THE WORKING GROUP ON LEVEES AND FLOOD DEFENCES UNDER THE EUROPEAN CLUB OF ICOLD

ISSUE 08 NOVEMBER 2021

lfd-eurcold.inrae.fr

LEVEES Working Group Newsletter

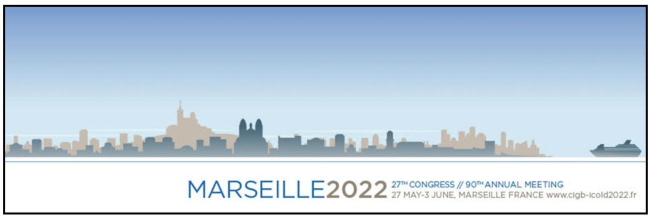
Note from the Chairman

Rémy Tourment

I will start my introduction on the same note as the last issue of our newsletter, and unfortunately the COVID 19 pandemic situation still has a very deep impact on our everyday life, in our regular work, and even more on our international community activities. We have seen many international conferences and meetings postponed or even cancelled along with the regular group activities (working groups, technical committees, …) that could sustain one year of virtual / online meeting, however we are now suffering a second year without actual meetings.

Hopefully, and this is my personal opinion, either because of an improvement in the situation of the pandemic itself, thanks to vaccination and other measures, or because of the adaptation of society to living with the virus, it looks like activities involving physical presence will happen more and more in the future. On a positive note, we organized our first webinar this year, which was a success (more about this on the website), and we plan to organize more in the future, in addition to more classical types of events.

ICOLD 27th congress in Marseille, initially planned for June 2021, was first postponed to November 2021, with a subsequent postponement to May-June 2022. Based on discussions at the ICOLD Board level and with the organizing committee in CFBR, the dates are now final and everything is complete to make this event a success.



The detailed program and the second bulletin are available on the dedicated web site.

Check this information now! As this is the ICOLD's 90th annual meeting, which happens to take place in a European country, I hope that we will take the opportunity for all our Working Group (WG) members to meet and create new links, or reinforce existing ones.

In the meantime, the 89th annual meeting is from November 15-19 2021 as an online event. I invite you to attend the symposium and the Technical Committee (TC) workshops, including the workshop organized by the TC on Levees, of particular interest to our European WG. More information to join on the ICOLD meeting is on the website https://www.icold2021.org/en/.

In our newsletter you will find interesting technical and scientific information, as well as news about projects. Please don't forget that we are always looking for information from YOU to share in the newsletter and on our web site! We need diversity in terms of contributing countries, and are eager to learn from every member country. We also welcome contributions from any countries, even non-European ones. Many flood events in 2021 around the world demonstrates again, if it wasn't obvious, that flood defences are an important topic for our societies.

A CALL FOR CONTRIBUTIONS

- Information about levees and flood defences projects and works
- News, media or press releases on current flood or storm events involving levees and flood defences.
- Current, ongoing or recently completed research projects.
- Documents related to levees or flood defences: handbooks, guidance, reports and regulations.
- Information on any event or conference relating to levees or flood defences
- Links to informative / educational websites and related organisations
- Pictures to be used in the web site banner, randomly chosen every time a page loads (resolution has to be 1024x300)
- Contact the WG web site team: lfd-eurcold@irstea.fr

IN THIS ISSUE

RODENT PROTECTION

New mini-invasive trenchless installation method implements vertical rodent barriers in challenging jobsite conditions

By Michael Arndt, DE

Rodents such as Nutria, Beaver and Muskrat cause severe damage to river embankments, dams and dykes.

Figure 1: Excavated beaver tunnel system, Hunze een Aa´s, NL, where 400 linear meters of vertical barrier had been installed by IWT in Oct. 2021, (Source: Watershap Hunze een Aa´s)

A common protection against rodents are metallic stainless steel grids or corrosion protected polymer coated steel wire nettings that are installed close to the surface along the dam, dyke or embankment slopes. In the case of beavers, the tunnel entrances are situated below the waterline. The superficial installation must cover both the underwater slope section and part of the riverbed, to block the rodents effectively.

Figure 2: : collapsed beaver tunnels, embankment Odra river, in the background: new entrances inside the dyke line (Source: LFU Brandenburg)

To avoid underwater installation, the rodent barrier can be installed vertically directly adjacent of or inside the river embankment, deep enough to block potential rodent tunnel entrances.

Based on the knowledge that beavers usually place the tunnel entrance less than 1,0m below the water line into the embankment, former guidelines e.g. The German DVWK 247/1997 recommended a total depth of 1,5m for vertical barriers.

The reason why many of these low depth vertical barriers are overwhelmed by rodents creating tunnels below the vertical barrier is simple: the variation between high water and low water level motivates the rodent to place the entrance inside the riverbed instead of into the embankment, and therefore the rodent digs deeper to create a stable tunnel tube. To stop this behaviour successfully, actual requirements for vertical barriers refer to a depth of 1,5m below the river bed level. To achieve the requested depth of 1,5m below the river bed level, the vertical barriers are designed at a total depth of between 3,0m - 5,0m depending on the embankment geometry.

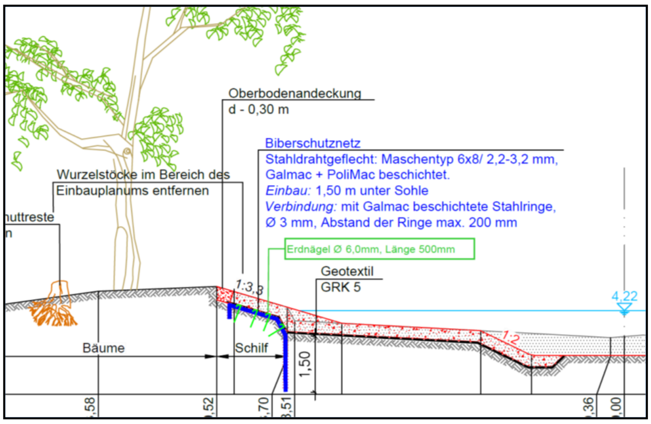


Figure 3: Cross section, Quappendorfer Kanal Brandenburg, Germany Vertical Barrier, 1,5m below river bed level (Source: LFU Brandenburg)

The insertion of the vertical barriers required the excavation of a stable trench until recently. Trench stability directly adjacent to water is a problem - fairly often the trench is flooded and tends to collapse before the barrier can be inserted. Therefore, the solution had been to increase the distance to the riverbank or to temporarily regulate the water level if possible and build the trench in dry conditions or, as the last and most expensive option, to install a steel sheet pile wall.

The company IWT Ingenieur Wasser und Tiefbau GmbH, based in Frankfurt Odra Germany and specialized in hydraulic applications (www.iwt-ffo.de), combined the sheet pile technique with beaver protection netting and patented (P102019001147 / 2019-0101/EP) the first trenchless installation of netting rodent barriers.

On site the netting is placed between two sheet pile plates using a semi automatic hydraulic working platform. The three-layer compound is then placed into its final position using an excavator with a specific vibration device. Once the required depth is achieved and the adjacent panel is placed with a small overlap, the sheet pile plates of the first barrier section are pulled out and the netting remains in its precise and defined position.

Figure 4 & 5: Barrier installation and detail of the 3-layer compound - netting between two sheet pile plates, embankment section Brandenburg area Biegen, Germany, barrier depth 3,0m (Source: SECON)

In comparison to trench based installation, the procedure is highly efficient in terms of installation progress and precise positioning. Furthermore, it provides a contribution to climate and environmental protection by an extremely mini-invasive insertion of the barrier with minimized damage of superficial vegetation without moving soil. This way fauna and flora is not affected by the installation.

The vibration during the installation process and the pull out of the steel plates in direct contact to the netting create an intense abrasion to the netting surface. Therefore, any simple metallic coated products would fail. The beaver protection netting consists of a hexagonal double twisted zinc aluminium (ZnAl 90/10) coated steel wire, additionally protected against corrosion and is highly abrasion resistant by a polymeric PoliMac coating that provides an expected 120 y lifespan in a C5-Environment in accordance to EN 10233-3.

The installation method has proven its suitability in numerous successful reference projects.

Figure 6: Excavator with vibration device, hydraulic working platform, dyke section along Odra River area Gross Neuendorf, Germany, barrier depth 4,5m (Source: IWT)

INTERNATIONAL GUIDELINES

Launch of the International Guidelines on Natural and Nature-Based Features (NNBF) for Flood Risk Management

By Matthijs Boersema, NL

On September 16, the virtual launch event was held to celebrate the monumental accomplishment of the NNBF International Guidelines. (free to download at the Engineering with Nature website https://ewn.erdc.dren.mil/?page_id=4351).

Todd Bridges, the National Lead for the Engineering with Nature initiative (US Army Corps of Engineers), hosted the digital event with around 600 participants. The 1000-page document is the culmination of a five-year, multi-sector effort that involved 77 organizations around the world.

The International Guidelines provide practitioners with the best available information concerning the conceptualization, planning, design, engineering, construction, and maintenance of NNBF to support resilience and flood risk reduction. The term natural and nature-based features (NNBF) refers to the use of landscape features to produce flood risk management benefits, and other co-benefits.

The guidance document is divided into 20 chapters, focussing on the opportunities for NNBF, the principles, engaging communities, planning, implementation, cost-benefits and adaptive management. Secondly the document covers a wide range of environments like the coast, rivers, islands, reefs, etc.

Although levees and dams are not a specific topic, they are part of riverine and coastal environments. Many case studies, described in this guideline, include engineering elements like dams and levees. Often, these can be incorporated in NNBF, leading to grey-green solutions. In that way, NNBF contributes to making these features more climate proof.

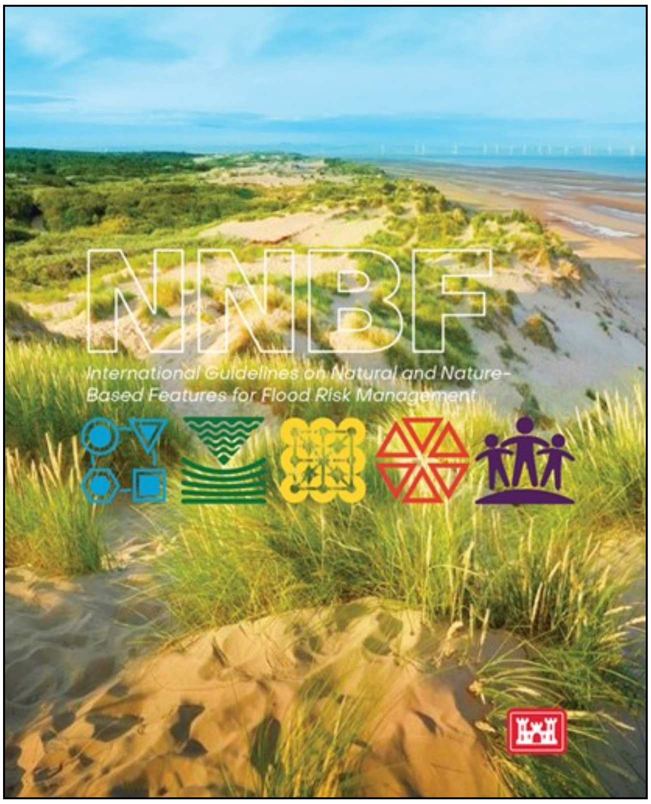


Figure 7: International Guidelines on Natural and Nature-Based Features (NNBF) for Flood Risk Management

FRENCH PUBLICATIONS ON LEVEE GUIDANCE

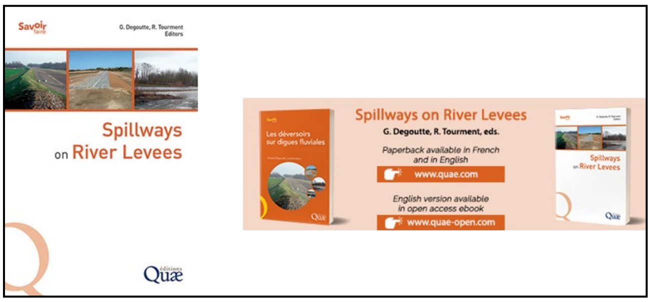
1. Spillways on river levees

By Adrien Rullière, FR

Given increasing international interest in levees and flood protection systems, particularly following ICOLD’s creation of a Technical Committee on Levees, a technical handbook entitled “Spillways on River Levees”, firstly published in French, is now available for free in an updated and translated English version: https://www.quae.com/produit/1720/9782759232857/spillways-on-river-levees.

This technical handbook outlines the benefits and limitations of spillways on flood protection levees. It covers different types of spillways on river levees, including their function, hydraulics, river morphology, civil engineering, and flood management. Written by a working group led by INRAE, it is intended for levee managers, control authorities, engineering firms, and hydraulics or civil engineering students. The highlights and the contents of the book are presented below:

The likelihood that overflow will occur on flood protection levees is far from insignificant. When water overflows an earthen levee, it greatly increases in velocity and erodes the levee slope or toe. This erosion extends backwards and opens up a breach that provokes sudden flooding in the supposedly protected area, often with significant economic impact. The swiftness of this process can lead to human casualties in areas with inhabitants or transport infrastructure. Levees are a double-edged sword: they offer protection against medium-sized floods if properly built, but can create a hazard during high floods if no provisions are made to secure them against overtopping.



It is therefore advisable to equip levee systems with spillways, which are common appurtenant structures on dams. Yet spillways on levees play a far more complex role than those on dams, from securing protected areas to flood control.

Installing a spillway on a levee offers many benefits:

The spillway will delay overflow on other parts of the levee (generally to a limited extent).

The spillway can introduce a stilling water cushion before water overflows on other sections of the levee. If this water cushion is well formed, it reduces the need for additional structures to make the levee overflow resistant.

However, even if none of these additional structures are built and overtopping causes a breach, it will be less violent thanks to the downstream water cushion and will occur after the area has been evacuated.

In any event, the spillway will reduce the risk of a levee breach and therefore substantially reduce the discharge and the volume of water. It also reduces the water levels, the velocities, and the flooding time in the protected area.

The location of the flows can be chosen ahead of time, whereas the location of a breach will remain unpredictable.

The moment overflow begins can be accurately predicted, and the discharge law is well known, facilitating emergency management (this benefit is not as significant with a fuse plug).

Detailed contents of the handbook are the following:

1. Background, definitions, various configurations (Typology of flood protection levees on rivers, protected areas and flood expansion areas, typology of spillways on levees)
2. The historical background of spillways in France
3. The hydraulic design of spillways (Spillway's impact on the waterline of the flooded river or protected area, spillway's flow law, spillway location, general hydraulic design principles)
4. Spillways and river geomorphology (Overview of sediment transport, morphological changes in watercourses, spillway's influence on sediment transport, sedimentation behind spillways, influence of bed change on spillway performance & torrents)
5. Civil engineering design for levee spillways (Safety criteria for levee spillways, principles of fuse plugs or movable devices, types of straight weirs and constituent materials, overflow erosion on earthen levees)
6. Emergency management of the levee system (The benefits and limitations of spillways in emergency management, considerations before drafting an Emergency Management Plan, Emergency management and levee managers)
7. Economic aspects

2. Methods and techniques for reinforcing and repairing flood protection levees

By Adrien Rullière, FR

This summer, the Executive Board of CFBR (French Committee for Dams and Reservoirs) has approved a new report, entitled "Methods and techniques for reinforcing and repairing protection levees".

As the title suggests, this report aims to present different methods, applied to the repair and/or reinforcement of the flood protection levees, whether in river or coastal areas, with the elements allowing the design and implementation of each of these methods. It includes two parts: first a general part and a second part presenting thirty-six methods, each in the form of a standardized form. The techniques presented concern the functions of sealing, drainage, filtration, stability against sliding and protection against external erosion as well as crest raising. Elements are also presented, without a specific form, on the problems related to transitions, included or crossing structures, burrowing animals, tree vegetation management and breaches repairs.

This accomplishment is the result of many years of work. Currently, this document is only available in French, but the working group has started the process of translation into English, with the aim to have the first part ready for the Marseille ICOLD congress in 2022. The deliverable of the CFBR "Levees" Working Group is available for free at:

- First part, "General framework": https://www.barrages-cfbr.eu/IMG/pdf/recueil_confortement_digues_partie_1.pdf

- Second part, "Technical data sheets": https://www.barrages-cfbr.eu/IMG/pdf/recueil_confortement_digues_partie_2.pdf

In France, flood protection levee's represent a linear length of about 10,000 km (of which nearly 10% are on the coast). To date, the state of the art in terms of reinforcing and repairing methods for flood protection levee is essentially based on:

- Reinforcing and repairing methods and feedback from the methods developed for embankment dams. From an economic point of view, the methods with the best performance and lowest costs are generally preferred.
- Other fields of civil engineering (river and/or maritime developments, road earthworks, soil reinforcement ...), with adaptations to take into account the additional constraints linked to the permanent or temporary presence of water (internal and external flows for example).

Although similar in many aspects, levees are different from dams. Among others, the following main differences can be mentioned, which will have consequences on the design and execution of the works:

- In general, dams are mostly subjected to a permanent load, while levee loading is rare and of a relatively short duration (from a few hours to a few days in general).
- Geometry (length/height ratio): levees can have very long crest lengths compared to their height (potentially several thousand times) with crest lengths much larger in comparison to dams.
- Foundations: the foundations of levees are generally only treated on the upper portion, or not at all (which is obviously not recommended) because of :
    - the above-mentioned consideration of the non-permanent loading of levees and therefore the lesser need for an impermeable foundation,
    - the location of the levees (generally on alluvial soils, often very thick compared to the height of the structure).
- The flood protection levees are often old or even very old structures and their composition (cross section, zones and materials) is therefore often unknown. The composition of some small older dams may also be unknown , however the large linear length of the levees and the variability associated due to the reuse of local materials during their construction, reinforce the lack of knowledge.
- Most of the dams are established on the continental hydrographic network, whereas many levees (about 1000 km, i.e. about 10% of the French levees) are established on the coast or in estuaries.
- The flood protection levees have been regularly reinforced and repaired over time. These works, often carried out at different times and with various techniques, provide levees a great heterogeneity and therefore a source of vulnerability to loading.
- The upstream face of a dam is subject to lateral water flows only in very exceptional cases, whereas the waterside faces of river, estuary or coastal levees are regularly subject to this water action.

Moreover, in France, feedback concerning reinforcement or repair works on flood protection levees are not well developed or shared between the different actors. This limits the development and improvement of reinforcement and repair methods.

This is why, in order to allow each of the levee actors to have the most exhaustive vision possible, the CFBR (French Committee for Dams and Reservoirs) launched a working group in 2014 to provide an initial knowledge base on the methods for reinforcing and repairing flood protection levees. This document is the result of the work of the working group.

GROTE WAARD POLDER

A 600 year battle between land and water

By Arco van de Ree , NL

Translation by Marcel Bottema, NL

During the first quarter of the 15th century, three disastrous storm surges hit the Dutch Coast, all of them occurring in mid-November, which is why they all refer to the name day of Saint Elisabeth. The most legendary of those was the 2nd St Elisabeth Flood of 1421, in which levee failures led to the inundation of the Grote Waard polder to the south of the city of Dordrecht, a city some 20 km south-east of the city of Rotterdam. The number of flood victims is highly uncertain, with historical sources mentioning thousands of victims while recent insights rather point at dozens of people. An undisputed fact is that an agricultural area of over 6000 km2 got lost by the flood, which is the greatest flood-induced land loss that has ever occurred in The Netherlands. What used to be the bread basket of Holland, had to be given up to nature.

The development of the Grote Waard area started in the 11th and 12th century when large areas around and east of the city of Dordrecht were converted to agricultural land. This was done by removing scrubs and trees, and by digging ditches connected to the river for drainage. Back then, the land was still higher than the river, and initially, there was no need for levees.

Figure 8: Historical map, showing the evolution of part of the flooded Groote Waard area into the marshy area known as the Biesbosch (published with permission of the Biesbosch Museum in the town of Werkendam)

As time passed (and soil started to subside) people wanted more and more protection against floods. Levee construction started, first by local or even individual initiatives, but gradually in a more and more organized way, as people realized that only a closed levee system would provide proper flood protection. In this way, levee-surrounded agricultural areas developed, referred to as 'waarden' (flat areas near rivers , like the Dordtse Waard). Flood-protection related agreements between communities were registered, and in this way the first Water Boards developed.

The rivers surrounding these 'waard' areas were the Meuse, the Merwede branch of the Rhine, and three small rivers near the city of Dordrecht and the towns of Almkerk (to the east) and Geertruidenberg (to the south). After 1250, these rivers were dammed which led to a leveed area as large as 500 km2. For the Middle Ages, its size was huge. It took until the 1940's before a larger polder was constructed (the Noordoostpolder along Lake IJssel). The importance of the Grote Waard was stressed by the fact that Floris V, Duke of Holland, became involved in the levee maintenance, through an agreement with local authorities that was concluded in 1273.

All these land development efforts brought their benefits. Higher grounds were used to grow cereals (note that cereals were then the main staple food, since potatoes were not yet introduced), lower grounds were used for cattle grazing. Peat was excavated for fuel or was burnt for salt (essential for food conservation), and there was a lot of fishing activity. All in all, the Grote Waard was a prosperous area and became known as the bread basket of Holland. Surrounding cities and towns benefited and prospered as well, like Dordrecht, Heusen, Geertruidenberg and Zevenbergen.

Figure 9: Impression (1) of the present Biesbosch area (published with permission of the Biesbosch Museum in the town of Werkendam)

Towards and in the 15th century, the prosperity started to turn into a struggle against the water. Land subsidence became noticeable, peat excavation weakened the levees, and levee failures occurred from time to time, followed by repairs. However, persistent political and military conflicts put pressure on the budgets, and as a result also on levee maintenance.

Then, by mid November 1421, the Elisabeth Flood struck through from a combination of a severe north-westerly storm and fairly high river levels. Both in the south-west and (later) in the north-east, levees broke and the area became flooded. Two years later, repairs were well underway as a result of vast efforts, but in 1424, a third Elisabeth Flood struck, causing the levees to break again. At that point, the Grote Waard polder was given up to the waves.

Perhaps contrary to the legend, the Grote Waard was not abandoned overnight. A fair few people decided to cling on to their farms and existence, until the situation really became untenable and people moved to neighbouring dry areas. For example, inhabitants of the village of Weede moved to the remaining part of the Grote Waard levee where the village of Cillaarshoek (nearly 10 km west of Dordrecht) was founded. Others moved to Dordrecht, although the city was now deprived of many of its connections, and much of its income. Church towers remained witness of the flooded area for several years, but finally were demolished to provide construction material for communities in the flooded area. Remaining peat layers were either excavated or removed by the flood waters, until a large wetland with several tidal and river branches developed. A significant part of this flooded area still exists today, and is known as the Biesbosch.

Figure 10: Impression (2) of the present Biesbosch area (published with permission of the Biesbosch Museum in the town of Werkendam)

Gradually, more and more land was lost, and after some decades, there remained little more of the Grote Waard polder other than a legend. This is all the more so, since no pre-flood maps of the Grote Waard (as it was before 1421) have been preserved, so that historical chronicles and archaeology are the main information source left to us.

The flood impact on the region was massive, with traces of the impact still visible today. A special experience centre has been created, in which the Water Boards of the region tell the story of the flood, while answering questions such as: How to deal with the fact that water can be both friend and foe? How to build a sustainable relation with water? What role the Water Boards play in that? For people wanting a preview or people not being able to travel to the region, there is also an on-line interactive experience centre.

Several parties contributed to the experience centre, such as the Water Boards of Hollandse Delta, Brabantse Delta, Rivierenland, Delfland, and Schieland & Krimpenerwaard, but also the National Flood Protection Programma HWBP and RIjkswaterstaat. There are also other commemoration activities in the region, for example in museums. A full overview of activities is given at 600jaarelisabethsvloed.nl/.

Main source of information (in Dutch) Article by Willem Janssen- www.bhic.nl/ontdekken/verhalen/de-grote-waard-rond-1420

Recommended web links:

- sint-elisabethsvloed.theimagineers.com/tour
- 600jaarelisabethsvloed.nl/
- dspace.library.uu.nl/handle/1874/314923
- sciencedirect.com/science/article/

AUTOMATED RISK ASSESSMENT

Challenges of a levee system probabilistic risk assessment

By Florence Mainguenaud, FR

Faced with increasing concerns around the flooding of urban areas, increasing the efficiency and accuracy of flood risk assessments is more than ever a challenge to overcome. An ongoing PhD supervised by INRAE (France) and York Engineering School (Canada) on "spatialized probabilistic study of flood risk assessments in areas protected by dikes" is presented below through a brief introduction of the risks, a presentation of the knowledge gaps and the method used in the PhD.

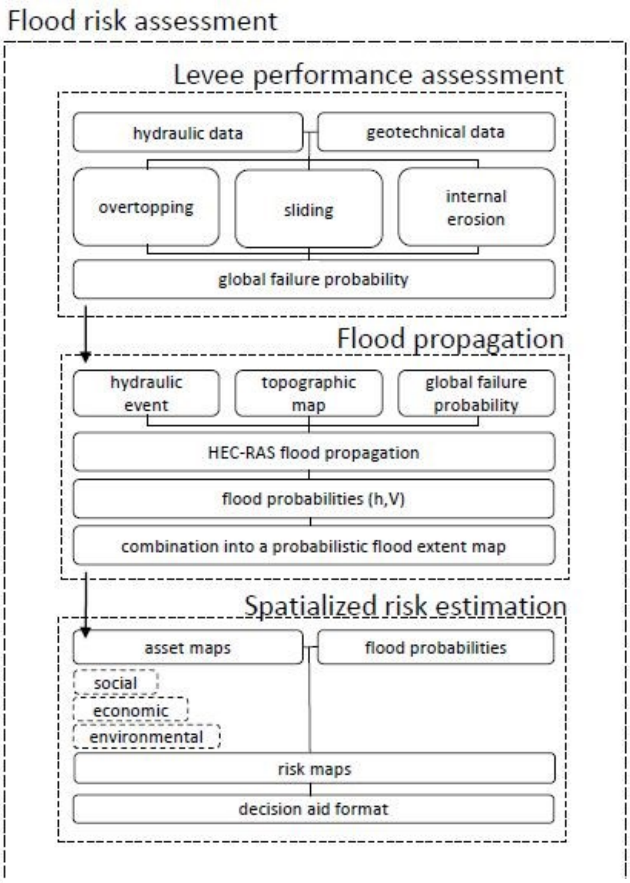


Figure 11: Flowchart illustrating the automated risk assessment process outlined in the PhD thesis.

Flood risk assessment is an intricate process requiring the involvement of several research fields: civil engineering, soil mechanics, hydraulics, hydrology, geomatics... Computation time and data acquisition are limits to a flood risk assessment. Relevant geotechnical data over an area of interest and up-to-date data are usually not available. At the beginning of a flood risk assessment, the following hypotheses must be answered: which risk(s) are of interest for the study, outline the relevant area to consider, decide which elements of the flood defense system should be considered and which approach to use: deterministic or probabilistic

In practice, flood risk assessments are usually done on a local scale, thus they do not take into account the impact of downstream or upstream modifications. Large-scale flood risk assessments were not included in this thesis project due to their inherent need for high simplification, therefore lowering the accuracy. Moreover, large-scale methods tend to require the availability of robust data, and to meet this requirement, a national institutionalized support is best, such as in the UK or in the Netherlands.

The main objective of the PhD is the automation of probabilistic flood risk assessment. The automation of this process should be reusable and include reducing as much as possible, the simulations and computing time, while preserving significant results for decision-making. Thus the PhD aims to provide a spatially consistent solution for local to intermediate-scale risk assessments and their subsequent temporal evolution.

The PhD is articulated around a full risk assessment:

- Estimate the levee performance with a probabilistic approach for 3 failure mechanisms (overtopping, sliding and internal erosion)
- Estimate the probability of flooding (height and velocity) over the urban area of interest during the hydrological event
- Provide risk maps of the area (social, economic and environmental) based on the probability of flooding and assets maps.

For the levee performance evaluation, a semi-probabilistic approach is intended using Monte-Carlo simulations. For flood propagations, a pre-existing software package will be used to determine water height and velocity during the flood event. This will be sampled for several return periods to provide global flood probabilities over the area. For risk estimation, asset maps will be added to the probabilistic flood map.

CLIMATE RESILIENT LEVEES

Towards CO_2 - neutral levees and environmental circularity

By Jan Baltissen & Marcel Bottema, NL

Recently published EU Guidelines (see web link below article) express the urgency of making the transition towards climate resilient infrastructure. The two aspects of climate policy are clearly reflected in this EU guideline: mitigation through CO_2 neutrality for building and reconstruction plans for infrastructure with planned life time beyond 2050, and adaptation to make sure that future climate is accounted for in the design and life cycle of infrastructure. The actual scope of the Guidelines will be determined by subsequent national legislation.

With regards to climate adaptation, flood defences are in the forefront since trends in flooding are a key consequence of climate change, both through sea level rise and increases in extreme precipitation and river discharges. On the other hand, environmental circularity and climate neutrality are fairly new and also challenging issues. The National Dutch Flood Protection Programme HWBP has recently developed a strategy to make sure that by 2023, sustainability is systematically integrated into levee reinforcement projects, in that way acting along the ambitions of the aforementioned EU Guideline. Some experiences with respect to their implementation are highlighted below.

In the Netherlands, about 1500 km of primary flood defences will probably need to be heightened or strengthened (or both) in order to meet the new safety standards that were implemented in law about 5 years ago. This amounts to nearly half of the total primary flood defence portfolio in The Netherlands. In order to meet the safety standards by 2050, a sustained investment of about 350 million Euro per year is required, as well as a systematic and programmatic approach.

The Dutch Flood Protection Programme HWBP is an alliance of the Dutch Water Boards and Rijkswaterstaat, and it plays a key role in supporting their endeavour to meet the safety standards by 2050. It does so by providing most of the funding, as well as technical assistance through guidelines, professional networks and reviews. At present, reinforcements have already started for about 600 km of primary flood defences, with support of HWBP. In the planning of HWBP, levee reinforcement will progress at a steady pace, with about 50 km of levee reinforcement being finished each year.

Climate resilience has played a role from the beginning because levee reinforcements are to be designed in such a way that levees and other flood defences structures still satisfy the safety standards at the end of their planned lifetime, even after accounting for the expected climate change. Yet the climate story does not end here, since there is a second challenge to be dealt with.

Levee reinforcement projects have a fairly long duration (typically 3 years) and a significant environmental impact. Their impact on landscape has been known and accounted for over several decades. The environmental impact of the transport and processing of soil and other materials (such as sheet piles, sheet walls, grouting, hard revetments) also gets more and more attention. By way of speaking, levee reinforcements boil down to a continuous activity of lorries and other ground-moving equipment, with their emissions of nitric oxides, CO_2 and fine particles.

As for the CO_2 emissions, it was estimated that the CO_2 emission of 1 km of levee reinforcement was on average 4500 tons. Hence the projected pace of 50 km/year of levee reinforcement will lead to a total CO_2 emission of 225000 tons/year. Even though this is just 0.13 % of the emissions of the full Dutch economy, it still represents roughly half of all the CO_2 emissions of the Water Boards.

For that reason, HWBP has aimed for a programmatic approach on sustainability and spatial quality, which became effective from 2020 onwards, and includes a yearly sustainability monitoring action (see web link). The approach aims at making the transition towards sustainable, climate-neutral and circular levee reinforcements. The latter is quite important, since transport makes up a significant fraction of all emissions. So instead of quarrying clay at remote locations, transporting it to the levee, and transporting the removed levee material to yet another remote location, solutions are sought to reduce soil transport, for example by linking levee reinforcements to nearby river restoration projects. Nature-inclusive solutions may in some cases also contribute towards making the sustainability transition.

HWBP has also stepped up its ambitions towards net-zero emissions, since the ambition of the Ministry of Infrastructure and Water Management is to make climate neutral (net-zero emission) infrastructure projects standard practice within 10 years, by 2030.

Meanwhile, several Water Boards have challenged the construction companies hired by them to use emission-free transport and ground-moving equipment. Although there remains a long way to go, the first steps have now been taken.

Still, a key challenge remains the availability of heavy ground-moving equipment which is emission free (electric). As yet, there is hardly any systematic production of such equipment, and certainly not by a sufficiently large amount of producers to allow for an equitable public procurement with reasonable contract conditions. Given the relatively remote location of many levee reinforcement projects, electrical recharging facilities for the equipment are also a significant challenge. Therefore, HWBP has chosen a dual approach of clearly and firmly communicating its ambition of net-zero emission by 2030 on one hand, and allowing for a gradual 9-year transition path towards that aim on the other hand. Time will tell whether construction and production companies will be able to fully meet that challenge.

Figure 12: Levee reinforcement with the aid of a new foreshore, located along parts of the Houtribdijk, a levee-like dam separating Lake IJssel and Lake Marken, and connecting the towns of Enkhuizen and Lelystad (Photo by Rijkswaterstaat)

WEBLINKS

From Marcel Bottema, NL

- New technical guidance on climate-proofing of infrastructure projects for the period 2021-2027, as published by the European Commission: https://ec.europa.eu/regional_policy/en/newsroom/news/2021/07/29-07-2021-commission-adopts-new-guidance-on-how-to-climate-proof-future-infrastructure-projects
- (see also the article about CO_2 neutral levees)
- Meuse Floods: A climate attribution study, see: worldweatherattribution.org
- Some first web links related to evaluations of the Eifel / Ardennes / Meuse floods of July 2021:
  - NL: Report of fact finding mission (in Dutch with English Summary): enwinfo.nl
  - Belgium/Wallonie: Report of fact finding mission in the Ardennes region in Belgium (in French): wallonie.be. Report (PDF)