Opdrachtgever: **WODC**

Randvoorwaarden verticale evacuatie bij overstromingen

Auteurs
B. Kolen
C.J.M. Vermeulen
T. Terpstra
J. Kerstholt (TNO)

Dit onderzoek is uitgevoerd in opdracht van het WODC, afdeling Extern Wetenschappelijke Betrekkingen, ministerie van Veiligheid en Justitie.

PR2916.10 maart 2015

Summary

Introduction and problem focus

Evacuation is a possible measure to reduce the risk of casualties in case of flooding. This research focuses specifically on *vertical* evacuation in the Netherlands as a strategy to cope with flood consequences due to failure of primary flood defences along the Dutch coast, Lake IJssel and the major rivers (Rhine, Meuse, Scheldt). In a vertical evacuation people evacuate to a high, dry place within the threatened area (in the U.S. literature referred to as sheltering in place). Previous research has shown that preventive evacuation in the Netherlands (i.e., people evacuate to a safe location outside the threatened area before failure of flood defences) is not always possible. Vertical evacuation is an alternative to preventive evacuation. Vertical evacuation can be a forced choice (when there is insufficient time for preventive evacuation) or a strategic choice (when both vertical and preventive evacuation is an option, but where vertical evacuation is estimated to result in fewer casualties). People (and their families) who evacuate vertically have to cope with the event on their own, and need to survive in the flooded area. The question is whether it is possible and appropriate to define conditions and requirements (e.g., for buildings, water, electricity, transport, communication) that facilitate vertical evacuation. The objective of this research is twofold and reads:

1. Under what conditions will vertical evacuation contribute effectively to the safety of people (i.e., focus on prevention of casualties)?
2. What measures can (reasonably) be taken by government or private sector (stimulated by government) in order to improve circumstances during survival (i.e., focus on 'quality' of survival circumstances)?

Context of vertical evacuation

In this research vertical evacuation is defined as the displacement of people to dry floors in buildings or public shelters that are located inside the threatened or flooded area. Vertical evacuation strategies can be implemented in combination with, or as an alternative to, preventive evacuate in case preventive evacuation is not entirely possible (because the time available is insufficient) or desirable (because of the impact and probability of flooding in the warning phase). Research has shown that in some cases casualty estimates for vertical evacuation are lower than for preventive evacuation.

During a flood threat a number of phases can distinguished. In this study, we distinguish between a 'cold phase' (i.e., no threat present), a 'warning phase' (i.e., a flood threat is detected), a 'transition phase' in which an evacuation decision is made by government, and an 'implementation phase' which focuses on implementation of the evacuation strategy. In the implementation phase further distinction can be made between the phase before and the phase after onset of actual flooding. After onset there will be a period of a few days in which the flood spreads through the area and people seek shelter, after which the situation stabilizes. Evacuation decisions made before onset are always fraught with uncertainties about whether, when and where flood defences will fail, and uncertainties about the effectiveness of measures.

Research method

The outcomes of this study are based on scientific and grey literature (such as policy documents) and knowledge among experts and managers of utility networks, infrastructure and disaster response organizations ('safety regions'; police, fire and health departments). Their knowledge was unlocked in two workshops, one focused on the physical infrastructure and one

focused on people's behaviour. These workshops were supplemented by face-to-face and telephone interviews. In addition, two case studies were performed in cooperation with the local safety regions, one in the city of Dordrecht (safety region South-Holland South) and one in polder Mastenbroek (safety region IJsselland). These two regions were selected based on their experience with developing vertical evacuation strategies and underlying threat scenarios.

Defining conditions and requirements is a decision problem

Although flood probabilities are small in the Netherlands, they cannot be neglected. As stated by the minister of Infrastructure and the Environment on November 2014 (during the closing meeting of the project "Flood Risk in the Netherlands" (Dutch: Veiligheid Nederland in Kaart): *"But if something really goes wrong, the government has also failed."* The question is therefore what can be expected from the government. In the same speech, the minister said *"What can they (citizens) actually expect from us? Where does their own responsibility begin? It is our job as politicians to keep asking these questions in public debates."* There are two perspectives for defining conditions and requirements for vertical evacuation:

1. The perspective of reducing the impact of a (potential) flooding. Currently there are (only) general requirements for disaster management such as informing the public about risks in general. There are also generic requirements for setting regional risk profiles, contingency plans, exercises and spatial planning. However, these requirements and roles are not related to the prevention of casualties or improving the circumstances for survival during (vertical) evacuation.

2. The perspective of an acceptable (casualty) risk for flooding. Recently new standards for flood probabilities were presented in the Dutch House of Representatives. These standards are based on a risk approach (risk = probability times consequences). These standards are based on a new criterion that provides 'basic safety' to every citizen. That is, the probability of dying due to flooding on any location that is protected by primary flood defences may not exceed 1:100,000 per year. In areas where major social disruption is expected, even more stringent standards for flood probability can be defined. These additional standards are based on cost-benefit and group risk analyses. Since flood defences commonly are the most (cost) effective measure in reducing flood risks in the Netherlands, basic safety and standards for acceptable flood are provided through standards for the flood defences. The possibility to shape safety through smart (i.e., cost-effective) combinations of flood defences, spatial planning and crisis management, is viewed by experts as a potential but exceptional solution.

Conditions and requirements for vertical evacuation

Conditions and requirements are defined as requirements that governments may impose on themselves or others, and which must be met to enable or facilitate vertical evacuation. It is noted here that currently there are (also) no conditions and requirements for preventive evacuation. Preferably, conditions and requirements for vertical evacuation are considered in conjunction with preventive evacuation. Defining conditions and requirements is a political and managerial choice. These conditions can be regarded as additions to the current way of managing and organizing our country such as building regulations for housing, traffic and water management, requirements for information technology and utilities and informing the public. In everyday life, citizens and companies have their own responsibility for coping with risk, facilitated by public authorities that provide policy frameworks and operational means. For example, the government has responsibilities in spatial planning (e.g., location choice and zoning, building codes) and for informing the public about risk (risk and crisis communication).

The idea behind the conditions and requirements for vertical evacuation is that they facilitate the reduction of flood consequences. Therefore they must have a significant effect on the number of casualties or on survival conditions. In addition, they must be feasible and realistic. In defining the conditions and requirements there are a number of considerations:

1. the costs of measures, including their relation to the efficacy of other measures to reduce casualty risk;
2. the feasibility of measures, given the lack of flood experience due to the small flood probabilities in the Netherlands;
3. the extent of flooding and evacuation associated with scarcity of resources in infrastructure capacity;
4. the uncertainty in the lead time and the way public authorities, experts and citizens respond;
5. the acceptance of casualty risks by citizens and public authorities.

Based on this research the following conditions and requirements for vertical evacuation have been defined. Some apply only to (vertical) evacuation, while other also have benefits for crisis management in general:

1. Determine the availability of dry locations in houses or public shelters:
   - Determine the available capacity per neighbourhood (number of locations and square meters) in houses and compare to the expected number of people that evacuate vertically;
   - Determine per neighbourhood the need for additional public shelters and evaluate fitness of use for existing buildings;
   - Assess the need for additional measures such as 1) the designation of public shelters and making agreements for management of these shelters, 2) influencing spatial planning to create sufficient shelter locations in the long term, and/or 3) setting priorities for the preventive evacuation of specific, vulnerable neighbourhoods or population groups (e.g., elderly).

2. Provision of information to the public about preventive and vertical evacuation should be added to generic information about risks:
   - Risk communication; stimulate awareness among citizens about vertical evacuation in homes and public shelters in relation to the (in)feasibility of preventive evacuation in the region, and give structural attention to this issue. It should be crystal clear to people that they will have to take care of themselves. Responsible authorities need to provide preparedness tips, for instance, about how to leave the area after flooding or how to make clear they are in need of help. We recommend using public shelters as evacuation hubs, so that people can gradually leave the area through these locations assisted by rescue workers.
   - Crisis communication; ensure timely warning of the public aimed at influencing their sense of urgency, and their attitudes towards the desired type of evacuation, accompanied by practical tips for preparation (water, food, warm clothes, etc.). Crisis communication experts should be able to give specific advice for preventive and vertical evacuation. It can be considered to prepare standard messages adapted to the local situations as the first step in the communication with citizens during the warning phase.

3. Enable the assessment of the effectiveness of contingency plans, evacuation strategies and decision-making as part of the generic requirements for evacuation in case of floods:

- The assessment of the effectiveness of evacuation strategies (both preventive and vertical) for planning and, in case of imminent flooding, avoiding casualties and damage in accordance the 'Framework Large Scale Evacuation'.
- Development of decision diagrams on evacuation to support decision-making based on a predetermined line of reasoning.

4. Agreements on the continuity of information technology networks and utilities in the warning phase:
   - This concerns the functioning of networks and utilities in the warning phase until the onset of flooding. These agreements should also include (possibly generic) arrangements for compensation of additional damage to these networks within the flooded area resulting from extended network shut down, and the acceptance of increased chain effects outside the flooded area and environmental damage.
   - It should be noted that, since evacuation is a precautionary measure, evacuations will occur more frequently than actual floods. In those situations where flooding does not occur extended network shut down results in lower social disruption and economical damage.

5. Agreements between government and grocery stores about logistics and supply of food and drinking water (and potentially medication).
   - These agreements concern extended opening times during the warning phase, to distribute food and replenishing food stocks (possibly supported by emergency services). These agreements should include arrangements for damage compensation. Such arrangements may be beneficial for other crisis situations. To inform the need for these agreements, research should be considered on household food supplies.

6. Specific rules for utilization of the available rescue capacities (this will shorten the duration of vertical evacuation; these conditions may be beneficial for other crisis situations).
   - Explicit choices about the utility and necessity of location choices for crisis coordination centres and police/fire departments and hospitals, equipment, working schedules for emergency staff and personnel in order to increase the resilience of the affected emergency services within a flooded affected area;
   - Facilitating citizens in rescuing themselves and other people (e.g., creating evacuation hubs as intermediate station, provision of information);
   - Initiating international disaster assistance during the warning phase.

7. Registration of vulnerable groups (e.g., elderly, patients and needy) to shorten the period of being vertically evacuated:
   - A registration system that allows people in need of help to provide their location and specify their needs during the warning phase; this information can be used in the rescue operation. This measure may be beneficial for other crisis situations as well.

Conclusions and recommendations

Based on this study, the following conclusions are drawn:

1. Vertical evacuation can reduce the number of casualties in situations where an overall preventive evacuation is not feasible because the time available is insufficient, or not realistic given the moment at which the evacuation decision is made.

A prerequisite for vertical evacuation is the availability of sufficient (high and dry) shelter locations within the flooded area, where people can stay temporarily during the phase that the flood develops. These shelter locations can be in their own homes or (public) buildings that function as public shelters. Although vertical evacuation is not without risk, it reduces the probability that people are exposed to the (evolving) flood during transport (which is the most dangerous situation) since sheltering locations are nearby.

The two case studies showed that in almost all neighbourhoods there are ample opportunities to evacuate to buildings with a dry floor. In addition, the responsible safety regions have been able to identify buildings that can be used as a shelter. These buildings were selected on the basis of available facilities and their daily use by large groups of people.

Maps delivered in the MEGO-study show the percentage of dry buildings per CBS-neighbourhood. The maps confirm that there are ample opportunities for vertical evacuation in people's homes. We advise to further analyse the presence of potential shelters in each neighbourhood.

2. In order to evacuate vertically, it is important that citizens are familiar with vertical evacuation and know where to find shelter locations. Theories of flight behaviour indicate that people take known routes, but that does not always have to be the most effective route. It is therefore important that vertical evacuation is placed in the perspective of the (in)feasibility of preventive evacuation, so that it is clear that by sheltering the chances of survival are greater compared to being exposed to the flood while driving a car. It is also important that citizens are aware of the (difficult) circumstances during vertical evacuation, so they can take emergency preparedness actions. The availability of supplies and utilities (such as the presence of food, water, electricity, etc.) and how this is framed in communication can affect attitudes towards evacuation strategies.

   During an actual flood threat information can be repeated and specified by providing explicit and clear evacuation options. These options can be further specified and updated as the threat evolves and more information becomes available.

3. Vertical evacuation is a temporary measure to shelter during the period that the flood develops. Hereafter citizens will need to move from the flooded area on their own, or with the help of fellow citizens or rescue workers. We do not find it realistic to set a criterion for a fixed number of days in which people are evacuated vertically before moving out of the flooded area, given the uncertainties in the (potentially large) extent of a flood, the number of people in the flooded area, the available time for preventive evacuation and the limited resources. The exact duration of this period is highly dependent on the measures taken by people themselves. Based on flood events abroad, it seems likely that after (approximately) a week, most people have been rescued or have saved themselves. A period of three days, which is often used in the Netherlands, seems too short for large flooding events.

4. The quality of survival circumstances during vertical evacuation can be influenced by continuity in functioning of information technology and utilities (gas, electricity, water and waste water) immediately before and after a flood, and inside and outside the flooded area. In this study, the following is concluded:

- Information technology, electricity and gas supplies will be shut down during the warning phase, in order to reduce damage, and to facilitate recovery and continuity outside threatened area. If this is done too late, there may be (dangerous) complications inside the flooded area and chain effects outside the flooded area will increase. Shutting these functions down in the warning phase causes chain effects such as failing traffic management and sewage, making both vertical and preventive evacuation more difficult.

- Emergency equipment (such as pumps) only has local and temporary effects, due to the scale of the disaster (large) in proportion to the required resources (limited) and the fuel needed (problematic).

- Additional investments in robust spatial planning and design and in additional emergency measures are costly and are unlikely to be considered by network managers unless enforced by legislation. However, current climate adaptation initiatives are looking into more robust networks. If these initiatives provide new insights in improving the continuity of critical infrastructure, survival conditions may be improved. However, since these measures are studied form a different perspective (such as climate change and sustainability, which are different from flooding); their efficacy remains to be seen.

- For health care organizations there is a more direct relationship between improving services and the number of casualties. However, the (costs of) measures that are needed are considerable. Eventually, these organizations will evacuate too. Therefore we recommend strengthening the resilience of these organizations by using available resources efficiently in the warning phase (such as personnel and inventories). Flood awareness among health care organizations is needed.

- The relation between survival circumstances and loss of life in homes and shelters has not been demonstrated in this study.

5. Both government and citizens (including needy people) are responsible to take care of themselves in a vertical evacuation. The overall result depends on the severity of flood consequences, and on the cooperation between citizens and government. For all of the protected areas in the Netherlands, floods may occur unexpected.

   The responsibilities of citizens are an extension of everyday life such as having sufficient food, drinking water and medication, and taking care for their own safety. ‘Sufficient’ in this respect depends on the person and his/her abilities to survive the event. Research shows that resilience and self-efficacy of citizens is often underestimated. People tend to support each other in crisis situations. People’s needs during the period of vertical evacuation is highly dependent on the particular circumstances. In addition to being well informed, good health, community involvement and basic skills such as first aid are key to people’s resilience.

   If the government sets standards for the preparation of citizens (such as having a certain amount of food resources, batteries and blankets) criteria are need to determine the appropriate preparedness level as well as enforcement to ensure that people comply. Because of the low flood probability, high costs and capacities needed this seems unrealistic.

The government will have to take people's own responsibility as a starting point. Experts indicate that information and generic measures that strengthen self-reliance (such as first aid and involvement of communities) will be much more effective. However, these generic measures go far beyond the specific issue of vertical evacuation. Such measures should not be addressed from the perspective of vertical evacuation alone.

6. The government can better facilitate evacuation by defining conditions and requirements. The extent to which this occurs, and which requirements must be met (such as facilities in shelters) is a political choice since these requirements do not follow from flood risk policy.

   There is a constant tension between the need to set specific conditions for vertical evacuation and the provision of more generic standards. An example involves the distribution of food. Experts state that, based on logistic capacities and distribution legislation, much can be arranged in cooperation with EU members as long as food is available. However, the distribution within the flooded area to those that are in need remains a bottleneck. Improvising adequate solutions will be important.

Based on the study, the following recommendations are made:

1. Strengthen the generic resilience of people, for example by providing first aid courses and encourage their general health.
2. Consider vertical and preventive evacuation in conjunction. Define standards or result requirements related to the casualty rate and the quality of survival circumstances. Based on these standards and requirements evacuation strategies can be developed and their implementation by the safety regions (crisis management and crisis communication focusing on different target groups) and municipalities (spatial planning policy for shelters, risk communication) and by national authorities (a broad, national communication campaign and information provision).
3. Further research is needed into the causes of casualties and the factors that influence the quality of survival circumstances in connection with availability of utilities, wastewater and of information technology. New empirical research will be needed since existing databases do not contain this information.
4. Insights are needed in household's food reserves, and to what extent these reserves are suitable for survival during vertical evacuation. This can, for example, be examined by questionnaire surveys.
5. Develop maps that provide insights the spatial possibilities of vertical evacuation. These maps may include information about the presence of dry floors, locations of businesses with hazardous materials, locations of shelters, vulnerable objects etc.