown

4 Drowning — Indicates if the occupant experienced death from drowning.

Y - Yes
N - No
U - Unknown

5 Restraint — The type of restraint worn by the occupant at time of impact is listed as 2-point (lap belt), 3-point (lap belt with single shoulder harness), 4-point (lap belt with shoulder harness), 5-point (lap belt with shoulder harness and belt tie-down strap), none, or unknown. Codes are:

- 0 - None used, 0
- 2 - 2-point
- 3 - 3-point
- 4 - 4-point
- 5 - 5-point
- U - Unknown

6 Position in A/C — For categorization and analysis purposes, the location of each occupant is also assigned a seating position code corresponding to the following table. The table depicts nine seating positions from a top view of the aircraft.

Seating Position Codes

	Port	Center	Starboard
Front	FP	FC	FS
Middle	MP	MC	MS
Aft	AP	AC	AS

Codes are as follows:

- FP - Front, Port
- FC - Front, Center
- FS - Front, Starboard
- MP - Middle, Port
- MC - Middle, Center
- MS - Middle, Starboard
- AP - Aft, Port
- AC - Aft, Center
- AS - Aft, Starboard
- OT - Other
- UK - Unknown

7 Exit Type — The type of exit used, either aided or unaided, is classified by the following codes:

- D - Door
- W - Window
- H - Overhead Hatch

F - Fuselage Split
U - Unknown
X - Not Applicable, X, never exited aircraft

8 Location of Exit Used — The location of each exit an occupant used in exiting the aircraft is assigned a code corresponding to the following table. The table depicts nine exit locations from a top view of the aircraft.

Exit Location Codes

	Port	Center	Starboard
Front	FP	FC	FS
Middle	MP	MC	MS
Aft	AP	AC	AS

Codes are as follows:

FP - Front, Port
FC - Front, Center
FS - Front, Starboard
MP - Middle, Port
MC - Middle, Center
MS - Middle, Starboard
AP - Aft, Port
AC - Aft, Center
AS - Aft, Starboard
OT - Other
UK - Unknown

9 Aircraft Status — Indicates the status of the aircraft during occupant egress. The codes are:

FLO - Floating
PSB - Partially Submerged
SUB - Submerged
UNK - Unknown
OTH - Other

10 Egress Mode — Indicates how the occupant's ability to egress was affected by the impact. The codes below describe further.

UN- Unaided

AI - Aided
EJ - Ejected
UK - Unknown
NA - Not Applicable

11 Personal Floatation Equipment Available? — Indicates whether or not personal floatation equipment was available.

Y - Yes
N - No
U - Unknown

12 Used? — Indicates whether or not personal floatation equipment was used.

Y - Yes
N - No
U - Unknown
X - Not Applicable, X, no personal floatation equipment available

13 Non-Inflatable Vest Used? — Indicates whether or not an inflatable life vest was used by the occupant for floatation.

Y - Yes
N - No
U- Unknown
X - Not Applicable, X, no personal floatation equipment available

15 Liferaft Used? — Indicates whether or not a liferaft was used by the occupant for floatation.

Y - Yes
N - No
U Unknown
X - Not Applicable, X, no personal floatation equipment available

16 Seat Cushion Used? — Indicates whether or not a seat cushion was used by the occupant for floatation.

Y - Yes
N - No
U - Unknown
X - Not Applicable, X, no personal floatation equipment available

Page No. 1 Data Dictionary for INJ_CMD>dbf File

03/19/91

Field	Name	Type	Length	Dec	Index?	Range	Default
1	CASE_NO	N	3	0	Y	1 to 999 Cases	Next Case#
1	OCC_NO	N	3	0	Y	1 to 999 Occupants	Next Case#
1	TYPE	N	2	0	N	01 to 99 NTSB Codes	
1	LOCATION	N	2	0	N	01 to 99 NTSB Codes	
1	SEVERITY	N	2	0	N	01 to 99 NTSB Codes	
1	CAUSE	N	2	0	N	01 to 99 NTSB Codes	
1	INJ_IMPACT	N	1	0	N	I, P, U	

Water Impact Reconstruction Form
Data Definitions and Codes

Sequence 3, Injury Information

INTRODUCTION

Sequence 3 of the Accident Reconstruction form records information on the injuries by occupants during the accident. The purpose is to assess each occupant's relationship to and interaction with the aircraft involved in the accident. Information recorded includes each occupant's name and number; injuries sustained including injury type, location, severity, cause, and injury relationship to impact; and drowning information. There is also room for comments and/or an explanation for each injury.

The forms used in accident reconstruction were also used as data entry forms for the computer database. The following describes the information groups/database fields and their appropriate codes. Where character codes are descriptive, the appropriate letters are underlined in the descriptions. The field number is also indicated first in bold. Information is broken into 8 logical areas as follows:

1 Case Number — The number assigned, for record keeping purposes, to each accident report obtained for this study.

2 Occupant Number — The number used to identify the occupant throughout the reconstruction form. Also, the role of the occupant is listed as pilot or passenger and the name is given if available. Recording the name is often useful in facilitating the interpretation of accident report transcriptions of interviews and conversations between occupants.

3 Injury Type — The specific type of the particular injury (from NTSB Form 6120.4 Supplement K (1-84), Lesion - C is listed as:

01 Laceration	11 Amputation
02 Contusion	12 Burn
03 Abrasion	13 Fracture and dislocation
04 Fracture	14 Severance (Transection)
05 Concussion	15 Strain
06 Avulsion	16 Detachment (Separation)
07 Rupture	17 Perforation (Puncture)
08 Sprain	18 Suffocation
09 Dislocation	88 Injured unknown lesion
10 Crush	99 Other

4 <u>Injury Location</u> — The bodily location of the particular injury (from NTSB Form 6120.4 Supplement K (1-84), Body Region - A is listed as:

01 Head (Skull, scalp, ears)
02 Face (Forehead, nose , eyes, mouth)
03 Neck (Cervical spine, C1-C7)
04 Shoulder (Clavicle, scapula, joint)
05 Upper limb (Whole arm)
06 Arm (Upper)
07 Elbow
08 Forearm
09 Wrist
10 Hand-fingers
11 Chest (Anterior and posterior ribs)
12 Abdomen (Diaphragm and below)
13 Back (Throracic spine T1-T12)
14 Back (Lumbar 11-15)
15 Pelvis-hip
16 Lower limb (Whole leg)
17 Thigh (Femur)
18 Knee
19 Leg (Below knee)
20 Ankle
21 Foot-toes
22 Whole body
88 Injured, unknown region
99 Other

5 <u>Injury Severity</u> — The general severity of the particular injury (from NTSB Form 6120.4 Supplement K (1-84), Abbreviated Injury Scale - E is listed as:

00 Not injured
01 Minor injury
02 Moderate Injury
03 Serious Injury (Not life-threatening)
04 Severe Injury (Life-threatening survival probable)
05 Critical injury (Survival uncertain)
06 Maximum (Untreatable)
07 Injured (Unknown severity)
88 Unknown if injured

6 Injury Cause - The cause or source of the particular injury (from NTSB Form 6120.4 Supplement K (1-84), Injury Source List - F is listed as:

01 Windshield
02 Windshield frame
03 Window
04 Window frame
05 Instrument panel
06 Side console
07 Center console
08 Control stick/cyclic stick
09 Collective
10 Control yoke /column
11 Throttle quadrant/levers
12 Rudder pedals
13 Ceiling
14 Sidewall
15 Floor
16 Fuselage framing/structure
17 Table
18 Seat
19 Seatback tray
20 Restraints—seatbelt/tiedown
21 Restraints—shoulder harness
22 Unsecured item(s) in cockpit
23 Unsecured item(s) in cabin
24 Other occupants
25 Ground/runway
26 Unsecured seat(s)
27 Outside object(s) entering aircraft
28 Galley item(s)
29 Food/beverage item(s)
30 Other interior objects
31 Other exterior objects
32 Evacuation slide/slide raft
33 Escape rope/tape
34 Escape inertia devise
35 Ejected from aircraft
36 Propeller/rotor blades
37 Exterior aircraft surface
38 Engine
39 Wheel/tires
40 Ground vehicle
41 Toxic/noxious/irritant fumes
42 Fire/radiant heat
43 Flying glass
44 Door/hatches
45 Acceleration forces
46 Exposure
47 Glare shield
48 Eyeglasses
49 Inhalation of Water
88 Unknown
99 Other

7 Injury-Impact Relationship — Indicates the causative relationship between the injury sustained and the impact.

Codes are as follows:

I - Impact Injury
P - Post-Impact Injury
U - Unknown relationship b/w injury & impact

WATER IMPACT RECONSTRUCTION FORM

INJURY DATA

Sequence 3

Case No.: __________ Reg. No.: ______ Sheet ______ of ______

OCCUPANT IDENTIFICATION INFORMATION	INJURY IDENTIFICATION INFORMATION					
	TYPE	LOCATION	SEVERITY	CAUSE	INJ IMPACT IMP-POST-UNK	COMMENTS
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	
CASE NO.:					I P U	
OCC. NO.:					I P U	
NAME:					I P U	
					I P U	
					I P U	

APPENDIX C - SAMPLE CASE TO DEMONSTRATE ACCIDENT RECONSTRUCTION METHODOLOGY

Summary: A weight class A aircraft with a low wing and a nose-mounted engine began to run rough and lose power at 5000 ft. above sea level and approximately three miles from shore. Shortly afterwards the engine began shaking and oil and smoke were observed coming from the engine area. The pilot shut down the engine and initiated a glide-out, intending to land at an airport approximately five and a half miles away. Strong quartering headwinds decreased gliding performance therefore the decision was made to ditch the aircraft. The pilot feathered the prop to reduce drag and ditched the aircraft in the ocean about 1/8 mi. offshore. The sea state was not recorded but the wind was 7 knots.

Aircraft Damage: The aircraft impact damage was recorded as minor but no details were documented.

Survival Aspects: The pilot was wearing a lap belt and dual shoulder harness at the time of impact. The aircraft remained afloat for two to three minutes and drifted to shore. The pilot escaped through the front right cockpit door and received no injury.

Accident Kinematics: The landing was recorded as having caused no injuries to the occupant and only minor damage to the aircraft.

Based on the above observations, the aircraft was assumed to have 0 - 5 deg. pitch nose up, 0 deg. roll, 0 deg. yaw, and a shallow flight path angle of 3 deg. The aircraft's stall speed of 147 ft/sec was used as the longitudinal velocity component. This resulted in a sink rate of 20.7 ft/sec.

Velocity Component Estimates:

Let the pitch angle be 5° noseup and the flight path angle be 3°. The velocity components in aircraft coordinates can then be calculated as follows:

Vertical velocity = 147 tan (5+3)

$$V_v = 147 \tan 8^\circ$$

$$V_v = 20.7 \text{ ft/sec}$$

Resultant velocity = $V_R = (147^2 + 20.7^2) = 149 \text{ ft/sec}$

Deceleration Pulse Estimates:

A uniform triangular deceleration pulse was used to simulate the vertical impact conditions. The vertical stopping distance was assumed to be 1 ft to account for water displacement and fuselage crush. With this stopping distance and a vertical velocity of 20.7 ft/sec the vertical pulse was calculated to be 13 g's. The occupant was properly restrained with a four-point restraint and there were no reported injuries due to vertical impact loads therefore the 13 g pulse seems reasonable. The stopping time calculated for the vertical velocity of 20.7 ft/sec was 0.049 seconds. A 13 g pulse of 0.01 seconds duration is within the limits of human tolerance without injury from whole body acceleration.

$$a_g = \frac{(Vv)^2}{S} \qquad t = \frac{2(Vv)}{G(a_g)}$$

$$a_g = \frac{(20.7\ \text{ft/sec})^2}{1\text{ft}} \qquad t = \frac{2(20.7\ \text{ft/sec})}{13(32.2\ \text{ft/sec})}$$

$$a_g = 13\ \text{g's} \qquad t = 0.01\ \text{sec.}$$

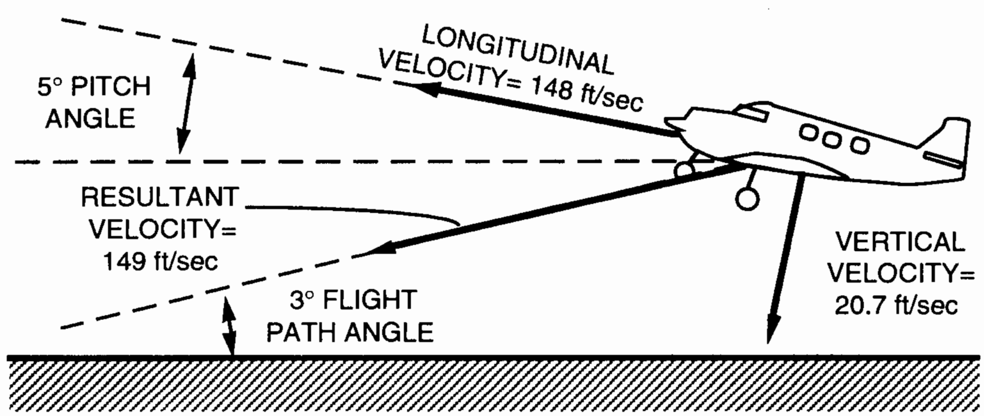


FIGURE C-1. IMPACT ATTITUDE AND IMPACT VELOCITY COMPONENTS

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