Cars submerged in water: escaping problems

Safety Study

The Hague, 2003

Transport Safety Board

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FOREWORD

When cars become submerged, the chances of the passengers being seriously injured by the impact on entering the water are high, but not one hundred percent. Sometimes the initial injuries are slight. However, if the occupants do not manage to escape from the vehicle, such accidents have fatal consequences.
This scenario is one that is particularly feared by car occupants, who are ultimately powerless to escape the vehicle. The research that led to this study, however, showed that even well-trained, healthy people like police officers, were unable to escape no matter what they did. The experience is a nightmare for assistance providers too. If they (bystanders or fire fighters) fail to gain access to the vehicle, they must watch helplessly as the car sinks with its occupants still inside.

In the Netherlands in particular, each year many vehicles end up submerged in water. In real terms, the number of people who drown as a result form only a small percentage of the total number of annual road accident fatalities in the Netherlands. Seen in this light, it may appear that the problem is small. However, once it becomes clear that these fatalities could be avoided, such accidents deserve further public and government attention.

Based on its research, the Board is convinced that proper information provision to and instruction of Dutch road users could definitely result in a reduction in the number of deaths by drowning. In addition, it appears that outside built-up areas, particularly in corners and on sloping verges, cars often become submerged in water.
For this reason, roads authorities should examine their networks to find out whether further measures should be taken at dangerous points.

Initially, the suspicion arose that for some of the accidents studied short circuiting of the cars' systems played a role in the occupants' inability to escape. However, this suspicion was neither confirmed nor denied by the results of the study. We must therefore assume that the short circuiting of systems could play a role. Consequently, the government has been asked to examine this aspect. Furthermore, with regard to this issue in connection with submerged cars, the Board will continue to follow developments in cooperation with the US National Transport Safety Board, to investigate the possibility of risks being increased by the introduction of more advanced vehicle technology.

Pieter van Vollenhoven
Chair of the Board

J.H. Pongers
Acting Secretary Director

SUMMARY

On 29 July 1998, a serious accident took place in Edam involving a police car that ended up in the water. All three of the occupants drowned because they were unable to escape in time. After hitting the water, the car remained afloat for a short time. During this time, various people entered the water and unsuccessfully attempted to free the occupants.

As a result of this accident, the Transport Safety Board decided to carry out a safety study concerning submerged cars.
In some ways, the fatal accident in Edam appeared not to have been in any way an exceptional case. Every year in the Netherlands, an average of 750 to 800 cars end up in water, resulting in the death by drowning of only about 30 people.
The victims in Edam drowned because they had no chance to escape from the vehicle in time. The suspicion is that technical problems played a role in the form of a short circuiting of the central locking system.
Similar problems can occur with electronic windows and sunroofs. When such problems arise, escape becomes even more difficult.

We were unable to prove that such problems occur frequently. A study of the relevant police reports revealed little information in this regard. Despite this fact, our investigation did uncover three relevant cases. Problems with electronic systems do, therefore, occur. Research shows that no legislation exists to ensure the continued functioning of such systems if vehicles enter water. Moreover, the components used are generic and their use is widespread across many makes of vehicle.

It is likely that future developments in vehicle technology will make escape increasingly difficult. More and more electronic anti-theft systems are being applied. In addition, electronic windows and locking systems are becoming increasingly common. The development of systems for side and rear windows is also underway (on a small scale), and this too could make escape more difficult. Laminated glass is being used more frequently for these windows to increase their strength. In collisions and rolls – which often precede cars becoming submerged in water – laminated glass helps keep occupants from being thrown out of cars. However, the use of seatbelts is a better method to this end.

Escaping from a vehicle in water demands the utmost effort from the occupants in a very short space of time. Research shows that people are not well informed about what to do when vehicles enter the water. Many do not know, for example, that the car will float for a time. Many are also unaware that they must begin their escape attempts immediately and should not wait for the car to be full of water before attempting to open a door. They are also unsure of which window they should attempt to break if they cannot open a door or window. Many choose to try and break the strongest window – the windshield (laminated and bonded) – instead of a less-strong side window. Two-thirds of people would attempt to break a window in the middle, when a corner is preferable. Finally, only a small percentage of people keep an emergency hammer in their car. Such hammers make breaking a window much easier, but it is not a compulsory piece of equipment.

Although this study focuses on escaping from vehicles in water, the prevention of such accidents is also important. However, the research failed to uncover any definite ‘black spots’. However, accidents involving cars entering water have a number of typical characteristics and generally progress along specific lines. Such accidents occur more often outside built-up areas and at bends in the road. The vehicle concerned regularly first enters the right shoulder and returns to the road when the driver corrects his direction. The vehicle begins to skid when back on the road, moves to the left of the road, sometimes in a spin, and then rolls down the sloping verge, which often leads to it flipping over.

Recommendations

It is recommended that the Minister of Transport, Public Works and Water Management, in cooperation with traffic and consumer organisations, importers and dealers of passenger cars, inform the public at large – and not just driving licence holders – about the dangers of cars entering water, the role of seatbelts, and in particular, the desired actions for escaping from the vehicle (see annex 5 of the report).

It is recommended that the Minister of Transport, Public Works and Water Management argue for the European Commission to support requirements for passenger cars that would contribute to preventing:

- electric systems from unintentionally locking doors by short circuiting on entering water;
- electric window and locking systems ceasing to function on entering water.

It is further recommended that the Minister of Transport, Public Works and Water Management:

- if necessary together with other information on accidents involving water
- (recommendation 1) lobby for Dutch passenger cars to be equipped with the means to break windows, known as a life hammer, and to ensure that government vehicles carry such equipment;
- promote research into an alternative for the existing life hammer that is capable of breaking the new, reinforced glass used in side windows.

In so far as and for as long as no adequate solutions are found, consumers need to be warned about the dangers.

The VNG and the IPO are recommended to encourage roads authorities to, at the very least, warn road users of sections of road where the danger of ending up in water is relatively high.

1. MOTIVATION FOR THE STUDY

This study was motivated by the serious accident involving a police car that took place on 29 July 1998, in Edam. The vehicle entered deep water and all three occupants failed to escape in time and died by drowning. After hitting the water, the car remained afloat for a short time. During this time, various people entered the water and unsuccessfully attempted to free the occupants.
The consequences of a car entering water can be fatal. Moreover, this scenario was terrifying, particularly for the occupants. The experience was, however, a nightmare for assistance providers too: when they failed to gain access to the vehicle, they had to watch helplessly as the car sank with its occupants still inside.

Shortly after the accident, the suspicion arose that the short circuiting of the car's locking system had unintentionally locked all the doors. The question also arose as to whether similar short circuits were occurring on a larger scale. Apart form the problem of locked doors, it was also unclear why the occupants had not managed to escape through a window. For these reasons, the Board decided to investigate this issue further. This report looks briefly at the causes and circumstances of accidents resulting in cars entering water, and focuses on the subsequent problem of the occupants escaping or being freed by others.

2. ACCIDENTS

In 2000, there were some 40 reported incidents of fatalities resulting from vehicles entering water[1].

The police reports of a number of these accidents were analysed. The three accidents described below illustrate the safety issue being investigated. The first accident provided partial motivation for this study:

2.1 A police car in Edam

In the late afternoon of Wednesday, 29 July 1998, three police officers from the Zaanstreek-Waterland regional police were travelling in their police car from Volendam to Edam. The route taken was across the Zuidpolderzeedijk along the Markermeer and then on the Keetzijde along the Oorgat. The Oorgat is the canal that links the Markermeer with the Purmerringvaart. The Oorgat has a navigation channel of two to three metres in depth. The two-lane road runs along a dike just outside the built-up area. The speed limit is 80 km/h. The Zuidpolderzeedijk has a number of bends. The final bend before the Keetzijde has a positive camber common to most roads: the outside of the bend is higher than the inside. The road surface is asphalt concrete. On the day in question, the road was dry. The skies were clear and visibility was good.

Photograph 1. The final bend at the scene of the accident. Source: Police.

The police car was driving at high speed on the road on the dike, and for unknown reasons left the road and ended up in the adjacent Oorgat. There were a number of witnesses to the accident. Initially, the car remained afloat. Several bystanders entered the water and attempted to open the front and back doors. They were unsuccessful in freeing the occupants. They had no life hammer at the outset. When a life hammer was made available, the car had already sunk below the surface of the water.

The bystanders were able to speak to the police officer in the back seat of the car and had eye contact with her. This officer was unable to break a window or open a door. The bystanders had no eye contact with the two officers in the front seat. It is unclear as to whether these officers lost consciousness as a result of the impact. One of the witnesses called the 112 emergency services. Divers of the Purmerend fire brigade – and later from the Amsterdam fire brigade were alerted and rushed to the scene of the accident. The divers arrived at the vehicle when it was fully submerged, on its right side, at the bottom of the navigation channel.

[1] See annex 4 for the reports concerning these accidents.

The boot and both left doors were locked. The windows of both left doors and the rear windshield were still intact. There was a small hole in the left upper corner of the front windshield. In order to recover the bodies of the victims, the divers removed the front windshield piece by piece, as well as the window of the left side door. Once the glass had been removed, the divers could still not raise the locks of the doors[2].

Photograph 2: The bank of the Oorgat. Source: Police.

A technical inspection of the vehicle showed the following. At the time of the accident, the vehicle was in good condition. No defects were found that could have contributed to causing the accident. The deformation of the bodywork was not severe enough to have jammed any of the doors or the boot. The doors and the boot lid could be opened normally once the locking system was disabled.

The seatbelt tensioners had functioned at the time of the accident, but the airbags had not been activated. Based on the injuries sustained by the driver, the police concluded that he had been wearing a seatbelt. The seatbelts in the back seat were not able to be used because the belt buckles were under the rear seat. The boot lid had been locked from the outside (with the key). Child-safety locks had been used on both rear doors. The window winder was missing from the left rear door. The reason for this is unknown, nor is it known whether this applied to the right rear door as well. It was discovered that the absence of the window winder had been known for some time. The locking knob of the left front door had broken off. The impression of a heel of a shoe was discovered in the upholstery of this door. This could indicate that one of the front occupants had attempted to kick the door open to escape.

A life hammer was mounted on the front passenger side of the car. There was a crow bar and a fire extinguisher behind the right front seat. On the left and right of the front seats, two large metal torches were mounted. These items, however, had not been used to facilitate escape. The officers had also not attempted to use their service revolvers. Based on the statements of the assistance providers at the scene of the accident, the police suspected that due to an electrical short circuit in the water, the anti-theft system on the doors had been activated. As a result, the doors could not even be opened with a key. Paragraph 3.3 examines this matter in more detail.

[2]source: reports of the TOD Amsterdam-Amstelland (pages 34). The divers' statements show that they were unable to open the doors. The TOD provided further information (5 June 2002, reference NG/10779) that stated that neither of the locking knobs on the left side doors could be raised. (The knob on the front left door had been broken off.)

Photograph 3a (left): Left side of the car, section of the front left door. The broken locking knob can be seen pulled up at the bottom left of the window
Source: Police

Photograph 3b (right): Left side of the vehicle, section of the left front door. The unbroken locking knob can be seen in its entirety.
Source: Police

2.2 A van in Ens

On 23 February 1999, a 30-year-old man was driving a van at night outside the built-up area, during a heavy snowfall with gusting winds. He was travelling on the Zuiderringweg, along the Leemtocht canal in Ens. This is a provincial road with a maximum speed limit of 80 km/h. The section of road concerned was straight and the road was asphalt. According to the driver's statement, the van was travelling at 70 to 80 km/h, when it skidded and ended up in the canal. The driver was the only occupant. He stated that the doors (equipped with a central locking system) spontaneously locked down almost immediately on impact with the water. The locking knobs on the doors went down by themselves. The electrically operated windows failed to respond. The driver first tried to unlock the doors. When he failed to raise the knobs, he tried, unsuccessfully, to break a side window using a barcode scanner. Finally, he decided to try and remove the front windshield by kicking it in the right upper corner. He managed to escape from the van through the opening he created.
He first climbed up onto the roof and when the van floated to the other bank he jumped to shore. The van then slid at an angle under the surface of the water. The driver estimated that three to four minutes elapsed from the moment the van hit the water to the time he escaped. He used his mobile phone to call the 112 emergency services and the police arrived about 10 or 15 minutes later.
Only the driver's lower body had become wet. He still has some problems with his back resulting from kicking out the windshield. According to the police, the van's lights and windshield wipers were working when they arrived at the scene of the accident. The lights remained on for quite some time. The driver stated that the engine had switched off before the van hit the water. The van had first slid and skidded for quite a distance before entering the water.
The front windshield of the van was bonded. The driver is a car mechanic and was aware that he had to kick the corner of the windshield to break it loose.

2.3 A passenger car in Maastricht (in the River Maas)

On Monday, 16 April 2001 at around 10.10 p.m., a 63-year-old woman drove into her garage from her driveway. Both driveway and garage were situated next to the house, along the Maas River in Maastricht. It appears she drove too far into the garage and collided with a fridge and a shelf where frying fat was stored. She then reversed out of the garage, off the driveway, across the street, through barbed wire, across the riverbank and landed in the Maas. The neighbours heard the crash of the collision in the garage, and when they came

outside they saw the car reverse into the Maas. The car with the woman still inside, then floated downstream towards Smeermaas. The current was strong. A neighbour ran alongside the car and called to the woman to get out. She was unable to do so. She was able to roll down a window and talk to the neighbour. She said that the door was stuck. After travelling some 100 to 200 metres, the car disappeared under the surface of the water, at the spot where the Maas forms the border between Belgium and the Netherlands.
The emergency services had been alerted by this stage. The fire brigades of Maasmechelen and Maastricht and police from Lanaken and Maastricht arrived. They attempted to track down the car, but failed. Only after a 10-day search was the car located by an underwater camera. The driver appeared to have drowned. After the car had been salvaged, it was examined by the police. The brakes, hand brake and clutch appeared to be in good working order. A technical inspection of the vehicle showed no abnormalities.

3. ANALYSIS AND BACKGROUND

3.1 General aspects of accidents involving cars entering water

Accidents involving cars entering water are not at all unusual in the Netherlands. The frequency of such accidents resulting in death by drowning was investigated, as well as the circumstances surrounding such accidents[3].

Data was collected both in the Netherlands and abroad.

3.1.1 The Netherlands

Compared with neighbouring countries, water is in abundance in the Netherlands. Every year, around 750 to 800 passenger cars land in water whereby physical injury results. The Institute for Road Safety Research (SWOV) was commissioned by the Dutch Transport Safety Board (RvTV) to investigate accidents involving passenger cars entering water. The SWOV distinguished between accidents in:
• deep water
• ditches

Each year, over 50 incidents of physical injury are recorded involving cars in deep water. Such accidents result in around 20 fatalities per year. The cause of death in many of these accidents is drowning. In other cases, fatalities occur due to a collision before the cars enter the water. In about 700 to 750 cases involving injury, the cars land in ditches or gullies. Such accidents result in some 40 deaths every year. For a small percentage of these, about 40%, the cause of death is drowning. In total, the SWOV estimates that every year some 30 occupants of cars that enter water in accidents lose their lives due to drowning. This estimate is not one hundred percent accurate because the cause of death in the accidents investigated is relatively often unknown. However, the numbers are confirmed by figures from the Cause of Death Statistics of the Central Bureau of Statistics (CBS), which show that in the period 1996-1999 a yearly average of 33 car occupants died as a result of drowning. Compared with average traffic accidents, accidents involving cars entering water are relatively serious. In comparison with the total number of accidents resulting in physical injury, accidents in deep water more frequently result in death.
3% of average traffic accidents result in deaths; for accidents involving deep water the percentage is higher at almost 5%. The consequences of single-vehicle accidents (accidents involving only one party and collisions with stationary objects) are usually more severe than accidents involving two parties. Relatively speaking, single-vehicle accidents where cars enter water result more often in deaths than 'ordinary' single-vehicle accidents[4].

In past years, the absolute number of accidents involving cars entering water and in which occupants were injured, declined. Relatively seen, however, the number is increasing, given that the reduction in the number of other accidents has been more pronounced.
For all accidents involving passenger cars, the number of fatal accidents is about 35% lower in the period from 1997 to 2000 than in the period 1983 to 1986. For accidents involving cars in deep water, however, the figure is only 20%. The reduction in these accidents has therefore been significantly less.
Accidents involving cars entering water happen relatively often:
• on Saturday and Sundays
• at night
• in winter and March and May
• in mist, snow and hail

[3] See also the SWOV report.
[4] The institute for Road Safety Research (SWOV) was commissioned by the RvTV to conduct support studies. See annex 1 for the working methods of this report.

3.1.2 Outside the Netherlands

International statistics give no figures involving water and drowning. For this reason, at the request of the Board, the SWOV carried out a limited survey in eight neighbouring countries[5].

In these countries, accidents involving cars entering water are rare. In Denmark, Sweden and Finland the number of fatal accident and/or incidents of drowning was estimated at 1 to 4 per year. In Belgium, Germany, and Austria the problem was described as 'small' and no figures were supplied. Germany, the UK, and France still have to submit figures. There is no relevant international literature available on this subject.

3.2 Causes of cars entering water

Circumstances

At the request of the Board, the SWOV examined 137 police reports from 2000: all fatal 'water' accidents of that year and about 90 other 'water' accidents that had resulted in hospital admissions (about 15% of the total). The reports showed that accidents involving cars entering water are often complex.

Before the vehicle enters the water:
- it has often skidded or rolled over causing it to land on its roof or side;
- the chances are high that occupants incur serious injuries during the skid or roll;
- collision with another vehicle or obstacles on the verge has often taken place, or, frequently, with the hard side of the ditch or the bank, again with a good chance of serious injury;
- the doors sometimes become jammed as a result of the damage sustained in the skid, collision or roll.

The above elements hinder escape or being freed from the vehicle, even if the vehicle comes to rest in a dry ditch or gully.

The accidents examined typically progressed as follows:
- the vehicle drives onto the right shoulder;
- the driver attempts to correct his steering;
- the vehicle returns to the road;
- it begins to skid;
- he vehicle skids sometimes in a spin, to the left of the road[6];
- rolls down the embankment, which often results in rolling over;
- the vehicle ends up in the water – often on its roof or side - sometimes after colliding with obstacles.

Rolling over in particular is often the cause of fatalities in these accidents[7].

In 50% of the accidents examined, the vehicles both skidded and rolled over. In a limited number of cases occupants were thrown out of the vehicle (due to the force of the turning and rolling movements of the vehicle). As other studies have shown earlier, it appeared that this element has a high risk of ending up in fatalities or serious injuries. In the accidents of this type that were examined it appeared that seatbelts had not been used.

5 Eight countries were surveyed: Germany, France, Belgium, the UK, Austria, Finland, Denmark, and Sweden. The national statistics authorities of these countries were asked for data on accidents involving cars entering water.
6 Up to this point, this kind of accident shows many similarities to the accident on the N31 near Harlingen, on which the Board reported earlier.
7 Many aspects of passenger cars are tested today. Contrary to usual vehicle tests, roll-over tests do not examine the effects on the occupants.

Locations

An analysis of the traffic accident register did not reveal any clear problem locations (black spots). However, something can be said about the features of the accident sites. Accidents involving cars entering water often occur at bends in the road. Three-quarters of car-water accidents take place outside built-up areas. These areas have more ditches and gullies. In addition, the speed limit in these areas is higher which increases the chances of skidding.

Emmen, Haarlemmermeer, The Hague and Rotterdam had higher figures than other municipalities. The figures for the provinces of North and South Holland were higher than those of other provinces.

In many cases there was no physical barrier between the road and the water. The new handbook for road design does not recommend the use of crash barriers on non-arterial roads. According to the handbook, such devices give the impression that the road is an arterial road and this encourages motorists to drive faster[8].

Photograph 4 Example of a car on its roof and partially submerged. Source: ANP.

3.3 Escape from cars

Problems

It is not always possible to escape from cars that have entered water. The police reports examined showed that escape problems are frequently encountered (see table 1)[9].

	Severity of the consequences		
Escape problems	**Death**	**Hospital**	**Total**
Yes	15	13	28
No	3	21	24
Not known	32	53	85
Total	50	87	137

Table 1: Numbers of escape/being freed problems for car-water accidents of a particular severity in 2000. Source: SWOV, 2002.

In 30% of the fatal accidents and 15% of the hospitalisation accidents, escape problems were reported. Witnesses and those involved in the accidents stated that they were unable to get to the occupants, that the doors were jammed, or that the occupants had to escape through a window.

[8] See also annex 6
[9] Derived from the SWOV analysis of police reports (see also paragraph 3.2 and footnote 3.

In many cases (85 of the 137, about 60%) it is unknown whether or not escape problems were encountered. It is assumed that escape problems existed in a certain proportion of these accidents too. The total percentage for escape problems is therefore higher.

Former procedure

Back in the thirties, attention was given to the actions one should take when a car enters water. It was assumed that when cars sink, an air bubble would form at the top of the vehicle so that any occupants could continue to breathe. The advice was to allow the car to sink completely, and only then to try and open a door and leave the vehicle.

Current procedure

At the end of the sixties, it became clear that the chances of an air bubble forming were very small. This was due in part to the changed construction of cars. Older cars had a rounded roof under which an air bubble could form. In addition, the weight distribution of older cars was such that more often than not they remained upright when sinking (rather than turning onto their side). According to the SWOV the best procedure to follow is: Leave the vehicle as quickly as possible during the floating stage, through a side window, for example.[10] During the seventies, this new knowledge was included in driver information and driving lessons.

3.3.1 Knowledge

Survey

At the request of the Transport Safety Board, the NIPO conducted a survey in September 2001, to asses the level of public knowledge regarding the subject at hand. In autumn 2001, some 1000 people were asked what they knew about cars in water. The results showed that many people are not aware of the correct procedure for these circumstances.

No knowledge of floating

Most of those interviewed were unaware that cars will continue to float for several minutes and that this is the best time to escape from the vehicle. This is particularly important because this reassuring knowledge can help prevent panic.

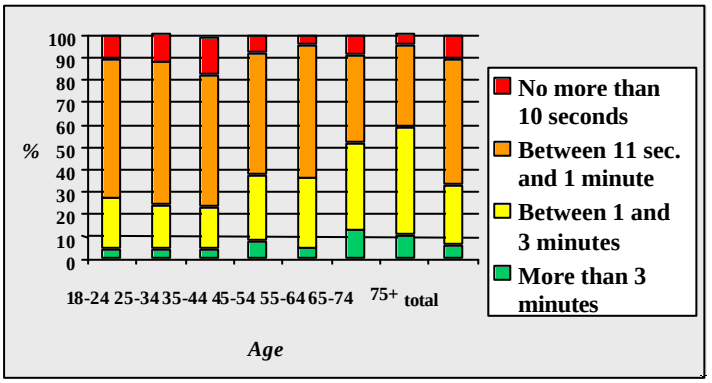

Table 2: For how long do you think a car can remain afloat? (Source: Nipo 2001, table 5).

[10] See also annex 4.

Half of those interviewed thought that a car would float for less than a minute before sinking. The answer was not related to income, education or driving frequency.
Age did affect the answers: the older the person, the better their knowledge that cars do in fact float and do not sink all that quickly (see table 2).
When to escape
Many people assume they have too wait until the car is full of water or totally submerged before trying to escape. They lose precious escape time in this way. However, most people seem to be aware that it is unlikely they would be able to open the doors at the outset.

The tendency to wait increases with the age of those interviewed. (see table 3).

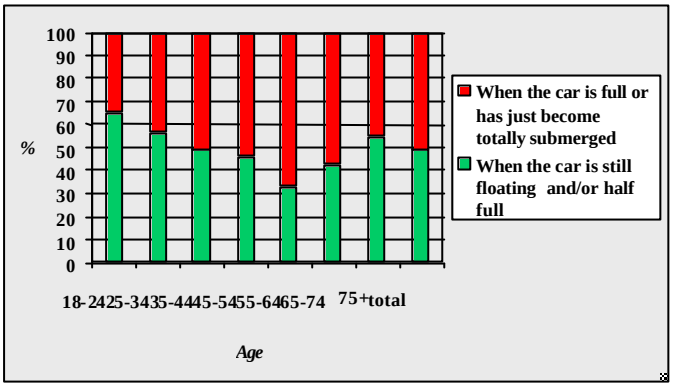

Table 3: What is the best time to escape from the car? (Source: Nipo, 2001, table 4)

The figures show that the 67% of the group aged between 55 and 64 years would wait until the car was full of water! In the past, this group probably received more intensive instruction in the former procedure (to wait) than younger people, and has remembered these instructions. From the seventies onwards, this information has been amended in driving courses. In the group aged over 65, a change can be seen[11].

Electric locks/windows

64% of those interviewed had at least one electronic system in the car. This applied in particular to the group that drives regularly (commuters), and for higher income brackets. About 87% believed they understood the operation of these well. In other words, 13% of this group did not fully understand these systems. Infrequent drivers in particular believed they lacked knowledge about how electronic locking systems work (24% of this group lacked knowledge in this respect).

Not familiar with breaking windows

In situations in which it is impossible to open doors and windows, occupants have to break a window. Those interviewed were asked which window they would choose to break.

Only one-third of those interviewed would choose a side window (the windows for which the chance of successful breaking is the highest). This also applies when the car is on its side; in these conditions only 31% would choose to break a window on the other side and half would try and break the front windshield.
Those interviewed would also choose a spot on the window whereby breaking the glass would be difficult.
Two-thirds (65%) would attempt to break the glass in the centre. This is not the best spot to choose – the chances of breaking the glass are considerably higher if a corner is chosen.
Only 20% of the motorists interviewed had a life hammer in the car. Such hammers have a sharp metal point and can be used to break windows. It is not compulsory for cars to be equipped with life hammers.

[11] However, those aged 75 + and to a lesser degree 65+, almost never drive anymore. The number of respondents in this age group was very small.

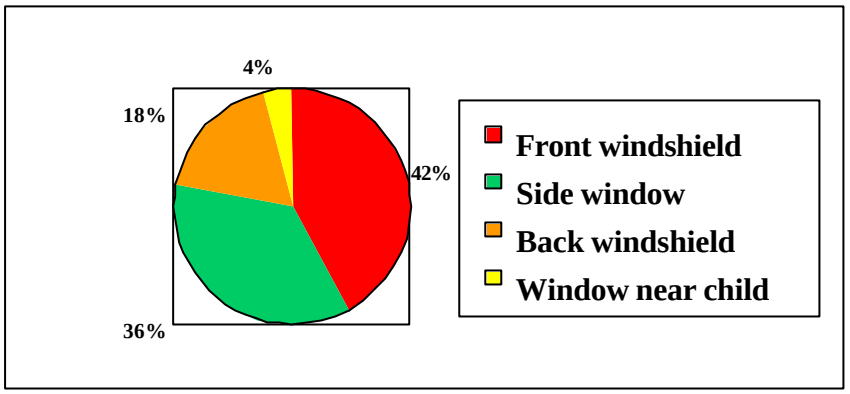

Table 4: Which window would you break? (Source: Nipo, 2001, table 8)

Personal experience

The NIPO study showed that 1% of those interviewed had at some time personally been involved in an accident where a car entered the water. Two of them did not complete the questionnaire. The subject raised strong emotions in many of those interviewed. Even when the interviewees had no personal experience of such accidents, the subject still elicited strong emotions. Quote from the questionnaire:
(The respondent imagines what could happen) …
An argument begins about when to open the doors or while escaping through a door... the screaming child makes it impossible to think… Oh, boy, that's enough, I really don't want to think about this anymore.

3.3.2 Physical/mental condition

Not only knowledge but also physical and mental condition are important in escaping. As far as the almost unimaginable physical and mental strain is concerned, no structural solutions exist.

Physical condition/dexterity

Some people are limited in their physical dexterity. A degree of physical suppleness is needed to escape through a broken window. Such openings are not very large and it is necessary to push off from the car seats in order to climb out. If the car is in deep water, and help is not available, it is necessary to swim. In general, cars land in relatively cold water which causes panic. The water may be dark and murky, and visibility poor and this makes it hard to orient. These elements have a negative impact on escaping.

Shock/panic

Landing in water is generally unexpected. Many actions must be taken in a short space of time. In these circumstances, some people no longer remember how to release their seatbelt, unlock the doors or operate the windows. Panic can also play a role. People find it difficult to think clearly, and cannot call on the necessary knowledge quickly.

3.3.3 Technical problems

Technical malfunctions in the car can make escape difficult. In this respect, a distinction can be made between serious problems with opening doors and windows and problems with breaking windows.

Problems involving automated locks and windows

A large number of passenger cars are equipped with central locking systems. Such systems enable all doors, the boot and the petrol cap to be locked from a single point. The system

can be operated using the key, a remote control, or a switch in the car. Some central locking systems work pneumatically. Thin tubes attached to a vacuum pump suck the locks downwards when the switch (at the driver's door) is activated, or when the locking system is activated by using a key on one of the front doors. If such systems short circuit on entering water, the doors may become locked unintentionally. If the short circuit takes place in a particular part of the system, it may cause the vacuum pump to work constantly so that the lock knobs keep being sucked back down.
Such problems occurred in the accident in Ens described earlier. The driver reported that shortly after the vehicle entered the water the central locking system was activated and the doors and windows could no longer be opened. The investigation carried out by the police and the importer of the make concerned, showed that the doors had locked themselves as a result of a short circuit. It also appeared that they could be unlocked by releasing the operating switch concerned. However, a force of 80-85 Newton is required for this, similar to the force needed to lift 8 kg – or a bucket of water – with (possibly cold and wet) fingers. An all but impossible task when the switch itself is cold and wet.

Similar problems with the central locking system probably played a role in the accident involving the police car in Edam, when the doors locked due to a short circuit and possibly the locks kept being sucked downwards. The police car was also equipped with an anti-theft system in the form of so-called double locking system, also known as a safe-lock or super-lock. In such systems the door locks are not linked to the door release knobs. When such systems are activated the doors cannot be opened from either inside or outside the car without the key. This prevents thieves from opening the doors by breaking a window. Double locking systems are only active when the engine is switched off.

Motivated by the accident involving the police car in Edam, the technical accident service of the Amsterdam-Amstelland regional police, the RDW Vehicle Technology and Information Centre and the Dutch Forensics Institute, carried out an investigation into the functioning of anti-theft systems. The investigation was conducted in response to the statements made by divers that the locking knobs could not be raised[12].

The different investigations did not reveal a short circuiting of the anti-theft system that was unintentionally activated in this accident[13].
The RDW tests did, however, show that when vehicles equipped with anti-theft systems, like the police car, land in water, the system can be activated by a short circuit. The situation can be recreated under laboratory conditions. Dirty water is an adequate enough conductor for a small electrical current to pass between two adjacent points (only a few millimetres apart). This can be sufficient to cause a malfunction in an electronic switch. Research showed that the components concerned are not well protected against water. Such protection is, however, not legally compulsory.
Malfunctioning of the electrical operation of side windows and sunroofs is also possible, making them impossible to open as a means of escape, unless they can be smashed[14].

For vehicles of the type involved in the accident in Ens, it appeared that the windows could no longer be operated electrically due to a malfunction of the system on entering the water. For such vehicles, it is the side windows that offer the best chance of escape. Data from the RDW Vehicle Technology and Information Centre shows that systems and components concerned are generic and are used by other car manufacturers. The technical problems referred to above concerning windows and doors do not only relate to the specific make of car concerned. Finally, it can be noted that no legislation is currently in force concerning the continued functioning or door locks and windows when cars land in water.

[12] See footnote 2.
[13] Even if no short circuit occurred, a logical explanation is possible for the fact that the occupants were unable to escape from the car in time, and for the fact that the left doors were locked.
Panic could have played a role, as well as the absence of a rear window winder, thewater pressure while sinking and the broken-off locking knob.
[14] No window winder is present for electrically operated windows.

Laminated windows

Laminated windows are far more difficult to break than tempered windows. If a laminated window is bonded (rather than mounted in rubber edging) it is almost impossible to push out the glass using physical strength. The fact that the driver in Ens succeeded in kicking out the windshield is the exception rather than the rule.

Frequency of problems

Although technical problems do occur, probably only a few cases are concerned. Two possible cases were dealt with in chapter 2.
In addition, there is a recent case in which technical problems were suspected. The police reports studied by the SWOV revealed no other cases apart from these three in which there were indications of technical problems connected with escape. On occasion, however, there was evidence of doors becoming jammed. This also applies to cases where the side of the canal or river prevents the doors from being opened (see 3.3.4).
The SWOV noted that the cars concerned in the study had often been constructed in the early nineties. Most of these cars lacked advanced electronic systems for operating doors and windows. The police do not always record such information, however, because in general it has no bearing on the question of blame. For this reason, the police cannot state with certainty how frequently such systems malfunction.

Photograph 5: Submerged vehicle. Source: Ricas

3.3.4 Circumstances

If cars are severely damaged in accidents, the bodywork can be deformed causing the doors to jam. In this respect, the quality of the safety cage construction is of importance. Currently, tests are conducted for cars rolling over, but the question of doors jamming is not looked at. Deformed doors do not prevent occupants from escaping through windows in some cases. Cars can also end up on their sides or roof when they land in water, causing the exits to be

blocked. If the side of the ditch is blocking the doors and the car is in water, bystanders can offer little assistance.

3.3.5 Developments

Currently, various developments are underway that may in the future further hamper occupants in escaping from passenger cars. At the request of the Transport Safety Board, the ANWB examined these developments.

Stronger glass

Since the seventies, vehicle windshields have been subject to legislative requirements. Windshields must be able to withstand a degree of impact to prevent occupants and objects being thrown out through the front windshield during a collision. Legislation covering the other windows is aimed at preventing injuries due to broken glass. In the future, windows will increasingly be an integrated part of the support construction of cars that protects occupants during collisions. For this reason, windows will probably be made from different, stronger material, like lexan, for example. The use of such synthetic material will make escape through (broken) windows all but impossible. Bonded, laminated windshields are a precursor of such constructions.

Laminated windows

Laminated and bonded windows are the cheapest way for car manufacturers to meet the legal requirements in force. Laminated glass is increasingly being used. Laminated windows contain one or more synthetic layers that can withstand much higher impacts without breaking. Laminated windows do not splinter because the layers hold the broken pieces together. Laminated glass offers occupants increased safety because they will not be thrown out through the windshield (see paragraph 3.4).
Laminated rear and side windows are rare, except in expensive, luxury makes. This is expected to change in the future.

Anti-car jacking systems

Anti-car jacking systems automatically lock the doors when the car is driven off. This usually occurs at a speed of 7 km/h. Anti-car jacking systems are aimed at preventing the doors or boot being opened when the car is momentarily stationary, while stopped at traffic lights, for example.

Comfort locking

Comfort locking enables any open electric side windows or the sunroof to be closed and locked automatically when the engine is turned off (using the key or a remote control).

Overview

The equipment discussed above can hinder escape from passenger cars. When cars land in water, electric/electronic systems could breakdown as a result of a short circuit. This applies for instance, to central locking systems and electrically operated windows. Table 5 below shows the percentages of cars in which escape problems could arise will increase in the future. In particular, stronger bonded and electrically operated windows, anti-theft systems and comfort locking could hinder escape. Moreover, central locking systems can make it difficult to free trapped occupants. The problems arising from stronger windows and the like in terms of freeing occupants can be encountered in any accidents in which the doors are locked and have to be opened from the outside (if the occupants are injured, for example, and cannot escape unassisted). Such vehicles are like impregnable fortresses.

		Fleet in mid-2001	Current sales	Fleet by the end of 2006
Central locking		48.8%	89.0%	72.5%
Electrically operated windows	Windows to be opened electrically operated	19.7%	46.5%	34,9%
	Combination of electric and manual operation	22.7%	36.4%	31,2%
	Completely electrical + combination	42.4%	82.9%	66,1%
	Windows to be opened manually operated	57.6%	17.1%	33,9%
Double locking (anti-theft system)		14.6%	46.0%	35%
Anti-car jacking system		4.1%	27.4%	27.9%
Comfort locking		9.3%	29.8%	21.8%
Laminated front windshield		99.9%	100%	100%
Laminated rear windshield		0.5%	4.0%	2.9%
Laminated side windows		< 0.1%	1.0%	1.0%
Glued front & rear windows		68.3%	100%	89.2%

Table 5: Developments in vehicle equipment. Source: The ANWB.

3.3.6 Escape in other circumstances

Escaping from cars is not only a problem in water. Occupants can also become trapped as a result of collisions on dry land. In many accidents, emergency services have to cut occupants out of cars. If the vehicle is deformed and the doors jammed, the occupants are dependent on the emergency services. Central locking systems can also lead to occupants becoming trapped. Anti-car jacking systems cause the doors to lock down immediately on impact. Such systems in some cars are linked to a crash sensor. Some user manuals include statements like: “Driving with centrally locked doors can hinder outside assistance in the event of an emergency”.

3.4 Being flung out of vehicles

When a car skids, spins, or rolls over, there is a high risk that the occupants will be thrown out. This occurred regularly in the accidents examined. The reason is usually that backseat passengers do not wear their seatbelts (the percentage for seatbelts worn in the backseat was around 40% in 2001), or that severe deformation causes the doors to be forced open. Being thrown out of a car usually leads to serious injury. Research carried out by the American National Highway Transport Safety Administration has shown that laminated glass significantly reduces the incidence of occupants being thrown out of cars. Many people thrown out of cars were not wearing seatbelts, while the seatbelt is an effective weapon against being thrown out. An objection raised to seatbelts is that they can hinder escape from the vehicle. However, the close examination of police accident reports showed that in most cases the cause of death was the force of the impact of the crash rather than being unable to escape from the vehicle. There is currently insufficient information available on the possible negative effects of laminated glass, such as problems in freeing trapped occupants and the increased severity of injuries resulting from being thrown against the extra-strong glass.

4. CONCLUSIONS

The fatal accident in Edam appears to be in no way an exception. Every year in the Netherlands, an average of 750 to 800 vehicles end up in water. These accidents claimed the lives of about 30 people by drowning. In the accident in Edam, the occupants drowned because they were unable to escape from the vehicle in time. In addition, technical problems in the form of a short circuit of the central locking system probably also played a role. Similar problems can occur with the electrical systems operating side windows and sunroofs. This can severely hinder escape.

The research did not reveals that such problems occur regularly. The police reports examined made little mention of such occurrences. It should, however, be noted that police reports are not primarily aimed at recording such occurrences. Despite this fact, the research did reveal three accidents in which this played a role, proving that it can, and does take place. It appears that there is no legislation ensuring the proper functioning of such systems when vehicles enter water. Furthermore, the components are generic and their use is widespread across many makes of vehicle.

Advances in vehicle technology will probably lead to escape from vehicles becoming more difficult in the future. Electronic anti-theft systems are being increasingly fitted in cars, and electrically operated windows are becoming increasingly common. The same applies to central locking systems. In addition, there are developments underway (on a small scale) involving side and rear windows that could make escape from vehicles and freeing occupants more difficult in the future. These windows are now frequently laminated making them much stronger. In collisions or roll-overs – that occur frequently before cars enter water – laminated windows prevent occupants from being thrown out of the vehicle, but wearing seatbelts is a better method of achieving the same result.

Escaping from a car in water requires an enormous effort from the occupants in a very short space of time. Research has shown that people are ill-informed about cars landing in water. In general, they are unaware that the car will continue to float for a time. They usually do not know that they must begin their escape attempts immediately, and must not wait until the car is full of water before attempting to open a door. People are usually unaware of the best window to attempt to break if they are unable to open a door. Many people would choose the strongest window (the laminated and glued front windshield) instead of the easier to break side windows. They are also unaware of the best spot to strike the window. Two-thirds of people would strike the window in the centre while a corner is preferable. Finally, only a small minority carry a life hammer in the car. Such hammers facilitate breaking windows, but they are not compulsory equipment in cars.

Although this study primarily focuses on escape from cars, preventing cars entering water is also of importance. The research revealed no clear black spots. However, a number of features typical of car-in-water accidents were revealed. Such accidents occur frequently outside built-up areas, on bends in the road. The vehicles first enter the right verge and the driver attempts to correct his direction. The vehicle then returns to the road, enters a skid and moves to the left of the road, sometimes in a spin. It then rolls down the embankment which often causes it to turn over.

5. RECOMMENDATIONS

The recommendations fall into two categories:
- recommendations aimed at increasing the chances of occupant survival in cases of vehicles landing in water. These measures are concerned with occupant response;
- a recommendation aimed at preventing cars landing in water.

5.1 Escape from vehicles in water

5.1.1 The response of occupants of cars in water

The large majority of people are unaware of the fact that a car in water will continue to float for a time, and that this is the moment to begin escape attempts. Most people are unaware of which window they should attempt to break and how to do so, if windows cannot be opened normally. Finally, people are unaware that wearing a seatbelt is very important if a car enters water. It should be noted that the occupants of a car in water should be as independent as possible in their attempts to escape and should not count on outside assistance. This applies to all cases of cars entering water – not only to those instances when technical problems arise. Given the degree of misunderstanding in respect of this topic, and the fact that intensive information provision could be realised simply and in a relatively short space of time, this recommendation has a high cost/efficiency ratio and therefore deserves a high priority.

> *Recommendation 1:*
> *It is recommended that the Minister of Transport, Public Works and Water Management, in cooperation with traffic and consumer organisations, and passenger car importers and dealers, inform the public at large – and not just holders of driver's licences – about the problems that arise when vehicles enter water, the role of seatbelts in this respect, and in particular, the correct actions to take regarding escape from the vehicle (see annex 5 of this report).*

The Board believes that the problems involving escape from vehicles in water should be included in the theory exam for category B driver's licences. In light of the fact that a similar recommendation is included in other ongoing Transport Safety Board studies (accidents involving lorries manoeuvring in the dark and emergency-lane accidents, for example), the relevant recommendations will be combined and presented to the Minister of Traffic, Public Works and Water Management in due course.

5.1.2 Features of vehicles

Neither occupants nor rescuers should encounter problems in opening the doors and windows of cars in water. Given that accidents involving cars landing in water occur mainly in the Netherlands, the Dutch government, supported by the RAI, should take the initiative in this respect.

> *Recommendation 2:*
> *It is recommended that the Minister of Transport, Public Works and Water Management argue to the European Commission in support of requirements regarding passenger cars that would contribute to the prevention of:*
> - *electrical systems unintentionally locking doors as a result of a short circuit on entering water;*
> - *electrically operated windows and/or locks ceasing to function on entering water*[15]*.*

[15] Due to the necessity of acquiring European-wide support for these measures, this report will also be sent to the European Commission (for the attention of the Transport and Energy Commissioner).

5.1.3 Miscellaneous

The presence in the cars of an easy-to-reach instrument for breaking windows (like a life hammer) that can no longer be opened in the usual manner, has been proved to be important. It should be noted, however, that in the light of continuing developments that will lead to the side windows in a large proportion of passenger cars becoming considerably stronger, life hammers may not be sufficient for smashing windows in the future.

Recommendation 3:
It is recommended that the Minister of Transport, Public Works and Water Management – possibly in coordination with the provision of other water-related information - (recommendation 1 – lobby for Dutch passenger cars to be equipped with a tool for smashing windows such as a life hammer, and also to have all government vehicles equipped with such a tool.

Recommendation 4:
It is recommended that the Minister of Transport, Public Works and Water Management lobby for research to be conducted into an alternative to the current life hammer, that would be capable of smashing the new, stronger side windows. In so far as and for as long as no adequate solutions is found, consumers need to be warned of the dangers.

5.2 Prevention / infrastructure

Virtually the only guaranteed way of preventing cars landing in water is for vehicles to travel at low speeds alongside open water and for such water to be fenced off. It is worth noting that fencing off water is less necessary when such water is passed at low speeds. A safe speed may in some spots be lower than the speed limit in force. In respect of driving speeds, road authorities have a choice: *to warn* road users of the danger through signs or to '*force*' the adoption of safe driving speeds through infrastructural measures. It goes without saying that although forcing the adoption of safe driving speeds is effective, it is also considerably more expensive than warning drivers.

The best results of measures taken are to be expected at the high-risk spots identified in this report as winding roads outside built-up areas, in combination with a steeply sloping verge leading to water.

Recommendation 5:
The VNG and the IPO are recommended to encourage road authorities to at least warn road users of the danger at places where the risk of entering water is relatively high.

ANNEXES:

1) *Literature list*
2) *Definitions*
3) *Justification of the Study*
4) *ANP articles (2000)*
5) *Instructions for escaping from a vehicle*
6) *Road Design Guidelines*

ANNEX 1: MONOGRAPHS AND CONSULTED LITERATURE

Monographs commissioned by the Transport Safety Board:

Neeteson, M. (2001). *Auto te water, een statistische verkenning.* The Hague: ANWB.

Van Kampen, L.T.B. (2002a). *Omvang, aard en ernst van ongevallen met auto's te Water.* Leidschendam: SWOV (R-2002-28 I).

Van Kampen, L.T.B. (2002b). *Problemen met ontsnapping en bevrijding uit auto's te Water.* Leidschendam: SWOV (R-2002-28 II).

NIPO (2001*). Auto te water. Peiling van kennis bij de Nederlandse bevolking.* Amsterdam: NIPO (A8846).

Literature:

CROW (2002): Road Design Handbook, Ede: CROW (publication 164).

ANNEX 2: DEFINITIONS

Anti-car jacking system: system that automatically locks the doors when the car is driven off.

AVV Traffic & Transport Advisory Service: part of the Ministry of Transport, Public Works, and Water Management, and responsible, among other things, for the registration of road traffic accidents.

Verge: unsurfaced section of road alongside the (surfaced) driving lane.

Central locking system: system that enables all doors, the boot, and the petrol cap to be locked at one time.

CROW: Information and Technology Centre for Transport and Infrastructure.

Double locking system: system that separates the operation of the door locks from the operation of the anti-theft system.

Residential roads: roads of the lowest priority offering access to residences (usually streets with a speed limit of 30 km/h).

Access roads: all roads with no arterial or residential function.

Tempered glass: (also known as safety glass or security glass). This glass is treated in such a way that when it breaks no sharp shards are formed but rather it shatters into cubes.

Laminated glass: glass with a layer of plastic or cellulose.

Crash barriers: constructions along roads intended to intercept cars that travel off course.

KLPD: National Police Service.

LVBT: Traffic Police Assistance Team, part of the KLPD focusing on the technical analysis of traffic accidents.

Life hammer: a tool with a sharp metal point that is used to break windows.

NFI: Netherlands Forensics Institute (formerly the Forensic Laboratory).

Public Works and Water Management: part of the Ministry of Transport and Public Works, responsible for maintaining national trunk roads and waterways.

Arterial roads: high priority roads with an arterial function (usually motorways and trunk roads).

ZOAB: Extremely Porous Asphalt Concrete.

ANNEX 3: JUSTIFICATION OF THE STUDY

The research was carried out by the staff of the Transport Safety Board under the supervision of the Traffic Chamber. Data supplied by the regional police forces of Amsterdam-Amstelland, South Limburg, and Flevoland was used.

In addition, interviews were conducted with various parties concerned. Support research was carried out by:
1. The SWOV Institute for Road Safety Research
2. The ANWB, Technical Inspections & Advice Department
3. The NIPO
The reports of these institutes form part of this study in the form of monographs and are available on request.

Information was also requested from involved parties. The following were contacted in writing:
- SWOV: Institute for Road Safety Research
- ANWB: Royal Dutch Touring Club
- RDW Vehicle Technology and Information Centre
- NIPO
- CBR: Central Driver Licensing Bureau
- KNBRD: Royal Dutch Drowning Accident Rescue Association
- RICAS Safety Training BV
- PON Volkswagen importer
- Amsterdam-Amstelland regional police
- South Limburg regional police
- Flevoland regional police
- KLPD: National Police Service

Comments were received from:
- SWOV: Institute for Road Safety Research
- ANWB: Royal Dutch Touring Club
- RDW: Vehicle Technology and Information Centre
- NIPO
- CBR: Central Driver Licensing Bureau
- RICAS Safety Training BV
- Amsterdam-Amstelland regional police
- KNBRD: Royal Dutch Drowning Accident Rescue Association

ANNEX 4: ANP ARTICLES CONCERNING CARS IN WATER (2000)

(1) Accident victim found 1 hour later
LEEUWARDEN (ANP) – A 19-year-old woman from Wouterswoude in the province of Friesland was involved in an accident on Saturday evening in Damwoude. Police suspect that the car left the road and ended up in a ditch due to a driver error. The woman was only found an hour later.

(2) Accident claims 1 life in Steenbergen
STEENBERGEN (ANP) – In the early hours of Saturday morning, a 26-year-old man from De Heen was killed in an accident on Zeelandweg Oost. No other vehicles were involved. The man, who was alone in the vehicle, was traveling home from Steenbergen. For unknown reasons, the vehicle veered onto the verge, the man lost control and the vehicle landed in an adjacent ditch.

(3) Man dies of injuries
HOORNSTERZWAAG (ANP) – In the early hours of Monday morning, a 26-year-old man from Wijnjewoude died after an accident near Hoornsterzwaag. For reasons unknown, the vehicle veered onto the verge and then shot across the road where it hit a tree, eventually coming to rest in the water. The fire service managed to pull the man from the vehicle, but attempts at the scene to resuscitate him were unsuccessful.

(4) Woman (89) dies in accident in Roosendaal
ROOSENDAAL (ANP) – An 89-year-old woman from The Hague died on Friday evening after an accident on the A17 motorway just before the Roosendaal-Noord exit. The woman's 61-year-old daughter, who was driving the vehicle, suffered minor injuries. For reasons unknown, the woman lost control of the vehicle. The car then left the road and came to rest in an adjacent ditch. According to police, the woman was overtaking at the time of the accident. The mother died of her injuries on the way to hospital.

(5) Man drowns in road accident
SCHIEDAM (ANP) – A 69-year-old man from Schiedam died last Wednesday evening when he drove his car into Voorhaven harbour in Schiedam. Divers from the fire service arrived quickly at the scene and managed to pull the man from the water, but attempts to resuscitate him were unsuccessful. The man died later in hospital. Police say the cause of the accident is unknown.

(6) Woman dies in accident
LEEUWARDEN (ANP) – A 22-year-old woman died last Thursday in Leeuwarden Hospital from the injuries she sustained in an accident. Passers-by had found her vehicle upside down in a ditch earlier the same morning. The vehicle had left the road after hitting ice. The fire service had managed to rescue the woman from the vehicle and she was taken to hospital in a critical condition.

(7) Man dies after accident
HOOGBLOKLAND (ANP) – A 28-year-old man from Hoornaar died on Sunday evening following a serious accident on the Dorpsweg road in Hoogblokland. Presumably due to excessive speed, the vehicle left the road after hitting a speed bump and came to rest in an adjacent ditch. A 30-year-old passenger managed to free himself from the vehicle. The driver and his 28-year-old wife were freed by firefighters. Paramedics managed to resuscitate the man and he was transferred to the Queen Beatrix Hospital in Gorinchem. The man died shortly before midnight on Sunday. The other passengers were taken to the same hospital suffering from minor injuries and hypothermia.

(8) Motorist drowns in Amsterdam-Rhine Canal
NIGTEVECHT (ANP) – A 39-year-old man from Amsterdam drowned last Tuesday evening in the Amsterdam-Rhine Canal in Nigtevecht. The man was travelling along the dike road alongside the canal when his vehicle entered the water for reasons unknown. A passing boat raised the alarm. Divers from the fire service were unable to free the man before he died.

(9) Motorist dies of injuries
HASSELT (ANP) – In the early hours of Friday morning, a 29-year-old man from Genemuiden died in a hospital in Zwolle after a car accident. No other vehicles were involved. The man was travelling between Genemuiden and Hasselt when, for reasons unknown, the vehicle left the road and came to rest upside down in a ditch. The alarm was raised by a passer-by. The emergency services managed to free the man from his vehicle and he was taken to hospital in a critical condition. He died from his injuries in the course of the night.

(10) Man from Krimpenaar dies from accident injuries
ROTTERDAM (ANP) – An 18-year-old man from Krimpen aan den IJssel died Saturday evening in Dijkzigt hospital in Rotterdam after a car accident. At around 3 a.m., the man had driven his car into a ditch along the Ouverturelaan road. The emergency services rushed to the scene, where they found the man submerged in the water and unconscious. After resuscitating him, he was taken to hospital where he later died.

(11) Apeldoorn resident dies after road accident in Lieren
APELDOORN (ANP) – A 21-year-old man from Apeldoorn died Sunday morning when he was involved as a passenger in a car accident in Lieren. The car was found in a canal. The 20-year-old driver from Diepenheim and a 19-year-old passenger were also injured. For unknown reasons, the vehicle left the road, hit the side of a bridge and entered the water. The driver and the 19-year-old passenger managed to swim ashore, where they alerted the police that their friend was still trapped. After a 30-minute search, divers found the victim some distance from the vehicle, but were unable to resuscitate him.

(12) Man dies after accident
MINNERTSGA (ANP) – A 49-year-old man from Goutum died in hospital on Monday after a car accident in Minnertsga. The man lost control of his vehicle in a wide bend and the vehicle left the road. The car then skidded and ended up on its roof in the adjacent ditch. The driver was freed from the car and taken to hospital with serious injuries where he later died.

(13) Man dies in accident in Dronten
DRONTEN (ANP) – A 23-year-old man from Dronten died on Thursday after his car entered the water near the Drontermeer dike on Wednesday evening. The man was taken to hospital in Zwolle, but he died of his injuries in the early hours of Thursday morning. The car came to rest in the water on its roof. Bystanders jumped into the water to offer assistance, but the man had to be freed by divers from the fire service. The man presumably lost control of the car after swerving to avoid something.

(14) Road accident claims 1 life
BRIELLE (ANP) – A 25-year-old man from Oostvoorne died last Friday after an accident on the N218 (Oostvoorne-Brielle). His passenger, an 18-year-old from Oostvoorne, was taken to the Zuiderziek Hospital in Rotterdam with internal injuries and neck injuries. The motorist was on his way to Brielle when, for reasons unknown, he lost control of the vehicle. The car then hit a tree, throwing the two passengers from the vehicle. The car then turned over and came to rest in a ditch.
A team of divers were called in to rescue those trapped in the car. An air ambulance arrived, but it was too late to save the 25-year-old man, who died of his injuries at the scene of the accident.

(15) Motorist drives into ditch
EES (ANP) – In the early hours of Sunday morning, a 25-year-old man from Assen died after a road accident on the N34 between Emmen and Borger. For unknown reasons, in the vicinity of Ees his car veered onto the right-hand verge and he then lost control of the vehicle. According to police, the car then rolled across the road and came to rest in a ditch. The driver died at the scene of the accident from his injuries.

(16) Man from Arnhem drowns in stolen car
OUDEWATER (ANP) – A 27-year-old man from Arnhem died on Monday after an accident in Oudewater. The man was travelling with a 26-year-old man, also from Arnhem, who for unknown reasons lost control of the vehicle. The car landed on its roof in a ditch after crashing into a tree. The driver was able to bring himself to safety. The passenger was freed from the vehicle by passers-by, but died later in the evening at a hospital in Nieuwegein. It transpired that the vehicle had been stolen in Arnhem and that the driver did not have a licence.

(17) Motorist drowns
UTRECHT (ANP) – A 25-year-old man from Utrecht drowned on Sunday morning after he drove into a moat. A 22-year-old woman was seriously injured and was taken to the UMC hospital.
According to the police, the man drove at high speed through Gandhiplein square when he lost control of the vehicle. The car then hit a ridge and ended up in the moat of De Gagel castle. Both the driver and the female passenger were thrown clear of the car. The woman managed to climb out of the moat, but the man was presumably knocked unconscious during the crash.

(18) Motorist from Huizen drowns
ZEEWOLDE (ANP) – A 26-year-old motorist from Huizen drowned Friday evening after a car accident. His car entered the water alongside the Eemmeer dike near Zeewolde. According to police, the man had been speeding when he lost control of the vehicle. A man on a nearby pleasure boat who heard the accident tried unsuccessfully to locate the driver. Fire service divers managed to retrieve the victim from the water, but he was already dead. The man had been staying with his wife at the Eemhof holiday park in Zeewolde.

(19) Man dies in accident in Moerdijk
MOERDIJK (ANP) – A local man died after a road accident in Moerdijk on Tuesday. The 79-year-old was driving along the Koekoek dike on the edge of Moerdijk when, for reasons unknown, he lost control and the vehicle left the road. The vehicle came to rest in a deep ditch along the right-hand side of the road and the man died at the scene of the accident from his injuries. The police had initially assumed that a second person had been traveling in the car, but a search by fire service divers revealed that this was not the case.

(20) Motorist injured in Hijken
MIDDENVELD (ANP) – A 26-year-old motorist from Zwiggelte was injured in Hijken last Wednesday morning. His car was spotted in the Oranje Canal at around 6 a.m. by a local resident. A police spokesman said that indications were that the car had failed to take a bend. The man had presumably been in the water for a number of hours before being found.

(21) EURO 2000 – English football fan dies in accident on the A2
HEEZE (ANP) – An unidentified English football fan was killed in the early hours of Tuesday morning in an accident on the A2 motorway between Eindhoven and Maastricht. The man was returning with two other fans from the Portugal vs. England match in Eindhoven when their car came off the road near Heeze and landed in a ditch. One of the other fans suffered serious injuries, while the other had only minor injuries. No other vehicles were involved in the accident, but the cause remains unknown. The driver was not under the influence of alcohol.

(22) Fatal accident in Nieuw-Beerta
GRONINGEN (ANP) – A 45-year-old motorist from Drieborg died last Wednesday after a road accident in Nieuw-Beerta in Groningen province. The car left the road and landed in a ditch. The woman was killed instantly. The cause of the accident remains unknown.

(23) Woman drives car into water
DEN BOSCH (ANP) – A 70-year-old woman from Den Bosch died on Saturday after being involved in a car accident. The woman left a car park near the Bredehaven harbour at around 11 o'clock and drove straight into the water. Two passers-by tried in vain to rescue the woman, but it eventually took divers from the fire service to free her. Attempts by paramedics to resuscitate the woman proved unsuccessful.

(24) Man from Leeuwarden killed in accident
HARLINGEN (ANP) – An 18-year-old man from Leeuwarden was killed on Saturday in a road accident near Harlingen. Two friends, aged 18 and 20, were also traveling in the car when it left the road for unknown reasons. The car landed on its roof in the ditch. The 20-year-old driver and his 18-year-old friend, both from Leeuwarden, managed to escape. Together they pulled their seriously injured friend from the wreckage, but he died on the way to hospital.

(25) Car and body recovered from the New Maas
ROTTERDAM (ANP) – A floating crane was used to recover a car and the body of its occupant from the New Maas. The car was brought ashore at the Rijnhaven harbour and taken to Boezembocht police station for further investigation. The police hope to be able to establish the identity of the driver on Thursday. The car had been in the water for some time.

(26) Two occupants drown in car in ditch
BENNEBROEK (ANP) – Two occupants of a car drowned in the early hours of Thursday morning when their car landed in a ditch in Bennebroek. The driver, a 22-year-old man, and a 24-year-old passenger were both from Heemstede. The driver lost control of the vehicle in a bend and the car landed on its roof in a ditch. Local residents and police rolled the car onto its wheels and freed the occupants. Attempts to resuscitate them were unsuccessful and they died on the way to hospital.

(27) Couple killed in accident
KOUDUM (ANP) – A husband and wife from Hemelum in Friesland province were killed in the early hours of Saturday morning in a road accident near Koudum. At a junction of the N359, a 20-year-old man from Oudemirdum hit the car of 62-year-old man and a 60-year-old woman from the side. One of the cars landed in a ditch and the other hit a lamppost. The 20-year-old driver was taken to hospital in Sneek with injuries to his right leg.

(28) Police recover car and driver's body from the New Maas
ROTTERDAM (ANP) – Police in Rotterdam recovered a car from the New Maas on Monday along with the body of the driver. The car was winched from the water close to Noordereiland. The body was probably that of a 58-year-old man from Rotterdam registered as the owner of the vehicle. He had been missing since July. The police do not suspect that the man's death is connected with a criminal offence. Another car was recovered from the water, but was found to be empty. In late August, police recovered another vehicle from the New Maas – in the vicinity of Maaskade – along with the body of its occupant.

(29) Driver from Antwerp killed in accident on the A6
LELYSTAD (ANP) – A 53-year-old motorist from Antwerp died on Thursday evening after an accident on the A6 near Lelystad. Police suspect that the man became ill while driving. Witnesses describe seeing the car hit the central reservation then veer back across the

carriageway onto the verge. The car came to rest on its roof in the adjacent ditch. The man was already dead when the emergency services arrived at the scene.

(30) Motorist drives into the Aduarderdiep
GRONINGEN (ANP) – An unidentified motorist was killed on Saturday afternoon when his car landed in the Aduarderdiep, north of Groningen city. The car was traveling from Feerwerd towards Groningen when, for reasons unknown, the vehicle left the road and landed in water. The police have not ruled out that the man became ill while driving and then left the road. The vehicle has since been recovered.

(31) One fatality and two injured in accident
EINDHOVEN (ANP) – A 33-year-old man from Veldhoven was fatally injured in the early hours of Saturday morning in an accident in Eindhoven. Two passengers in the car escaped with injuries. The accident occurred close to Eindhoven air base. For reasons unknown, the car first veered onto the verge and then came to rest in a ditch. The man died at the scene of the accident.

(32) Man dies of accident injuries in Groningen
GRONINGEN (ANP) – A 22-year-old man from Drachten was killed on Monday morning in an accident on the old road between Zevenhuizen and De Wilp. A passer-by spotted the car in the water early on Monday morning and notified the police. The police found the body of a man and suspect the car had already been in the water for several hours. The motorist was driving towards De Wilp and, according to the police, lost control of the vehicle in the bend. The car then turned over and came to rest in the water.

(33) Motorist dies of accident injuries in Veenendaal
VEENENDAAL (ANP) – A 24-year-old motorist from Ede died on Monday morning after a road accident in Veenendaal. For reasons unknown, his car hit the trailer of an oncoming vehicle and landed in a ditch 200 meters further along the road. The driver died on the way to hospital. The other driver was uninjured.

(34) Three people drown in Maassluis
MAASSLUIS (ANP) – A young family from The Hague were drowned on Sunday in Maassluis. The accident resulted in the death of a 24-year-old man, a 21-year-old woman, and their 4-month-old baby. The car was parked on the quayside of Govert van Wijnkade, facing towards the water. For reasons unknown, the vehicle then drove into the water with the woman and baby inside. The man, who was standing a few meters away from the vehicle, jumped straight into the water to rescue his wife and child, but he and his wife were both drowned. Some moments later, a police officer entered the water with a rope. His efforts proved in vain. The baby was taken to hospital in a critical condition, but died a few hours later.

(35) Dead driver found hours later in the water
LEEUWARDEN (ANP) – An unidentified man was killed Friday night in a car accident on the road between Warns and Stavoren. The overturned car was spotted around 9 a.m. on Saturday morning by a passer-by. The dead driver was still in the car. The body had been in the water for some time already and the police are therefore assuming that the accident happened during the night. The cause of the accident remains unknown.

(36) Motorist dies of accident injuries in Zuidwolde
ZUIDWOLDE (ANP) – A 19-year-old motorist from Zuidwolde was killed early on Thursday morning after a car accident on the Meppelerweg road. The man was on his way to work when, for reasons unknown, the vehicle veered off the road and landed in a ditch. The man died at the scene of the accident.

(37) Fatal road accident in North Holland province
ALKMAAR (ANP) – A 26-year-old man from Enkhuizen was killed in an accident near Avenhorn. The man lost control after he veered onto the verge. The vehicle overturned and landed on its roof in a ditch. The driver was freed from the wreckage, but was already dead.

(38) Motorist dies of accident injuries in Meedhuizen
MEEDHUIZEN (ANP) – A 32-year-old motorist from Siddeburen was killed on Monday after an accident in Meedhuizen, Groningen province. After skidding on the muddy road surface, the van landed in a ditch alongside the road. There was no sign warning the driver of the muddy surface, although vehicles approaching from the opposite were warned with signs.

(39) Man from Groningen dies of accident injuries in Ruischerbrug
GRONINGEN (ANP) – A 25-year-old man from Groningen died on Saturday from the injuries he sustained in a traffic accident. The man was traveling from Groningen to Garmerwolde when he performed an overtaking manoeuvre and lost control of the vehicle. After hitting a raised platform in the road, the vehicle rolled over and landed in the water. Passers-by and then divers were unable to open the doors. The driver could only be freed from the vehicle after it had been lifted from the mud with a crane. The man was taken to hospital in a critical condition, but later died.

(40) Woman from Wijchen dies in road accident
SCHAIJK (ANP) – A 22-year-old woman from Wijchen was killed on Sunday afternoon after a road accident in Schaijk, Brabant province. According to a police spokesperson, the woman was driving along the A50 when she must have been hit from behind by another vehicle. The car landed in a ditch alongside the road and she died at the scene. The spokesperson was aware of the identity the other driver.

(41) Woman dies in accident
AMSTERDAM (ANP) – A woman (56) from Velsen was killed in a traffic accident on the Noordzeeweg road in the Amsterdam harbour area. She was heading out of town towards Velsen when she hit an oncoming vehicle while overtaking. Her car was shunted onto the verge where it rolled several times and came to rest on its roof in a ditch. The occupants of the other vehicle (father, mother and two children) were unhurt.

(42) Man from Zwolle dies after accident
ZWOLLE (ANP) – A 63-year-old motorist from Zwolle died on Sunday afternoon from the injuries he sustained on Saturday in an accident on Hattemerbroek intersection. Three other passengers suffered injuries. The driver was traveling along the N50 towards Kampen when he veered onto the verge. The car overturned and came to rest in the ditch. The occupants were freed by two passers-by.

ANNEX 5: Instructions for escaping from vehicles (SWOV)

When vehicles land in water, the occupants have to escape through the doors or windows. As far back as the sixties, the SWOV investigated this problem and drew up recommendations for appropriate responses. The optimum sequence of actions begins while the car is still afloat for a few minutes. In this period, there is sufficient time for the following actions:

a) If the doors and windows are locked: release the locks (using the appropriate switch or knob). Switch on dipped lights or high beam so that the vehicle is easily visible to those providing assistance.
   Do **not** switch off the engine as the lights could then go off. If the electric windows are not functioning there is a good chance that the doors are unintentionally locked. A short circuit will not cause a fire in the car.

b) Release or cut through seatbelts.
   If the car is upside down: protect your head with your hands and push your feet against the dashboard to force your body into the seat and release (or cut) the seatbelt. Somersault down and leave the car through a window. Release any children from child seats or seatbelts.

c) While the car is afloat (usually for severally minutes): leave the car through an open front window, sunroof or fifth door.
   If you cannot open a front window, attempt to smash it. To smash a window use a strong pointed object (life hammer) and hit the window in a corner using force.

d) If you are unable to smash a side window, try to remove the windshield by pushing, hitting and/or kicking it starting at one of the corners.

e) First help any children or other occupants who are unable to save themselves to escape from the car. When escaping through a window it is preferable to lie on your back. When leaving the car, where possible keep hold of any small children who cannot swim.

f) If you are unable to escape through a window or sunroof, try to open a door. This is only possible when the car is almost full of water and the inside and outside water pressure is almost equal. While waiting for the car to fill with water (this can take from seconds to several minutes) prepare for escape by adopting an appropriate position and taking hold of the door handle. The door will open in ‘slow motion’ and this can give the impression that it is not opening at all. When opening a door you should push against it with your entire body.

g) In general, it is important not to store items on the back window shelf as these can be thrown around the car with force, on impact with the water and can cause injuries to the occupants.

ANNEX 6: ROAD DESIGN GUIDELINES

This report briefly looks at the existing guidelines for fencing off bodies of water alongside roads.

Het Handboek Wegontwerp (Road Design Handbook)

This handbook was published in 2001. It is the sequel to the design guidelines for roads other than motorways (RONA) published by the CROW. The handbook provides advice to road authorities based on research. The recommendations are not obligatory. This new handbook contains several suggestions for fencing off water.

Access roads:

"When collision hazards or dangerous design elements are situated within the obstacle-free zone, a danger zone is created. Dangerous design elements include steeply sloping embankments, ditches, streams, and canals. The use of slightly sloping embankments increases the level of safety on the verge[16]."

"In principle, access roads do not need to have crash barriers (or railings). The introduction of crash barriers on these roads could give the impression to road users that the roads concerned are arterial roads.[17]"

The desired size of the verge is dependent on the road design style[18]."

Residential roads:

"[Here] fences can only be placed in exceptional cases. Situations for which larger obstacle-free zones (more than 1.50 m) can be considered include: a canal or water channel the dimensions of which constitute a danger of drowning and the outside curve of tight bends. The use of slightly sloping embankments increases the level of safety on the verge."[19]

[16] Road Design Handbook 2002, CROW publication 164c, p. 117.
[17] Road Design Handbook 2002, CROW publication 164c, p. 128.
[18] Road Design Handbook 2002, CROW publication 164d, p. 126.
[19] Road Design Handbook 2002, CROW publication 164d, p. 60.