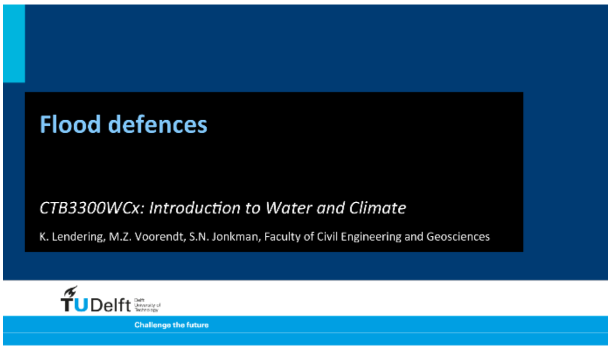
CTB3300WCx – Introduction to Water and Climate

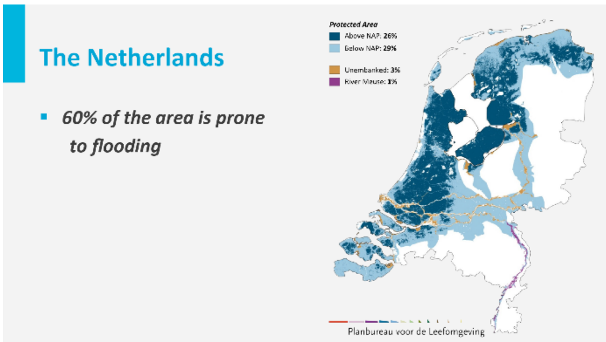
TU Delft

IN1a – Flood defences

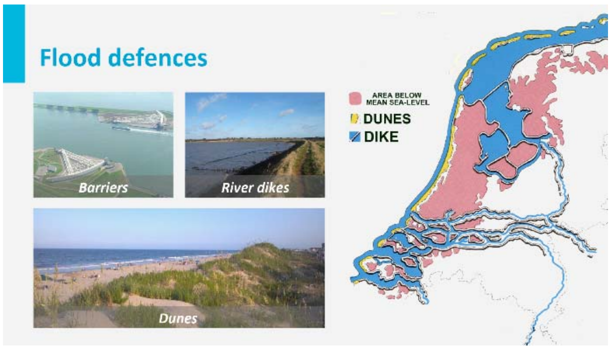
Bas Jonkman



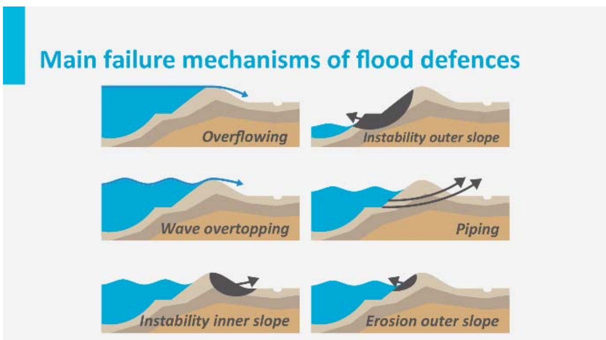
My name is Bas Jonkman I am a professor of hydraulic structures and flood risk at Delft University of technology.



In the Netherlands 60% of the surface is prone to flooding from rivers, the sea and lakes. Flood prevention is thus of national importance. A small part of the country, about 3%, is not protected by dikes but still prone to flooding. Examples, are the floodplains of the rivers and the port expansion of Rotterdam (Maasvlakte), this is raised 5 meters above sea level to prevent flooding.

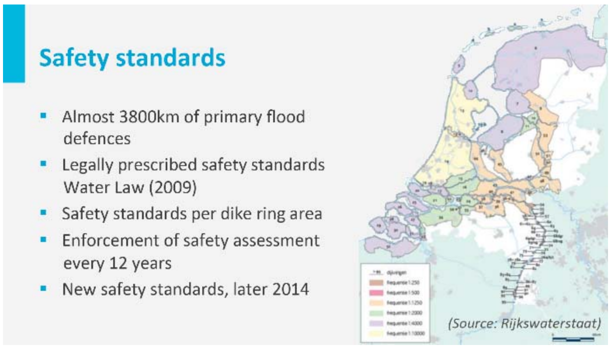


Flood defences are Structures whose primary objective is to provide protection against flood events along coasts, rivers and waterways. Examples of flood defences are earthen dikes, sand dunes, floodwalls and storm surge barriers. Various structures can form a dike ring together. An example is the dike ring around South Holland. It consists of sand dunes, a storm surge barrier and river dikes. In addition to flood defence structures, measures such as room for rivers or retention can be applied to reduce water levels on the outside.

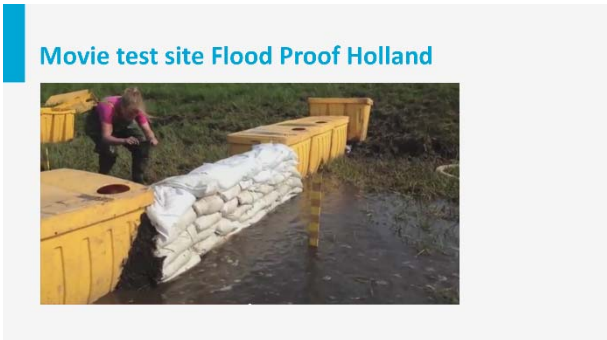


A flood defence can fail due to various failure mechanisms. We focus on some important mechanisms for an earthen dike. Overflow or wave overtopping can lead to erosion of the inside of the dike. During a high water level, the dike can get saturated and instability of the inner or outer slope can occur. Then there is piping or seepage: When the outside water level is high, increased groundwater flow will start under the dike and sandy soils can be eroded, thus undermining the dike. The initiation of this mechanism can be observed during high waters in the field, when so called sand boils start to form behind the dike. The outer slope can be eroded due to wave attack on the dike as well.

You can see that not only the height of the dike is important, but also its width, and its soil characteristics and its cover. The city centre of New Orleans was flooded during hurricane Katrina in 2005 when the dikes failed due to instability and piping! This means that various failure mechanisms have to be taken into account when designing a flood defence system.

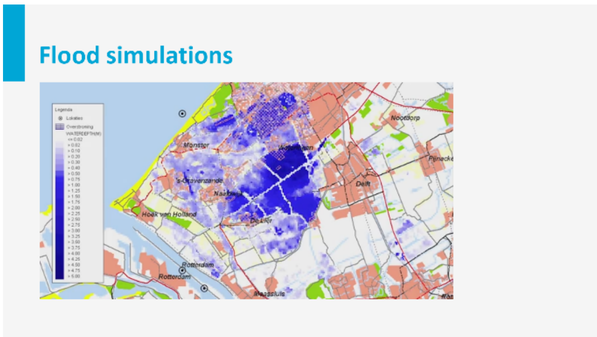


We return to the Netherlands. In total there are 100 flood defence systems called dike rings to protect the majority of the country against flooding. Over the last decades the safety standards for the flood defences in the country have been expressed by means of the annual probability of exceedance of a design water level. For example, the dikes around the area with the highest value – South Holland – have to be designed for water levels and waves that will be exceeded (on average) once every 10,000 years. Somewhat lower safety standards, are used for other areas with lower potential damages or more predictable floods. For example, for dike rings along the rivers in the Netherlands safety standards are between 1/1250 to 1/250 per year. In other parts of the world often lower standards are used, e.g. 1/100 per year in most of the United States. In recent years new approaches have been developed to estimate the failure probabilities for all the different failure mechanisms that we have discussed. And the new safety standards in the Netherlands that will be published in autumn 2014 will be expressed as a tolerable probability of failure instead of the previously mentioned probability of exceedance. And this change will allow a more complete assessment of the various failure mechanisms and the integral safety of flood defences.



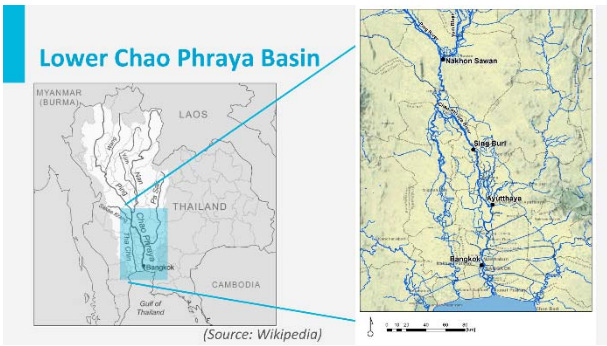
In extreme conditions emergency measures can be applied to prevent overflow or instability of dikes. The most well-known emergency measure is the sandbag. These require a lot of time to place, and therefore research is ongoing on innovative and faster alternatives. At Delft University we have a test site, called Flood Proof Holland, to test and develop innovative alternatives for the sand bag.

If emergency measures prove unsuccessful a breach is formed in a dike and enormous amounts of water will start to flow in. At this moment it will be almost impossible to stop the flood. However, miracles are sometimes possible. During the North Sea storm in 1953 in the Netherlands, a starting dike breach that threatened South Holland was miraculously stopped by manoeuvring a ship in the gap in the dike. However, the 1953 floods still led to catastrophic damages in the southwest of the country and 1835 people were killed during this disaster, and after that, the delta works were constructed.

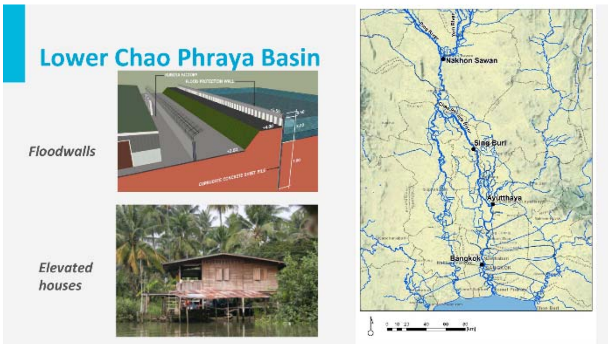


Computer models can show us how areas will flood. Here, you see a simulation for coastal flooding of South Holland. The flood pattern depends on the location and the amount of water inflow, and the topography and elevation of the area. Some floods can lead to rapid, deep and dangerous flooding, whereas others take several days to develop. Large-scale flood events can lead to billions of euros of economic damage, and significant life loss. This was for example demonstrated when New Orleans flooded due to hurricane Katrina in 2005. Models have been developed to estimate damage and life loss.

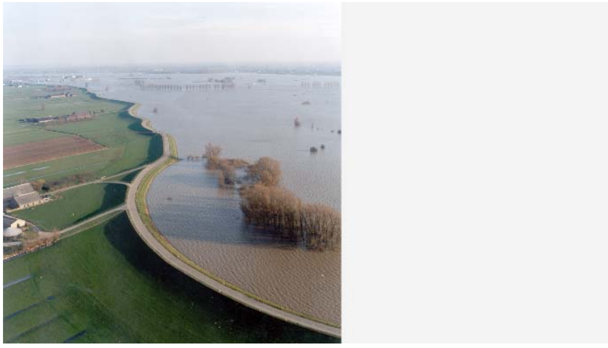
So far, we have discussed measures for prevention of floods (dikes, barriers and room for rivers). In addition measures can be taken to limit the consequences. Examples are raising houses to reduce damages, and evacuation and emergency management plans to limit loss of life due to floods. The choice for the (combination of) various measures will depend on the characteristics and functions of the system and the available budget. After all, a euro or dollar can only be spent once. For example, In the Netherlands, the primary focus is on prevention of flooding with flood defences. This is often the most cost effective measure for our country given the large values and populations at risk. However, in many other parts of the world defences are sometimes not present or less safe, and more attention is paid to reducing the consequences of flooding.



For example, in the Chao Phraya river basin in Thailand, seasonal flooding is important for agriculture. Large canal and irrigation systems are present and river dikes allow seasonal overflow.



In some places elevated housing is present to accommodate flooding. However, larger dikes and floodwalls are applied to protect cities, such as Bangkok, and industrial areas. Thus, the optimal mix of measures depends on the local situation.



In addition to the physical measures discussed, a good management system is required to regularly inspect the system, upgrade it in case of changing conditions and new insights. For example, sea levels and river discharges could increase due to climate change. Adaptation of flood defences over the coming decades or century could then be necessary. Also, new insights in the strength can lead to necessary reinforcements. As experience in the Netherlands has shown over the last centuries, lots of attention and work are constantly needed to maintain a good flood defence system. This is our challenge for the future in the Netherlands and abroad.