SWOV Fact sheet

Cars submerged in water

Summary
Crashes in which cars end up in deep water or in a ditch are often complicated and severe. Preventive measures (such as barrier constructions in road bends), adequate road design and infrastructural measures (such as shoulder surfacing), and education and information can reduce the risks of such crashes. Intelligent Transport Systems (ITS) developments can speed up the arrival of assistance, thus reducing the consequences of the crash. Measures such as seatbelt wearing are especially important in reducing the severity of this crash type and increasing the chance of escaping. It is also important to ensure that vehicle facilities such as a central door locking system and electric windows are no obstacles to escape. An emergency hammer can be an important tool to escape quickly from a car submerged in water.

Background and content
Certainly in comparison with other European countries, the Netherlands is a country with much open water. Crashes in which cars end up submerged in water are by no means rare and are often severe. Sometimes other road users also end up in water, but in 70% of the cases a passenger car is involved. This fact sheet deals extensively with the problem of cars submerged in water and describes how this crash type can be prevented and how injury severity can be reduced.

What is the size of this road safety problem?
Before 2004
Before 2004, the Dutch road crash registration made a distinction between crashes in which a car submerged in deep water and crashes in which a car ended in a ditch. This registration shows that in the period 1999-2003, each year there were, on average, 53 injury crashes in which the vehicle had ended up in deep water. In these crashes there were 18 fatalities on average per year. In addition there were, on average, 700 injury crashes in which a car ended up in a ditch; each year these crashes had an average of 39 fatalities. From the police registration forms it was estimated that approximately half of the total of 57 fatalities were from drowning; these drowning fatalities amounted to about 3% of all road deaths. This figure is confirmed by the Causes of Death Statistics of Statistics Netherlands (Van Kampen, 2002a).

Over the 20 year period 1984-2003, there was a reduction of about 30% in the number of fatal crashes with cars ending up in deep water and a reduction of 34% in the number of fatal crashes with cars ending up in a ditch. This was a smaller decrease than the 45% reduction in fatalities in all car crashes nationwide during this period.

From 2004 onwards
From 2004 onwards, the Dutch road crash registration no longer distinguishes between deep water and ditches. In the period 2004-2009, there were 58, 53, 40, 35, 39 and 52 fatalities respectively in crashes in which a car ended up in deep water or in a ditch. In the last of these years, the numbers of fatalities is higher than in the two preceding years. When we consider the period 1987-2009, the annual decrease of the number of fatalities in crashes in which the car ended up in water or ditch (-3.1%; see *Figure 1*) is only is only slightly smaller than the decrease of the total number of fatalities among car occupants (-4.1%). This smaller decrease can largely be explained from the fact that a large proportion (70%) of the crashes in which cars end up in water are single vehicle crashes with no other road users being involved. On the whole, the number of fatalities in single vehicle car crashes decreases at a lower pace than the fatalities in crashes involving a crash opponent (an average of -3.0% as opposed to -5.2% per year).

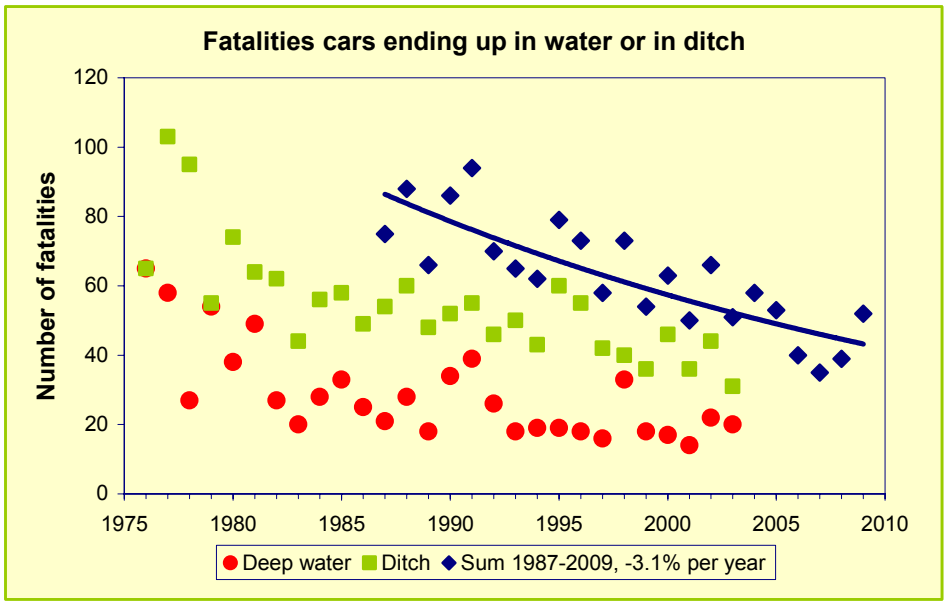

Figure 1. *Source: 1976-2003: AVV – Crashes and Network; 1987-present: Min. Transport – BRON.*

What are the international experiences?

Literature and crash data from eight other European countries (Germany, France, Belgium, the United Kingdom, Austria, Finland, Denmark and Sweden) shows that the problem of cars submerged in water is minor. This also applies to countries outside Europe. In general, relevant research results are only rarely found in international literature (Van Kampen, 2000b). The results of an American study in Sacramento County (California) where there is, relatively speaking, a lot of open water along the roads are applicable to the Netherlands. It recommends placing barriers especially in bends alongside open water (Wintemute et al., 1990). This study also showed that the number of drownings in America as a consequence of crashes with motor vehicles was about 1% of all road deaths; this is much less than in the Netherlands.

Which features are specific to submerged car crashes?

Crashes in which cars end up in deep water or in a ditch have a number of specific features (Van Kampen, 2002a; 2002b). Those in deep water are clearly more severe than many other crash types. This is, for instance, illustrated by their high percentage of fatalities and inpatients. Submerged car crashes are also complicated. Before the car actually hits the water, it has often slipped and rolled over in the shoulder before landing upside down or on its side. This of course makes it difficult to escape or to be rescued, even if the ditch is dry. In addition, such vehicle movements themselves can cause injury, making escape extremely difficult or impossible. Moreover, in many of these crashes there first was a collision, increasing the risk of injury and making escape less probable. All this damage resulting from these previous vehicle movements can also block the doors.

Another characteristic of crashes involving cars submerging in deep water is that these crashes occur most frequently outside urban areas and on 80 km/h roads. They are also more frequent in some of the Dutch provinces (North and South Holland, followed by Groningen and Drenthe) than in others, and happen most often in municipalities with a relatively large area of open water. There are not many locations where this type of crash happened more than once. During the period 2003-2007, 96% of these crashes happened at a unique location; during this period there were eight locations with three injury crashes involving passenger cars. The total numbers of casualties at these locations were 36 inpatients and no fatalities. No locations were found with more than three injury crashes involving passenger cars. Therefore, it is difficult to indicate high risk locations based on the crash data (see also the SWOV fact sheet *The high risk location approach*)

The majority of crashes happen in bends (60%). The remaining crashes happen on straight road sections (30%) and at intersections (10%).

Crashes with cars ending up in deep water or in ditches more frequently occur during weekends, hours of darkness, in winter, and in snow and fog.

Another feature of these crashes is that they are often single vehicle crashes (approx. 70%), i.e. no other road users were involved.

Furthermore, drivers of cars ending up in deep water or in a ditch are often young, male, and under the influence of alcohol. The police data used shows that also the victims of these crashes are more frequently young and male.

What research has been done?
The data used above is partly from the Dutch Ministry of Transport's crash data which is regularly made available, partly from the official police reports of these crashes, known as files. The purpose of the files' study by Van Kampen (2002b) was to gain insight in any problems connected with trying to escape from cars submerged in water. The result of this study was rather limited with regard to this purpose. This is mainly due to the fact that the police have a primary responsibility to indicate the guilty party, and not so much to investigate technical circumstances of an escape. For a clearer picture of the risks involved when occupants of a car submerged in water escape or are rescued, other methods should be used than investigating police reports. There is every reason for systematic monitoring because cars are more and more equipped with electronic car facilities that may hinder entrance to the vehicle and thus affect escaping and injury severity (Van Kampen, 2002b). The Dutch Safety Board ascertained that there are all sorts of car developments that could lead to (more) escaping problems. Especially the stronger (laminated), bonded windows and electrically operated side windows, anti-theft systems, and comfort closure for windows, could hinder escape if not working properly after a crash or if short-circuited by water. A central door locking system can hinder rescue from outside. These developments are actually turning the car into an impregnable fortress (Transport Safety Board, 2002).

In 2005, the Dutch Police Institute set up a national registration system for deep water and ditch crashes. The registration form that was developed for this purpose is intended to acquire more information about cars-submerged-in-water crashes. This national register, however, is not generally known by the police as only 28 report forms have been submitted over a 2.5-year period (Buning et al., 2008). The fire brigade is also working on a permanent survey of what happens to a vehicle in case of a calamity, including information about the central door locking system of submerged vehicles (Vehicle Technology and Information Centre RDW, 2008).

Recently, commissioned by the Ministry of Transport, a study was performed into the effects of water on the operation of electronic window controls and central door locking systems (Buning et al., 2008). Tests with the most popular models of the twenty best sold makes of car (sales figures 2005 and 2006) showed that in most cases the electronic window controls are no longer reliable immediately after hitting the water. In that situation the windows can no longer be opened properly. The central door locking systems remain reliable more frequently, but the vehicle doors are no good escape route. The problem mainly occurs with modern cars that have modern electronics. Three parts of the intelligent electronics can cause malfunction: the central operation unit, the window operating button, and the window engine. As soon as these parts make contact with water, the window controls become unreliable.

How can submerged car crashes be prevented?
Preventive measures are recommended because of the serious nature of crashes in which a car ends up in water. It is important to place barrier constructions particularly alongside open water, especially in road bends. Adequate road design and improvements to the infrastructure, such as replacing a soft shoulder by a hard one, can also prevent these crashes. In addition, a preventive approach towards driving behaviour problems among young, male drivers fits the current policy. This policy should be aimed at reducing crash rates by instruction and education, by applying restrictions in vehicle use, especially during weekend nights, and by reducing drink-driving. Because crashes in which cars end up in water are often so severe, but do not occur equally frequently everywhere in the Netherlands, it creates opportunities for local and regional policy (Van Kampen, 2002b).

How can the injury severity be reduced?
Vehicle safety
Although preventive measures are preferable, attention for measures that result in these crashes being less severe remain necessary. (Correct) seat belt wearing is very important to prevent injury before and while hitting the water, and thus to increase the chance of escape. It would also be advisable for car manufacturers to pay more attention to the car-in-water crashes and make their products even safer wherever possible (vehicle safety). This mainly refers to facilities that are important for escaping or being rescued (door locks, windows, et cetera). When a car hits water these

facilities must continue to function. The previously mentioned study (Buning et al., 2008) is certainly a stimulus here.
Because many of these crashes are complicated, demonstrations and courses aimed at escaping from cars submerged in water should be more realistic. More realistic circumstances refer to, for example, blocked doors and side windows that are stuck (Van Kampen, 2002b).

Intelligent Transport Systems (ITS)
There are many developments in the field of Intelligent Transport Systems that can decrease the severity of crashes in general (Wegman & Aarts, 2006). Two systems will be discussed here that can make faster assistance possible after a car has ended up in water. The first one is a so-called e-call system which is being developed by the European Union. This system can automatically signal the location of a crashed vehicle to emergency help stations. The idea is to equip all motor vehicles with this system. In the night time when there is very little other traffic, this may be the only way to establish that a crash has occurred in which a car has ended up in water. The second system is Electric Vehicle Identification (EVI). This system can also reduce the consequences of a crash by enabling emergency assistance to reach the location quicker if they can localize the vehicle with EVI. EVI could also contain information about the number and location of airbags, and the battery type in the vehicle. This will make a contribution to easier and speedier assistance (Rosmuller et al., 2005).

What is the present policy?
The Dutch Safety Board (2002) recommends that the entire Dutch population, and not only driving licence holders, is told about the risks of a car ending up in water and the possibilities of escaping. The Transport Safety Board as well as the Ministry of Transport (Buning et al., 2008) advocate an emergency hammer being present in each vehicle so that occupants can smash a (side) window in order to escape. Early 2009 , the Ministry of Transport together with RAI Association and the Dutch sector association for mobility BOVAG started a campaign to promote always having an emergency hammer within reach (www.eruitdoorderuit.nl); in October 2006, there already was an information campaign about what to do if you end up in deep water in a car. The advice now is to escape from the car as fast as possible. An indicative assessment of the most recent information campaign shows that the knowledge about what to do when a car hits the water (get out as fast as you can) is the same before and after the campaign: about half of the respondents know this. After the campain, however, more people know that escaping from a car is best done by using an emergency hammer (from 28% to 38%). The share of drivers who have a hammer in their car has also increased from 51% to 55%. During the campaign period considerably more emergency hammers were sold than during the same period in the previous year.
If the measures taken by the manufacturers are insufficient, the Dutch Minister of Transport will investigate the possibility of sharpening the vehicle requirements, so that electronic window controls and central door locking systems continue to function sufficiently long.

Conclusion
Crashes in which cars end up in deep water are generally more severe than many other crash types. This, for instance, is illustrated by the high proportion of fatalities and inpatients in such crashes. Submerged car crashes are mainly a typical Dutch problem and they are complicated. There are developments in the field of electric and electronic vehicle facilities that can result in (more) problems with escaping. Because of the serious nature of these crashes, preventive measures are recommended in relation with both infrastructure and vehicle safety.
Furthermore, it remains important to use all possible means to inform the entire Dutch population about the risks of ending up in water and the possibilities of a fast escape. In addition, the correct use of seat belts before and during hitting the water is of great importance to prevent injury and thus to increase the possibilities of escape.

Publications and Sources
(All Dutch SWOV reports have a summary in English)

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