Flood protection in a urban environment: innovations and new tendencies (techniques, knowledge and management)

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WROCLAW

Threats posed by an excess of water

= flooding (river floods, sea storms, debris flows in mountains)

Importance of flood risk

Like in many countries, in France, flood risk is the first natural risk considering the amount of damage it causes, the number of cities it threatens, the extent of the floodable zones (27 000 km²) and the populations living in these areas (5.1 millions of people)

The Rhône river in Fourques during the 2003 flood
Photo Paul Royet

Threats posed by an excess of water

= flooding (river floods, sea storms, debris flows in mountains)

Consequences

Floods have negative impact on:

- populations (death, sickness, …)
- buildings,
- natural or undeveloped areas,
- agricultural areas / activity areas /indistrial areas,
- transport networks / communication networks,
- public and sensitive buildings (education, health, prisons, ...),
- infrastructures (gas, water supply, sewers, water treatment plant ...)
- ...

Vulnerability can be measured in terms of:

- human consequences (death, sickness, …)
- social consequences
- financial and economic consequences
- environmental consequences
- consequences on heritage
- …

Wroclaw, July 1997

Flood protection

And flood prevention

History

People have dealt with flood risk since a long time, probably forever, but in different ways:

- For many centuries people built cities out of reach of floods (natural or artificial elevated areas)
- Levees have been built since the Middle ages (for agriculture first)
- Levees have been raised after every major flood
- Growth of cities resulted in building in more flood prone areas
- Until recent decades there were generally no national integrated approach to flood risk management and/or to safety of existing flood defences
- Recent catastrophic events in the lest decades in the developed countries have changed this.

Now: flood risk management flood and risk prevention

Flood defences (dams, levees) are a PART of it

Flood protection

And flood prevention

Structures

Flood protection relies on two main different types of structures : dams / levees, with associated structures or components (canals, safety spillways, …)

Structures work together inside flood protection systems

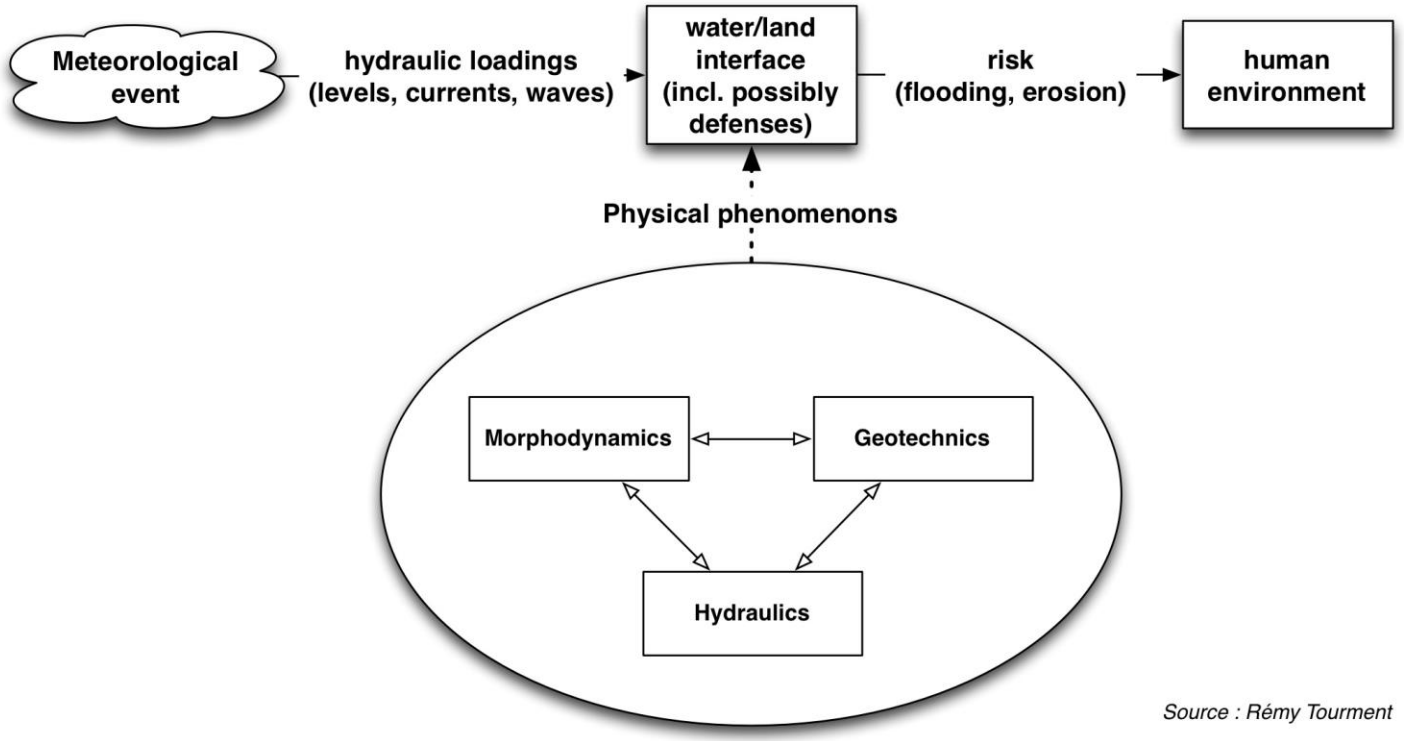
These structures have limits in their function :

- Dams limit the flow until they are full
- Levees prevent flooding until a certain level is reached
- They have to be safe (not to breach): their safety level should be a lot higher than their protection level

Flood protection

Morphodynamics

The importance of morphological change in relation to floods and flood protection structures has to be recognized and integrated in the design and management processes



Source : Rémy Tourment

Flood protection

Innovation

Innovation and new tendencies for flood protection

In terms of:

- Policy, governance and management
- Knowledge
- Techniques regarding flood defences structures

Based on national (France) and international cooperation perspectives

Policy, governance, management (1/2)

Challenges, recent evolutions and current tendencies

Policy

- European Flood directive (not directly/explicitly related to structures)
- National initiatives to improve water structures safety (levees and dams – all)
  - Inventory
  - Governance
  - Funding
  - Regulations (organisation, technical requirements)

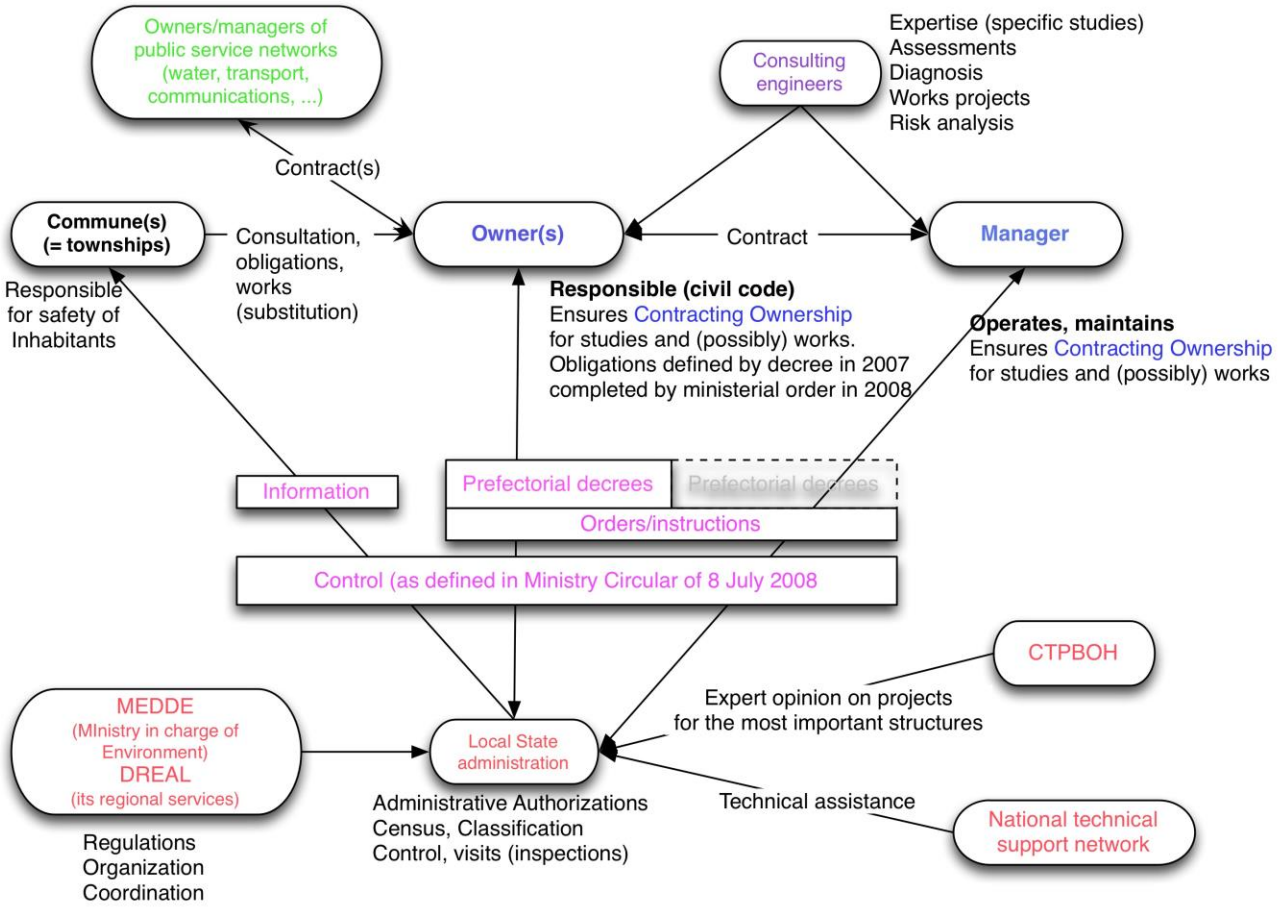
Governance

Organisation needs to be clear on the roles and responsibilities of the different actors:

- regulation, control,
- flood prevention,
- flood protection systems (deciding, building), management of structures,
- emergency management

Policy, governance, management (1b/2)

Challenges, recent evolutions and current tendencies



Actors and relations in the field of levees in France

Policy, governance, management (2/2)

Challenges, recent evolutions and current tendencies

Management

Building flood defences is not enough. They need to be properly maintained in the **long term** to be able to perform their function. Lessons learned from recent events have clearly shown this. Management includes :

- Knowledge of system and structures
- Inspections and maintenance in normal and flood times
- Eventually, deciding modifications of systems

Knowledge of systems :

- data management (use of GIS),
- knowledge management,
- investigation methods (lidar, use of geophysics)
- monitoring (optic fiber, smart sensors, …)
- assessment methods

Risk based management decisions (risk analysis)

Risk communication: protection level, protected areas, residual flood risk

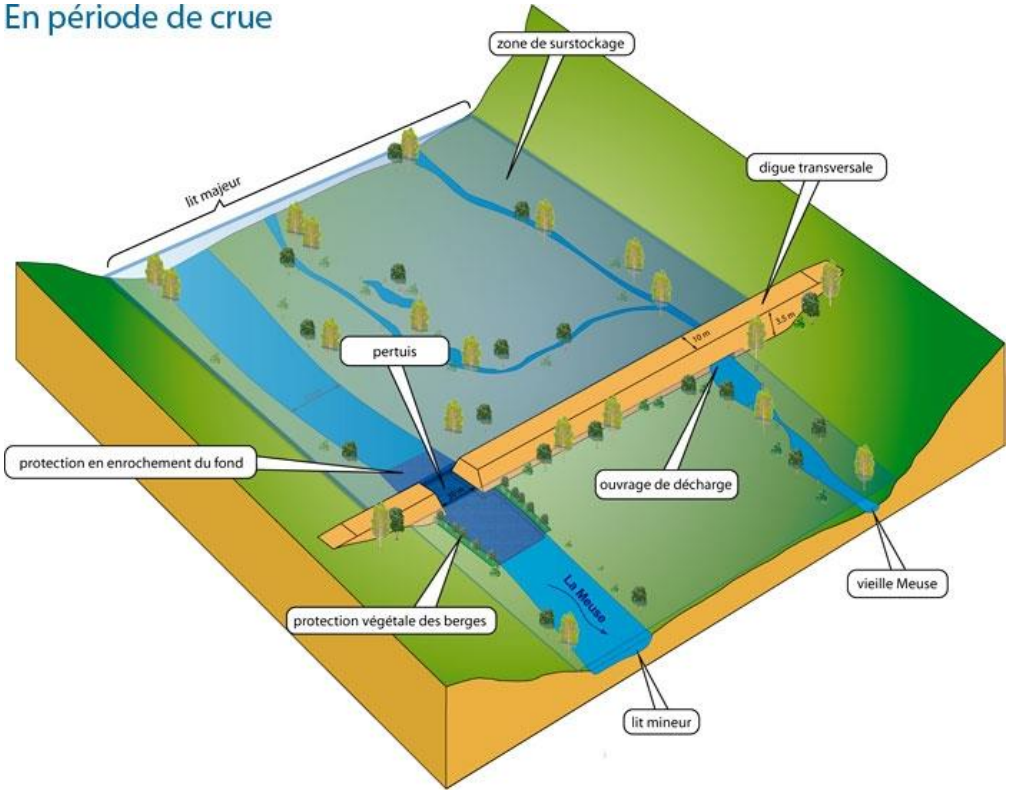
Design of defence systems and structures

"New" concepts

Dynamic flood retention

Retaining water upstream using new techniques (different from "classic" dams):

- Forests and other land uses slowing water
- Use secondary river beds
- Specific "dams" design



Design of defence systems and structures

"New" concepts

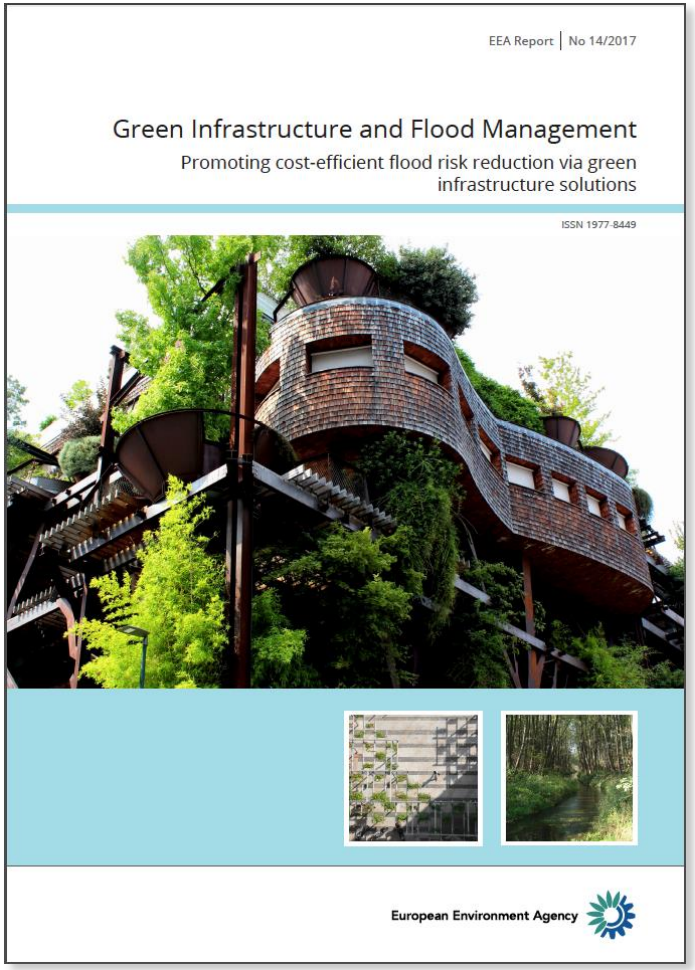
Building with nature

Including natural elements in levee systems :

- Wet land, dunes, forests, beaches, …

Designing "soft" dikes

Removing levees far from the minor river bed (or the sea), re-meandering, …



Design of defence systems and structures

"New" concepts

Multifunctional dikes

Levees designed and managed not only for flood defence but also for other urban functions:

- Recreation (parks), building (shopping mall), roads (car or bike), vehicle parking, …

Dakpark Rotterdam (photo credits: http://www.rotterdamarchitectuurprijs.nl/dakpark-1.html)

Design of defence systems and structures

"New" concepts

Lowering vulnerability and increasing resiliency

of the protected areas : buildings, infrastructure, society, …

Figure 2.4: Office building on stilts, Amsterdam (NL) (Groene.nl, 2011); Figure 2.5: Buildings on stilts, Trondheim (NO) (Blogspot.com, 2011)

Levee spillways (or overtopping resistant segments)

Avoid breaches when protection level is exceeded

Use of Failure modes analysis in structures design

Allows to improve performance to rare mechanisms or complex scenarios

Use of risk analysis in systems design

Allows to select "best" solution in terms of risk reduction. Associated to Multi-criteria analysis, allows to take into account other aspects (environment, costs, other uses, …)

Techniques

(Some) recently developed techniques

Structures

- cemented materials (more resistant to internal and external erosion)
- soil mixing (improve sealing of existing levees)
- temporary defences (raises level of protection)
- geosynthetics and geocomposites (many functions of geostructures)
- fusegates

Investigation and monitoring

- geophysics
- optic fiber for monitoring
- Lidar
- use of drones

Management

- data management

Techniques

temporary defences

Knowledge

(Some) recent outcomes and current ongoing research

Geomechanics

The best know failure mechanism for earth structures is slope sliding (shear stress), but for levees this is a minor factor compared to other mechanisms. Also, more rare mechanisms sometimes are involved in complex scenarios. Research was needed and is making progress on:

- Internal erosion
- External erosion
- Liquefaction
- Fissuration
- Durability

Geotechnics

Assessment methods

Risk methods

Risk analysis

Functional and failure mode analysis

Levee failure on Naruse river due to liquéfaction (2011) inJapan (Photo MLIT, Ministry of Land, Infrastructure, Transport and Tourism, Japan)

Research needs to be closely linked to stakeholders

Knowledge

Internal erosion: Hole Erosion Test

- Loi d'érosion

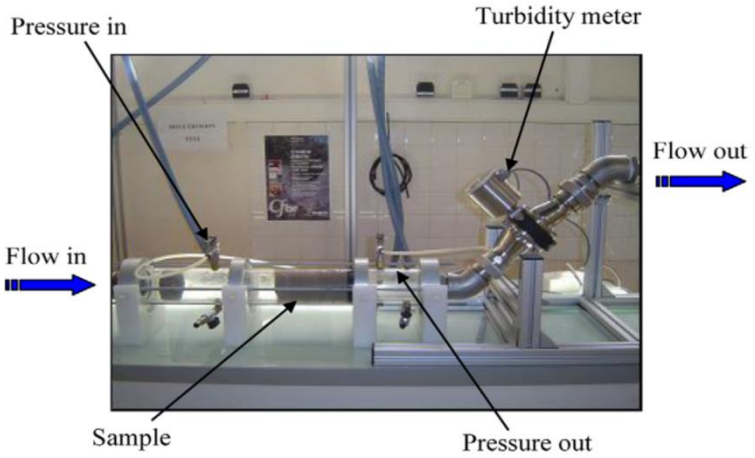
$$\varepsilon = C_e\,(\tau - \tau_c)$$

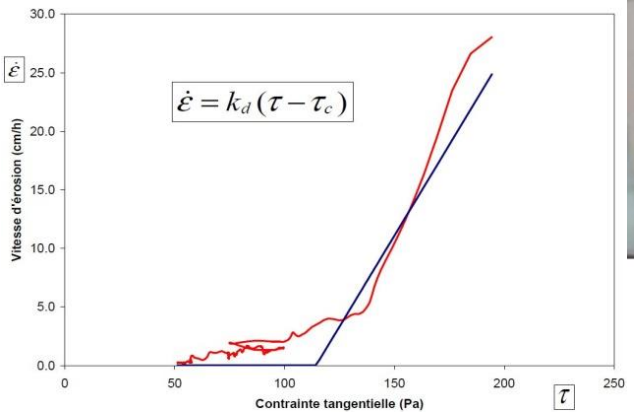
τ_c : Contrainte critique du sol

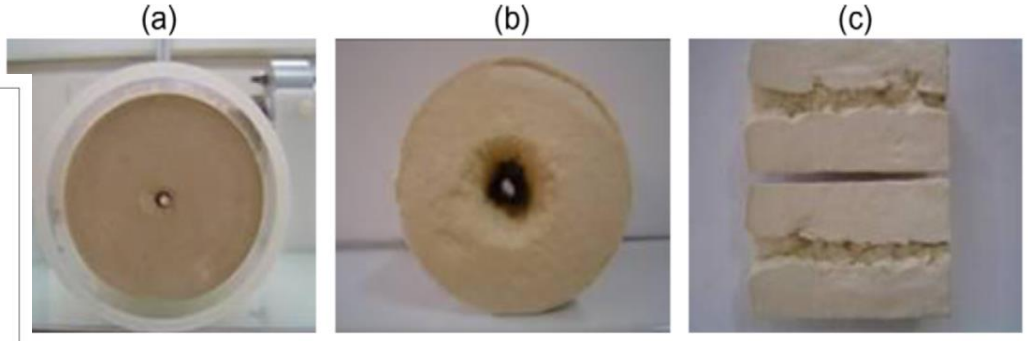
- À partir de laquelle il y a érosion

C_e : Coefficient d'érosion

- Caractérisant la vitesse d'érosion

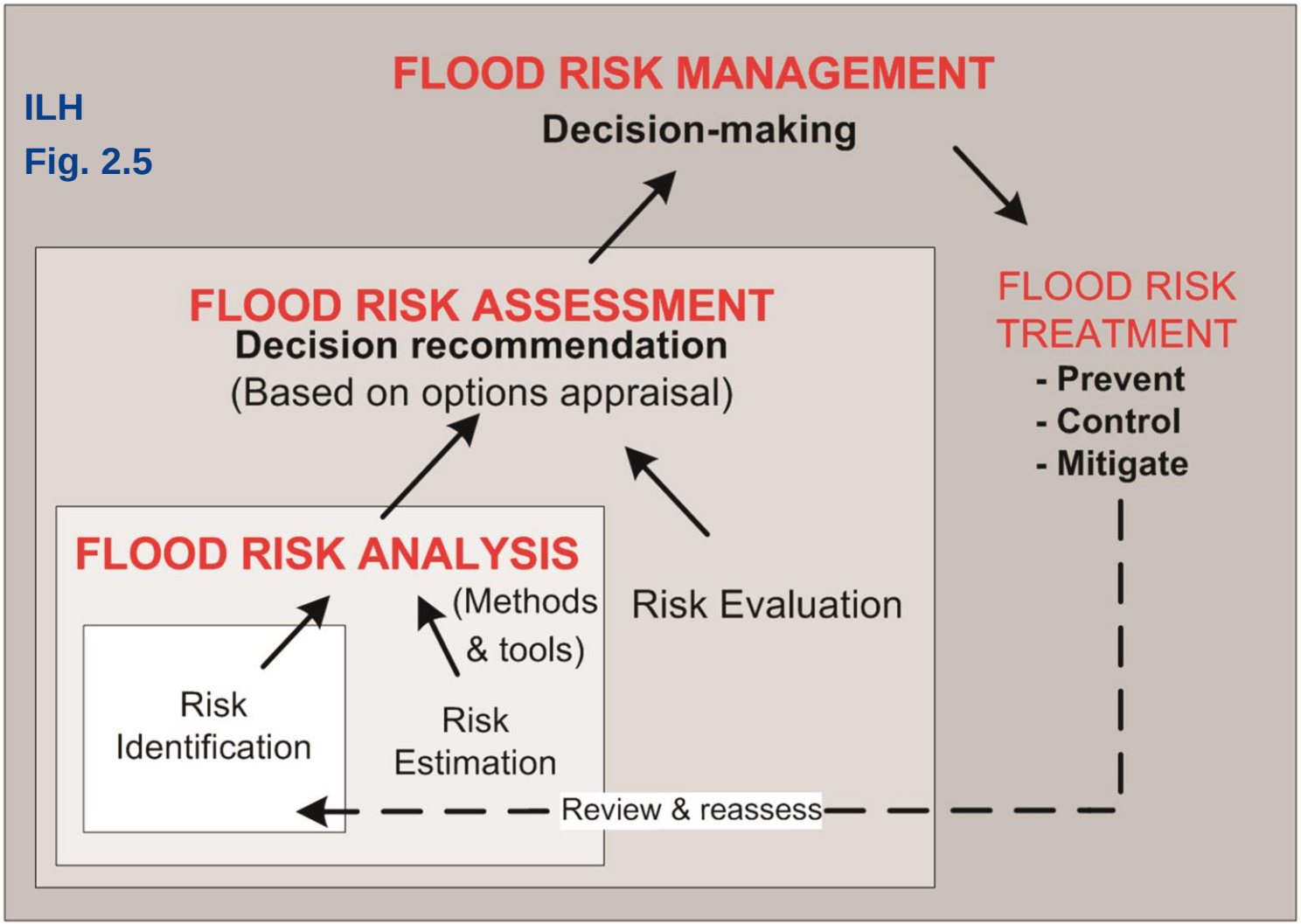






Knowledge

Risk analysis of levee systems and failure mode analysis



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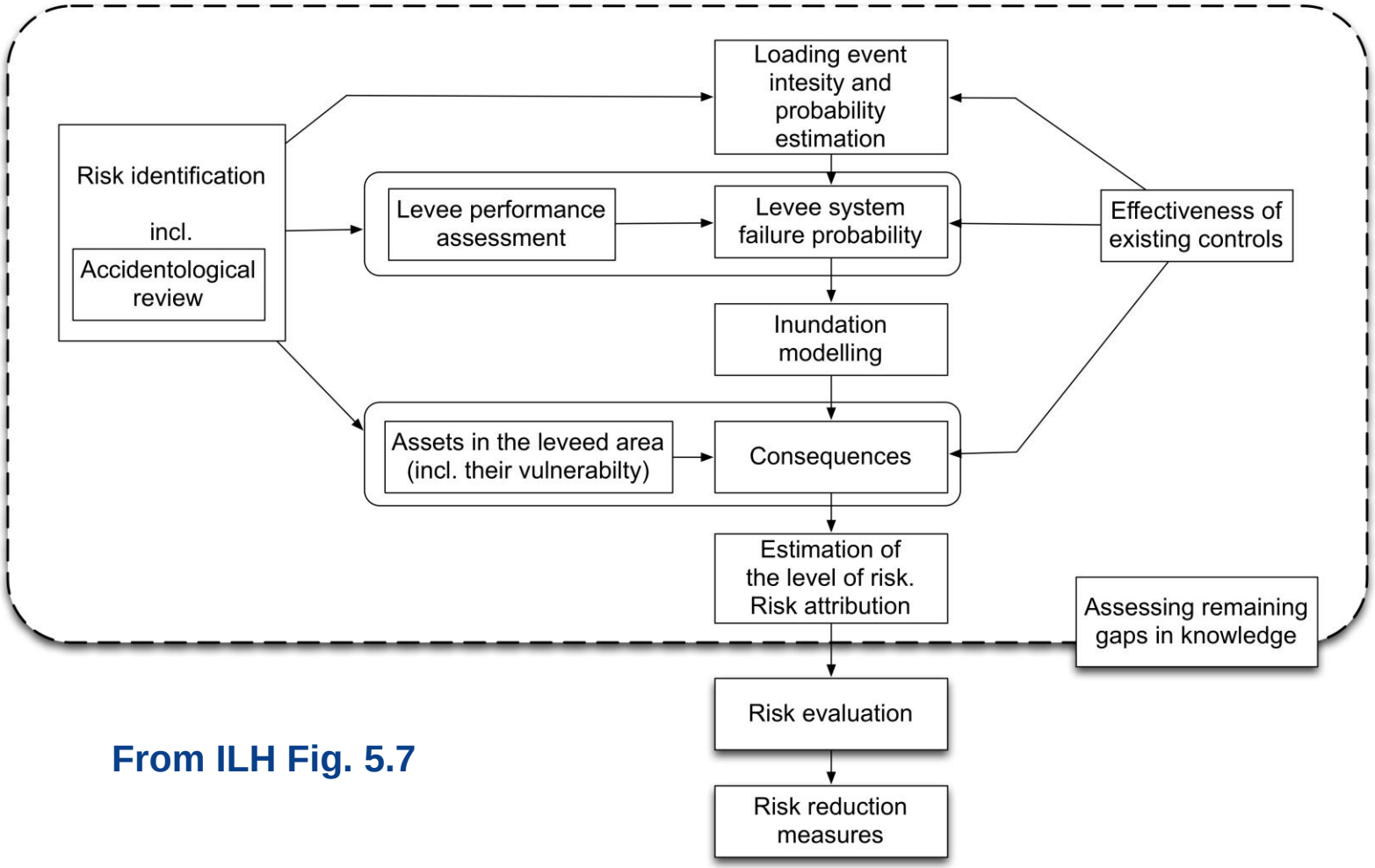
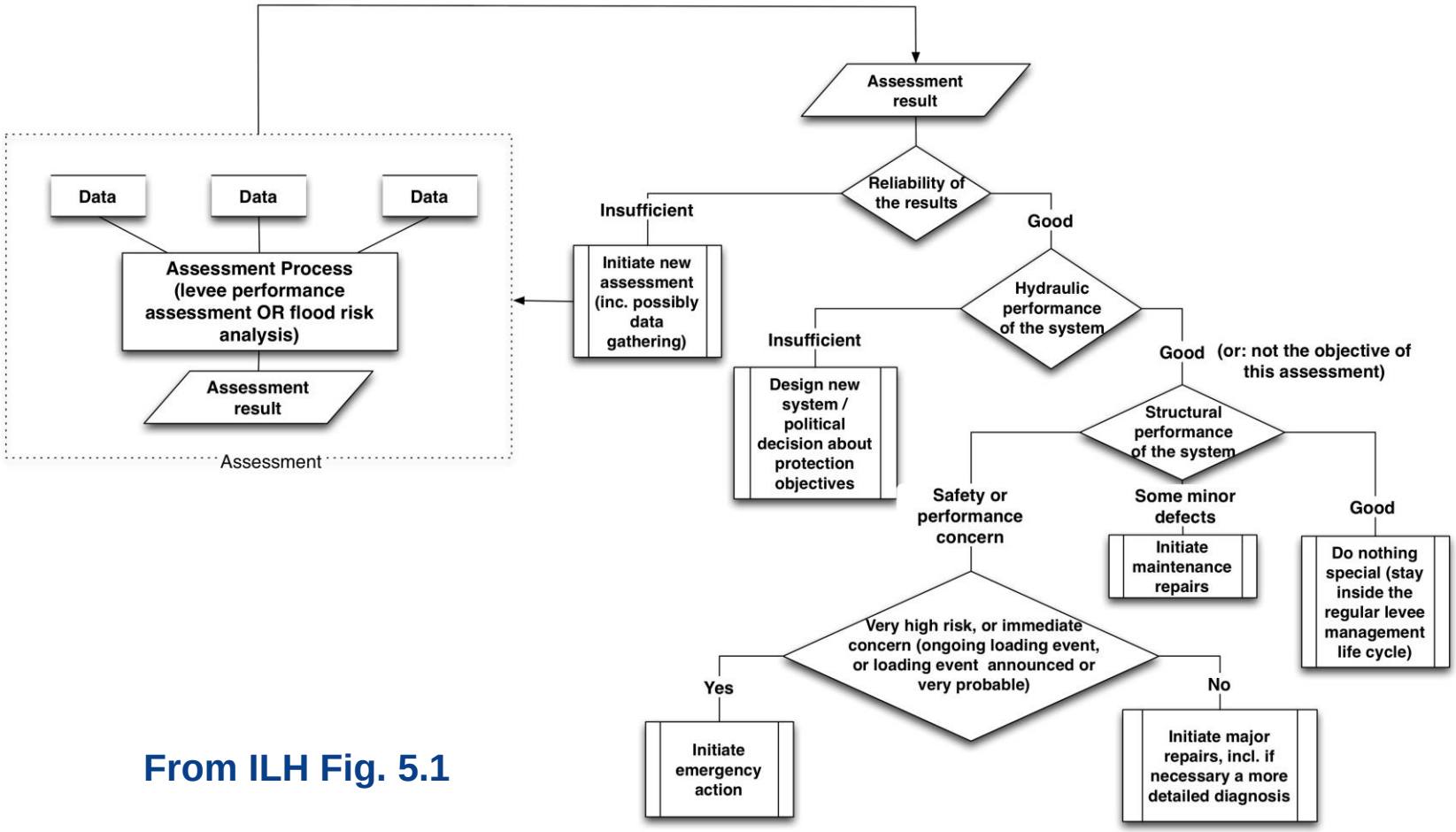


From ILH Fig. 5.7

Knowledge

Risk analysis of levee systems and failure mode analysis

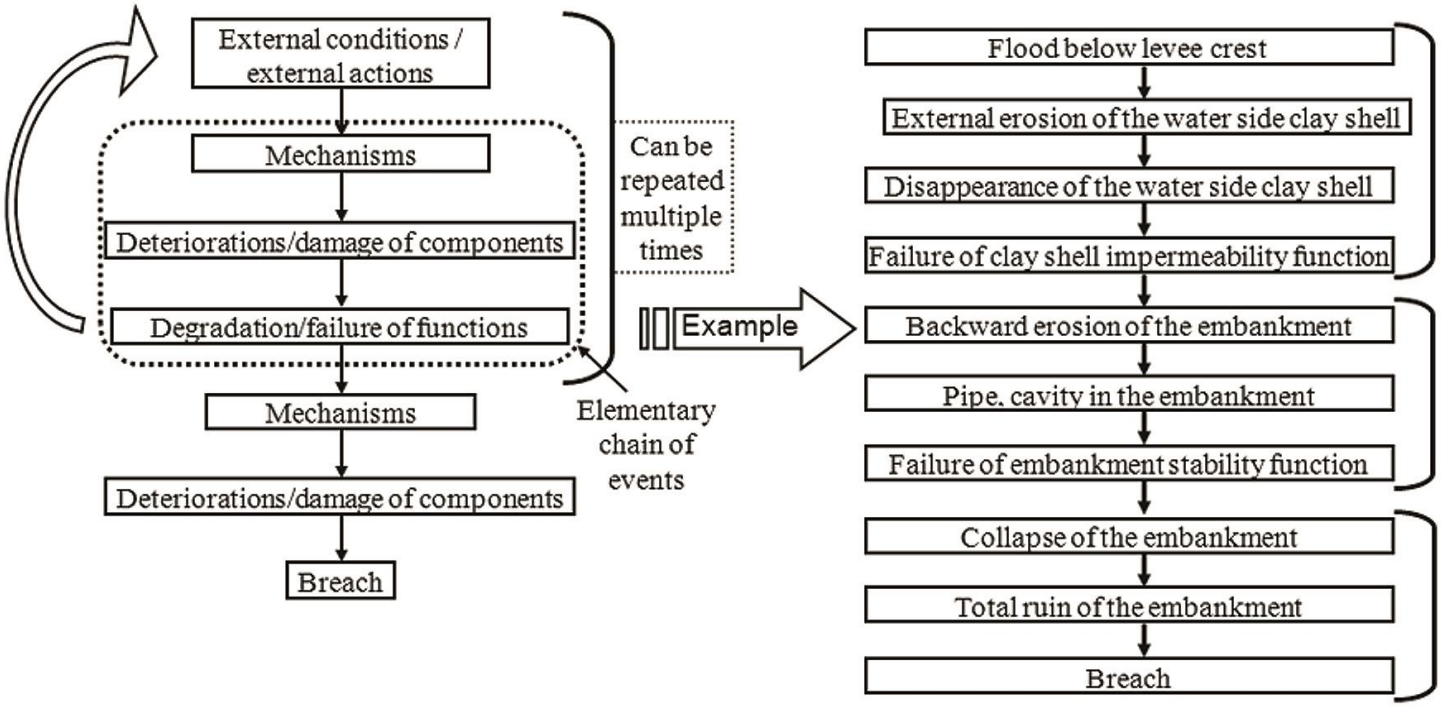


From ILH Fig. 5.1

Knowledge

Risk analysis of levee systems and failure mode analysis

- Structural failure scenarios



ILH Fig. 3.166

Knowledge

Sharing knowledge

Internationally

Exchange of knowledge allows to improve individual knowledge (access others' progress, validate own analyses and methods) but also to make progress together.

- ILH https://www.ciria.org/ciria/Resources/Free_publications/I_L_H/ILH_resources.aspx
- FRM CoP and FLOODrisk conferences http://floodrisk2016.net
- ISSMGE TC 201 https://www.issmge.org/committees/technical-committees/applications/dykes-and-levees-
- IAHR

Levees and dams community

An object based community (not discipline oriented)

Same disciplines used differently

Same engineering companies

A lot in common but a big effort to reach the goal:

- EUCOLD LFD WG https://lfd-eurcold.irstea.fr
- Question 103 in ICOLD Vienna 2018 congress
- ICOLD LE TC http://www.icold-cigb.org/GB/icold/technical_committees.asp

Remaining major challenges

Managing floods and droughts consistently together:
- is this really possible ?
- can structures help ?

Climate change: how can we manage to maintain a similar level of flood risk (or even improve it) with more frequent and extreme events ? Considering remaining uncertainties on climate change itself.
Climate change has influence on both the hydraulic performance of protection systems, but also on the structural performance (risk of damage / breach).

Managing / maintaining flood defences in the long term: it's rather easy to get funds after a catastrophic event, but what happens after a few decades without any event? Multifunctional defences can be a solution, but the risk of "forgetting" the flood protection function still remains.

Professionalizing the jobs related to levee and flood defence management

Conclusion

Flood risk management is a complex issue – we have to deal with multiple aspects, with a lot of interdependency

Management (and design) of protection systems need to consider different scales and also different functions

Cooperation is needed (and starting) between:

- Stakeholders
- Countries
- Disciplines
- Different scales of management / decision making
- Researchers and practitioners
- Engineers and (politic) decision makers

Some references (1/2)

- **Van Der Meij, R.**, **Van Den Ham, G.A.**, **Morris, M.W.**, **Lhomme, J.**, **Tourment, R.**, **Maurel, P.** - 2012. Combining different data sources for assessment of urban flood defences. 2nd European conference on Flood Risk Management FLOODrisk2012, Rotterdam, NLD, 19-23 November 2012 19/11/2012-23/11/2012, Rotterdam, NLD. Comprehensive Flood Risk Management. Research for policy and practice. p. 351-357
- **Van Der Meij, R.**, **Van Den Ham, G.A.**, **Morris, M.W.**, **Lhomme, J.**, **Tourment, R.**, **Maurel, P.** - 2012. Examples of data combining techniques for assessment of urban flood defences. 2nd European conference on Flood Risk Management FLOODrisk2012, Rotterdam, NLD, 19-23 November 2012 19/11/2012-23/11/2012, Rotterdam, NLD. Comprehensive Flood Risk Management. Research for policy and practice. p. 399-405
- **Oderker, M.** - Design concepts of multifunctional flood defence structures – FloodProBE Report n° WP04-01-13-02, 60p. http://www.floodprobe.eu/partner/assets/documents/D4.2ConceptsforMFDfinal.pdf
- **USACE, MEDDE, CIRIA** - 2013. The International Levee Handbook. *Igigabel, M., Pohl, R., Royet, P., Sharp, M., Simm, J., Tourment, R., Van Hemert, H., Wallis, M. (ed.)*, CIRIA, Londres, 1349 p.
- **Tourment, R.**, **Wallis, M.**, **Beullac, B.**, **Kortenhaus, A.**, **Schaaf, D.M.**, **Schelfhout, H.** - 2014. The risk analysis of levee systems. 3rd IAHR Europe Congress 14/04/2014-16/04/2014, Porto, PRT. 3rd IAHR Europe Congress, Book of Proceedings 2014. 13 p.

Some references (2/2)

- **Tourment, R.**, **Beullac, B.**, **Degoutte, G.**, **Patouillard, S.**, **Maurin, J.** - 2016. Levees, Diversion Canals or Flood Expansion Areas?. 3rd European Conference on Flood Risk Management FLOODrisk 2016 17/10/2016-21/10/2016, Lyon, FRA. E3S Web Conf. Volume 7, 2016. 3rd European Conference on Flood Risk Management (FLOODrisk 2016). 7 p.
- **Tourment, R.**, **Beullac, B.**, **de Leeuw, A.**, **Diermanse, F.**, **Gouldby, B.**, **Wallis, M.** - 2016. The risk analysis of levee systems: a comparison of international best practices. 3rd European Conference on Flood Risk Management FLOODrisk 2016 17/10/2016-21/10/2016, Lyon, FRA. E3S Web Conf. Volume 7, 2016. 3rd European Conference on Flood Risk Management (FLOODrisk 2016). 10 p.
- **Tourment, R.**, **Beullac, B.**, **Poulain, D.** - 2017. Structures for flood defense and management. *Floods - Edited by freddy Vinet, Volume 1- Risk Knowledge*, *Vinet, F. (ed.)*, ISTE Press - Elsevier, London + Oxford, GBR, p. 193-208
- **Tourment, R.**, **Beullac, B.**, **Poulain, D.** - 2017. Management and safety of flood defense systems. *Floods - Edited by freddy Vinet, Volume 2 - Risk Management*, *Vinet, F. (ed.)*, ISTE Press - Elsevier, London + Oxford, GBR, p. 31-44
- **European Environment Agency** – 2017. Green Infrastructure and Flood Management. EEA Report N° 14/2017 - ISSN 1977-8449 – 156 p.
- **Tourment, R.** - 2018. General report of Question 103 "Small dams and levees". In "Twenty-Sixth International Congress on Large Dams / Vingt-Sixième Congrès International des Grands Barrages: 4th - 6th July 2018, Vienna, Austria" CRC Press. 96 p.