GLOBAL CENTER ON ADAPTATION

Knowledge Exchange on Building an Adaptive Coastal City

Climate Risk Assessments to Improve Climate Resilience in Coastal City

11th January 2024, 12:00 CET, Virtual

Table

- Rotterdam Climate Resilience (Arnoud Molenaar)
- Flood risk assessment methods and tools with case studies of Vlissingen, NL and Shanghai, CN (Ke Qian)
- NbS for resilient coastal development (Pelle Bågesun)
- Climate adaptation in Copenhagen (Lykke Leonardsen)

Rotterdam Climate Resilient City

THE STRATEGY

THE IMPLEMENTATION

THE NETWORK

Arnoud Molenaar

Chief Resilience Officer, City of Rotterdam

@ResilientRdam

www.resilientrotterdam.nl

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RESILIENT ROTTERDAM

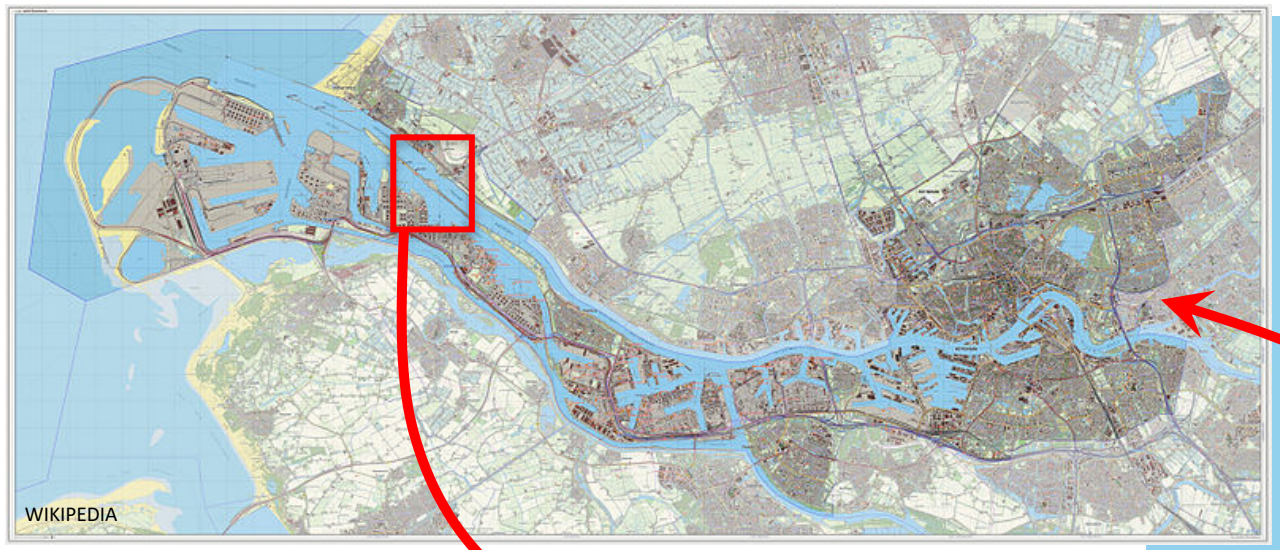
Rotterdam Resilient Port City

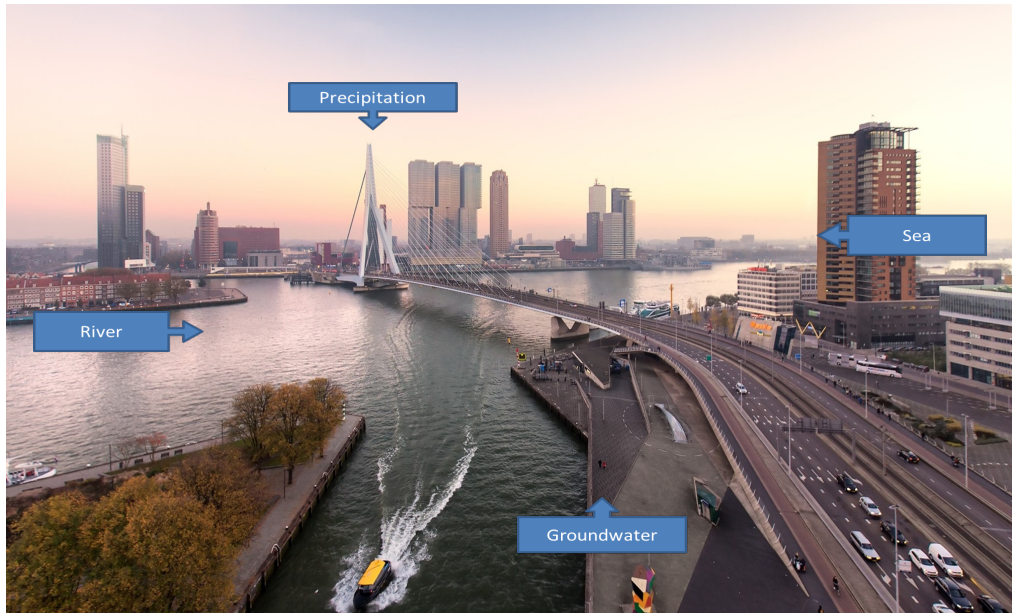
City

Area :	320 km2
Inhabitants:	650.000
Nationalities:	175
Municipal Budget:	4 billion Euro's

Port

Area:	105 km2 (50 km2 commercial sites)
Length of port area:	45 km.
Direct employment:	over 70,000 jobs




Precipitation
Sea
River
Groundwater


HANDEL


DIMENSION


ONGOING URBANIZATION
SHOW TIME
f/otografie

Effects related to Climate Change

Flooding Noordereiland

Water quality

Excessive rain fall

Levee breakthrough (drought)

Inundated cellars

Heat waves

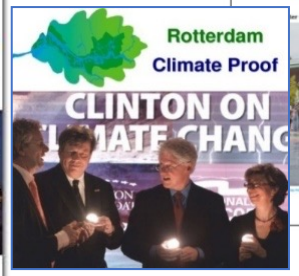
TIMELINE ROTTERDAMS' TRANSITION-PROCESS TOWARDS A (CLIMATE) RESILIENT DELTA CITY

2001

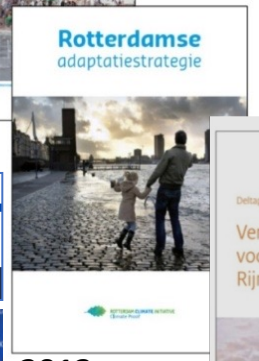
2005

2007

2008



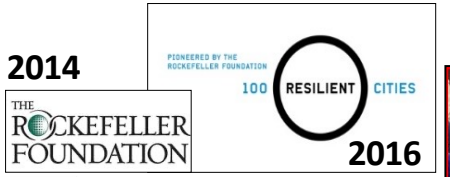
2010



2013

2014

2014



2016

2022

Resilient Delta

RESILIENT CITIES NETWORK

2017

2018

2019

2021

2022

2023

Water: ----------

+ Spatial Planning: ----------

+ Climate Change: ----------

+ Resilience (wide spectrum): ----------

ROTTERDAM APPROACH: GOVERNANCE

2007

GOVERNMENTAL ROTTERDAM WATER PLATFORM

Alliantie Waterkracht
Regio Rotterdam – Capelle aan den IJssel
Werken aan waterbeheer van morgen
2023

RISK ASSESSMENT
- IDENTIY CLIMATE RISKS
- AND URBAN HOTSPOTS

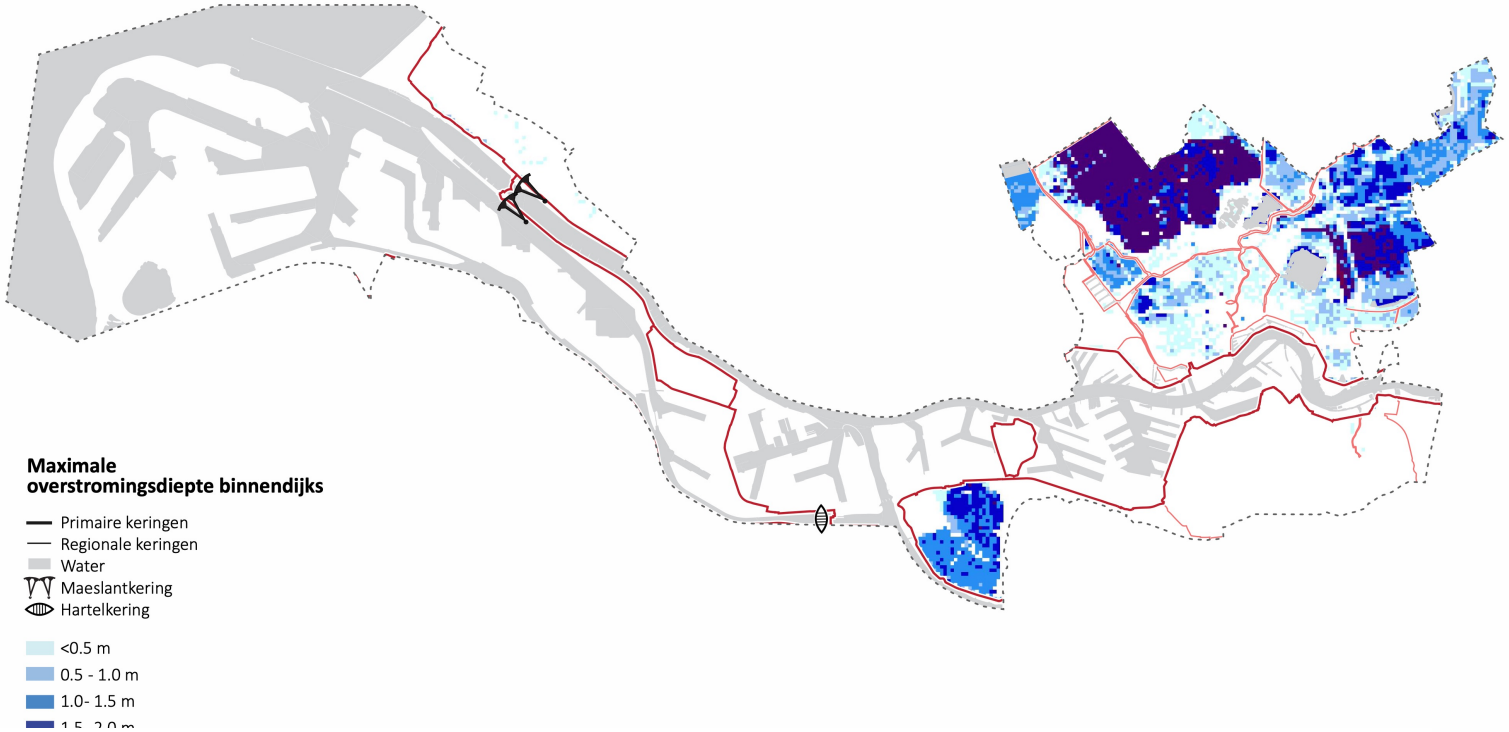
VISION
- HOLISTIC FUTURE PERSPECTIVE (LT)
- WATER AS VALUE
- LIVING WITH WATER

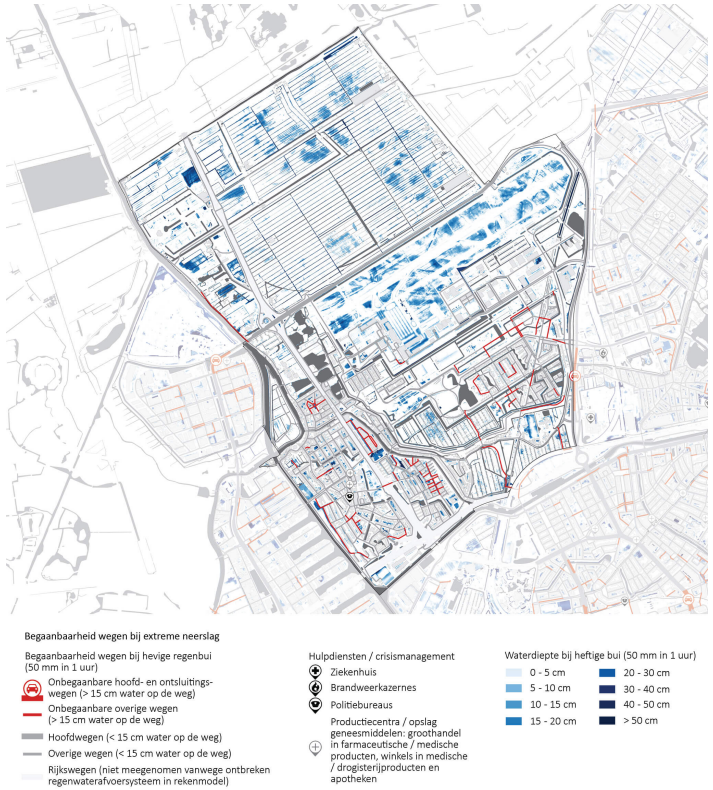
STRATEGY
- INTEGRATED: ALL ASPECTS
- CITY + DISTRICTS
- ANALYSES BASED

ACTIONPLAN
- SHORT TERM
- MONITORING
- NO REGRET

IMPLEMENTATION
- NO REGRET
- PILOTS
- DISTRICT LEVEL
- UPSCALING

STRUCTURED AND PROGRAMMATIC APPROACH – DATA DRIVEN





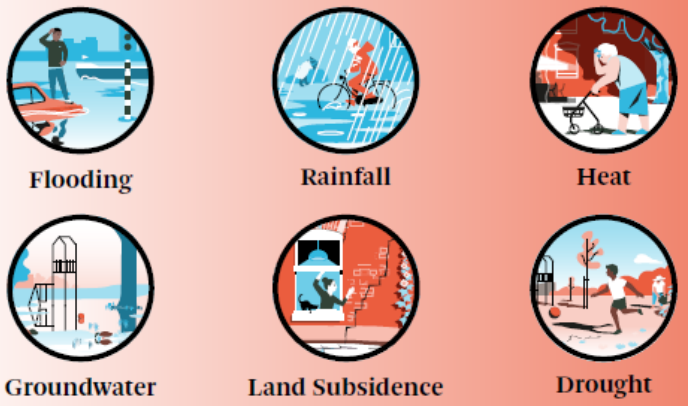
VULNERABILITY AND OPPORTUNITY CITY MAPS

DISTRICT MAPS (39)
VARIABLES (25)

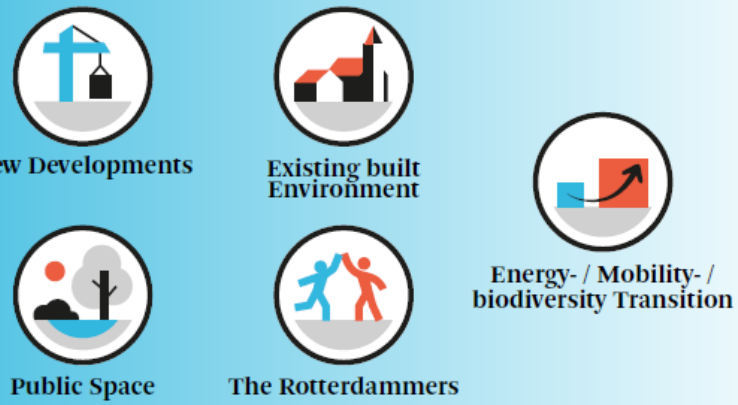
www.rotterdamsweerwoord.nl/professionals

PROGRAM FRAMEWORK ROTTERDAM WEATHERWISE 2030

1 CLIMATE ADAPTATION CHALLENGES



2 IMPLEMENTATION OPPORTUNITIES



ASSESSMENT FRAMEWORK

4 WEATHERWISE PRIORITIES 2030

3 TOOLKIT MEASURES

260 different measures

Implementation agenda 2022 - 2026

Implementation agenda 2026 - 2030

MULTI BENEFIT SOLUTIONS

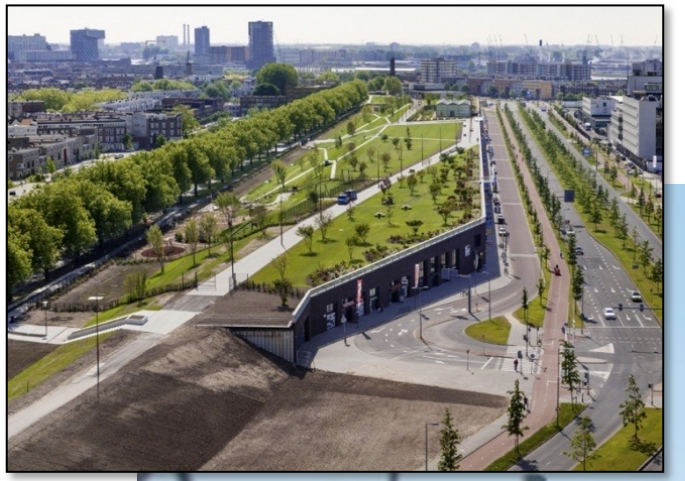
WATER SQUARE BENTHEMPLEIN…

WATER SQUARE BENTHEMPLEIN…

RESILIENT ROTTERDAM

… CLIMATE RESILIENCE BY DESIGN…

Green Roofs Program: community involvement



… SEA LEVEL RISE - CLIMATE RESILIENCE BY DESIGN…

BUILDING WITH NATURE: TIDAL PARKS

Huidige situatie

Current

Toekomstige situatie

Future

1: NEW ECO-HABITATS
2: REUSE OF SEDIMENTS
3: WAVE REDUCTION
4: BETTER WATER QUALITY
5: EDUCATION, LEISURE AND SOCIAL COHESION

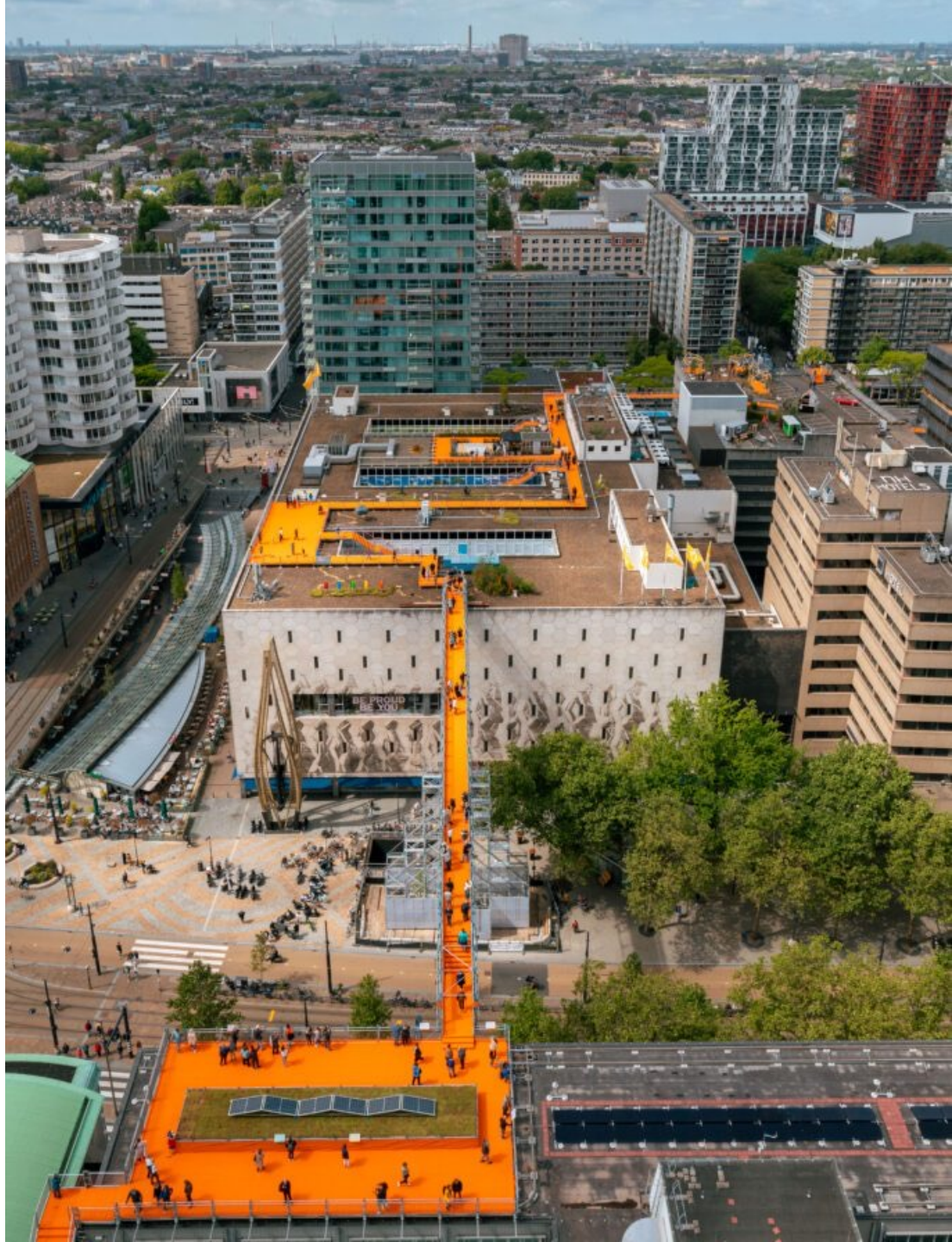
FLOATING URBAN DEVELOPMENT

EXAMPLES OF CLIMATE RESILIENCE BY DESIGN

WATER AS LEVERAGE

MULTI BENEFIT SOLUTIONS

MULTI-FUNCTIONAL ROOFTOP LANDSCAPE



COVID: Resilient Recovery! The BIG7: Rijnhaven

Artist Impression: Barcode architects

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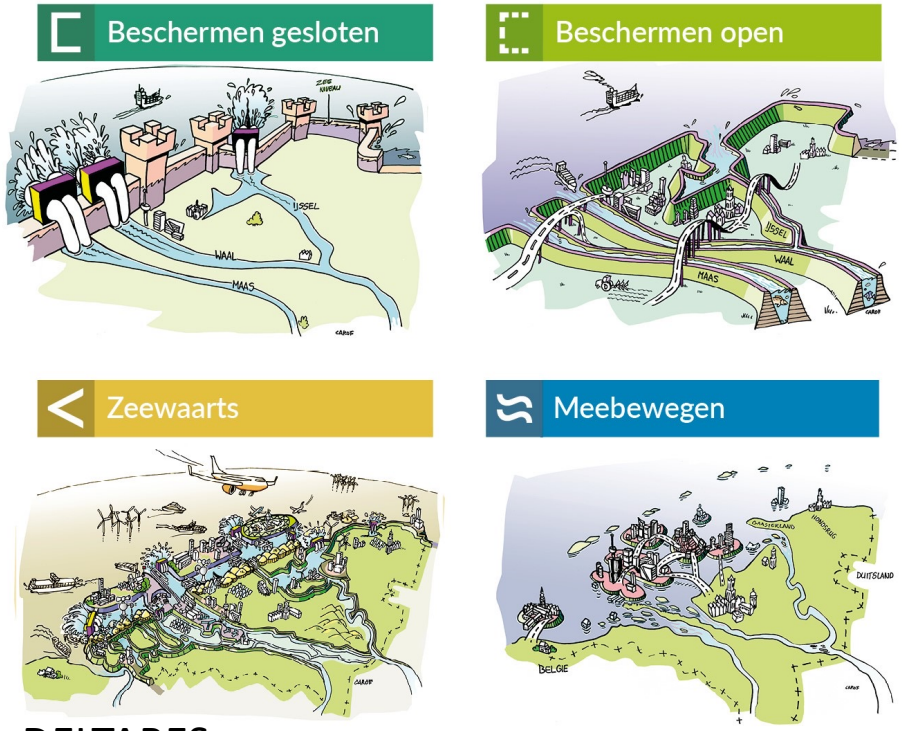
ReUse: Hofbogen (BIG7project)

DESIGN COMPETITIONS + FUTURE SCENARIOS



DELTARES

SOURCE:
H+N+S
EO-WIJERS
COMPETITION

… TAKING INTO ACOUNT >3M SEA LEVEL RISE
… ABOUT RETHINKING THE DELTA

AFRICA

Accra, Ghana
Addis Ababa, Ethiopia
Cape Town, South Africa
Dakar, Senegal
Durban, South Africa
Kigali, Rwanda
Lagos, Nigeria
Luxor, Egypt
Nairobi, Kenya
Paynesville, Liberia

EUROPE AND THE MIDDLE EAST

Amman, Jordan
Athens, Greece
Barcelona, Spain
Belfast, U.K.
Belgrade, Serbia
Bristol, U.K.
Byblos, Lebanon
Glasgow, U.K.
Greater Manchester, U.K.
Lisbon, Portugal
London, U.K.
Milan, Italy
Paris, France
Ramallah, Palestine
Rome, Italy
Rotterdam, The Netherlands
Tbilisi, Georgia
Tel Aviv-Yafo, Israel
The Hague, The Netherlands
Thessaloniki, Greece
Vejle, Denmark

ASIA PACIFIC

Bangkok, Thailand
Can Tho, Vietnam
Chennai, India
Christchurch, New Zealand
Da Nang, Vietnam
Deyang, China
Huangshi, China
Jakarta, Indonesia
Kyoto, Japan
Mandalay, Myanmar
Melaka, Malaysia
Melbourne, Australia
Pune, India
Semarang, Indonesia
Seoul, South Korea
Singapore
Surat, India
Sydney, Australia
Toyama, Japan
Wellington, New Zealand

LATIN AMERICA AND THE CARIBBEAN

Buenos Aires, Argentina
Cali, Colombia
Colima, Mexico
Guadalajara, Mexico
Ciudad Juarez, Mexico
Medellin, Colombia
Mexico City, Mexico
Monterrey, Mexico
Montevideo, Uruguay
Panama City, Panama
Porto Alegre, Brazil
Quito, Ecuador
Rio de Janeiro, Brazil
Salvador, Brazil
San Juan, Puerto Rico
Santa Fe, Argentina
Santiago Metropolitan Area, Chile
Santiago de los Caballeros, Dominican Republic

NORTH AMERICA

Atlanta, U.S.
Berkeley, U.S.
Boston, U.S.
Boulder, U.S.
Calgary, Canada
Chicago, U.S.
Dallas, U.S.
El Paso, U.S.
Greater Miami & the Beaches, U.S.
Honolulu, U.S.
Houston, U.S.
Los Angeles, U.S.
Louisville, U.S.
Minneapolis, U.S.
Montreal, Canada
Nashville, U.S.
New Orleans, U.S.
New York, U.S.
Norfolk, U.S.
Oakland, U.S.
Pittsburgh, U.S.
San Francisco, U.S.
Seattle, U.S.
St. Louis, U.S.
Toronto, Canada
Tulsa, U.S.
Vancouver, Canada
Washington, D.C.

Resilient Cities Network

A new global initiative

INTEGRATED/HOLISTIC APPROACH NEEDED!

DATA DRIVEN

ON ALL LEVELS WE HAVE TO BRAKE DOWN SILO'S

CREATE OWNERSHIP AMONGST KEY STAKEHOLDERS

BASED ON ACTIVE PARTICIPATION OF RESIDENTS

MULTI BENEFIT SOLUTIONS ARE NEEDED

COLLABORATE EN EXCHANGE WITH OTHER DELTA CITIES

ROTTERDAM WEATHER WISE

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RESILIENT ROTTERDAM

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Resilient Rotterdam Strategy 2022-2027

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IHS, institute for housing and urban development studies of Erasmus University Rotterdam

Webinar of ‘Climate Risk Assessments to Improve Climate Resilience in Coastal City’

- flood risk assessment methods and tools with case studies of Vlissingen, NL and Shanghai, CN

11 January 2024

Dr. Qian Ke

(ke@ihs.nl)

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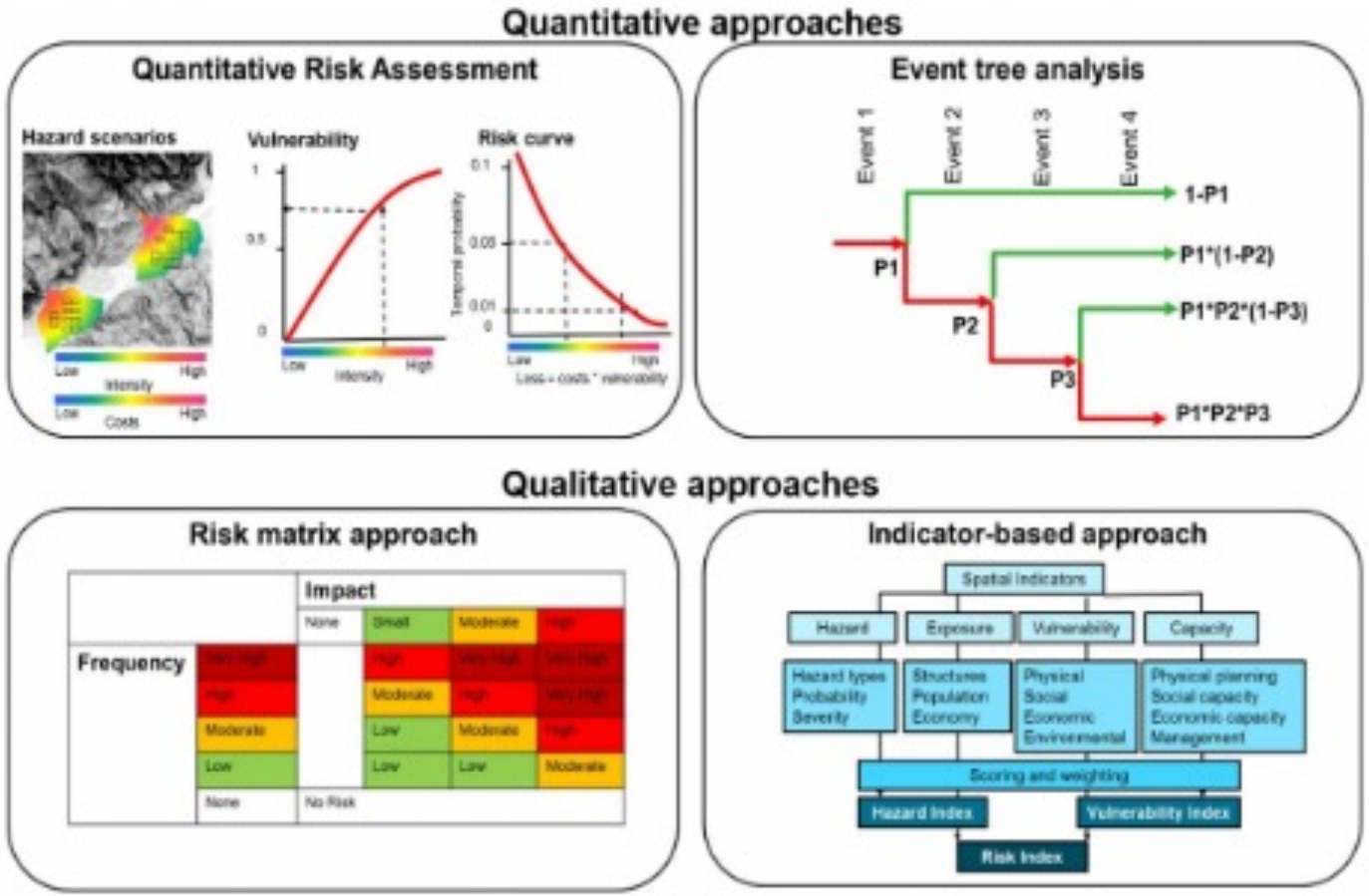
Outline

- Climate risk assessment methods and tools
- Case study
- Reflection and discussion

Risk assessment (风险评估)

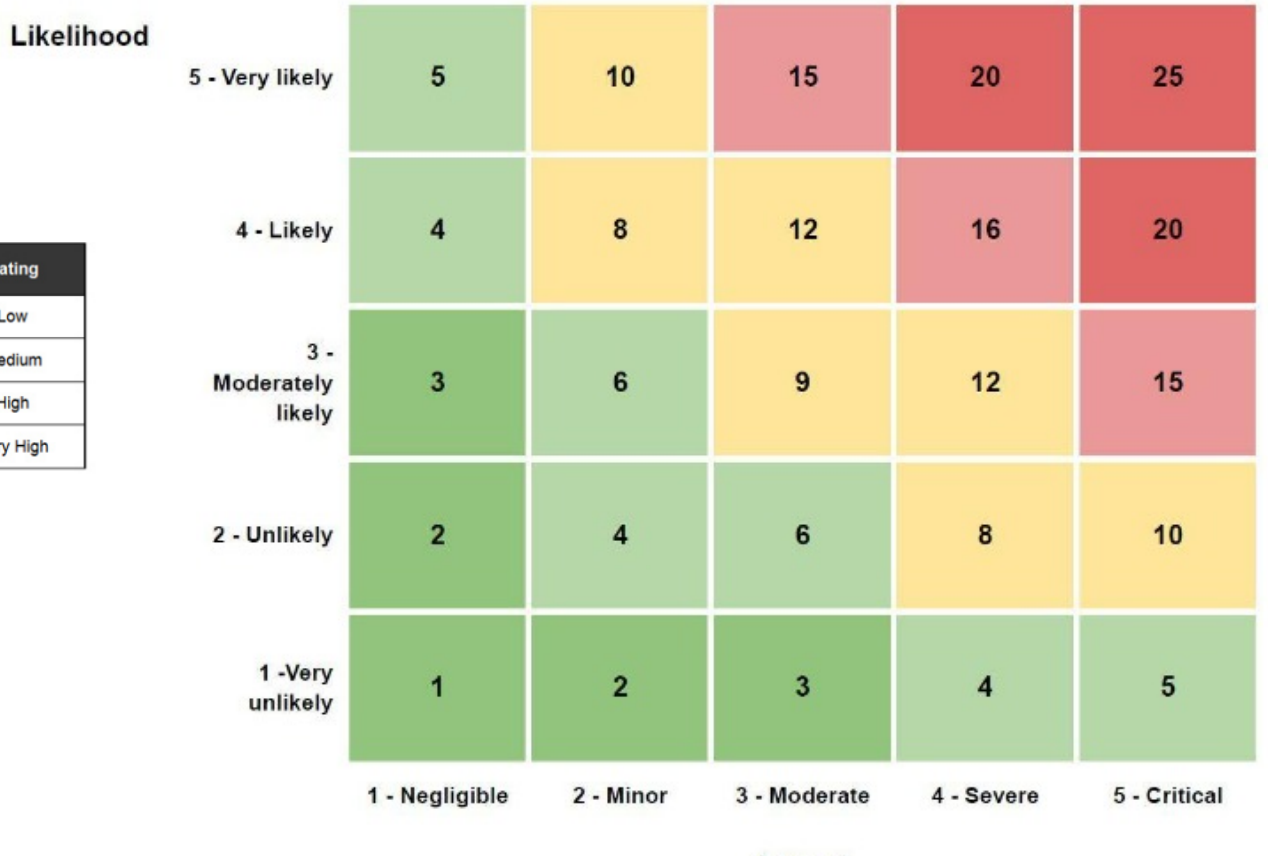
- Quantitative approach (定性方法)
- Qualitative approach (定量方法)



Qualitative analysis – an example of risk matrix (定性分析-以风险矩阵为例)

LIKELIHOOD ↑ / IMPACT →	Low (1)	Medium (2)	High (3)	Very High (4)
Very High (4)	4	8	12	16
High (3)	3	6	9	12
Medium (2)	2	4	6	8
Low (1)	1	2	3	4

Risk Score	Rating
0 – 3	Low
4 – 6	Medium
6 – 9	High
10 – 16	Very High



Risk matrix retrieved from Strengthening risk analysis for humanitarian planning, UNDRR (2022)

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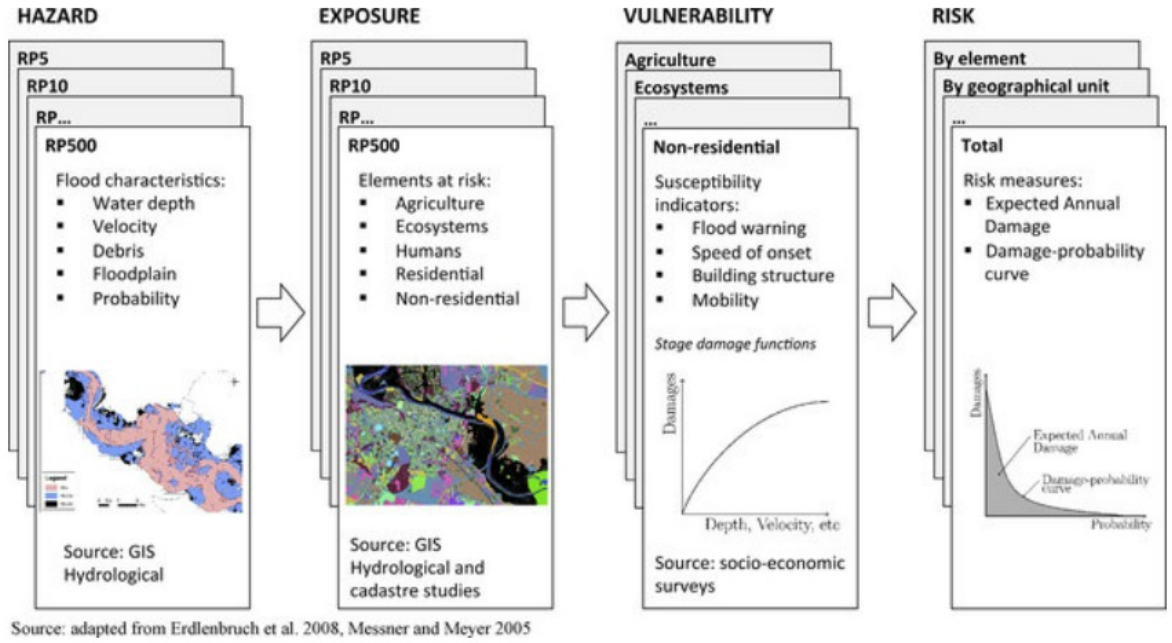
Quantitive analysis （定量分析）

- Risk assessment
  - Calculation of occurrence probability （计算风险事件的发生的可能性）
  - Damage assessment （评估风险事件所带来的损失）
    - Exposure assessment （暴露度评估）
    - Vulnerability assessment (脆弱性评估)



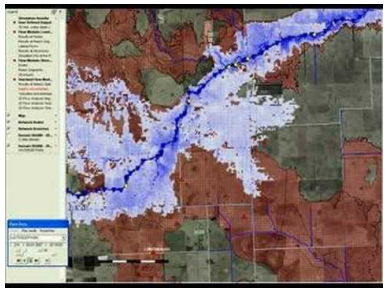
Source: adapted from Erdlenbruch et al. 2008, Messner and Meyer 2005

Input （输入数据)

水文统计模型
水文水动力模型

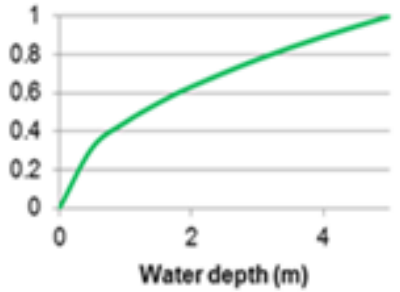
Statistical models
Hydrological models
Hydro-dynamic models

- D-FLOW FM
- Delft 3D
- Sobek
- W-FLOW
- Probabilistic toolkit



脆弱性曲线

- Mostly expert judgment.
- historical records



地理信息数据 （人口，社会经济，土地利分类用等)

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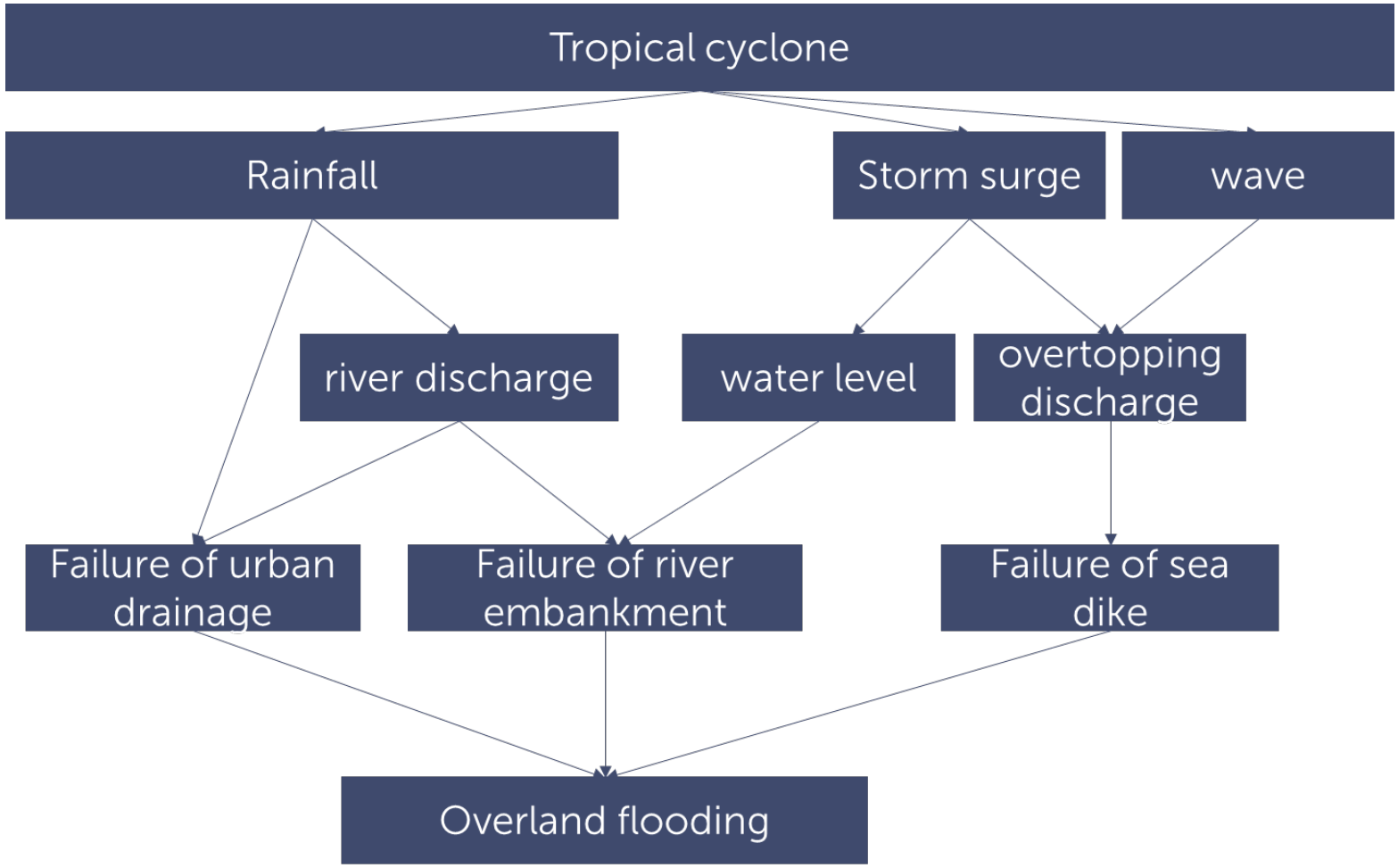
Hazard modelling

- 风险灾害事件的危害程度模型
- 考虑热带气旋（台风），所导致的风暴潮，海浪，降雨，以及随时引起的高水位、高流量以及越堤流量等使得河堤、海堤以及城市排水管网的失效，最终导致淹没灾害



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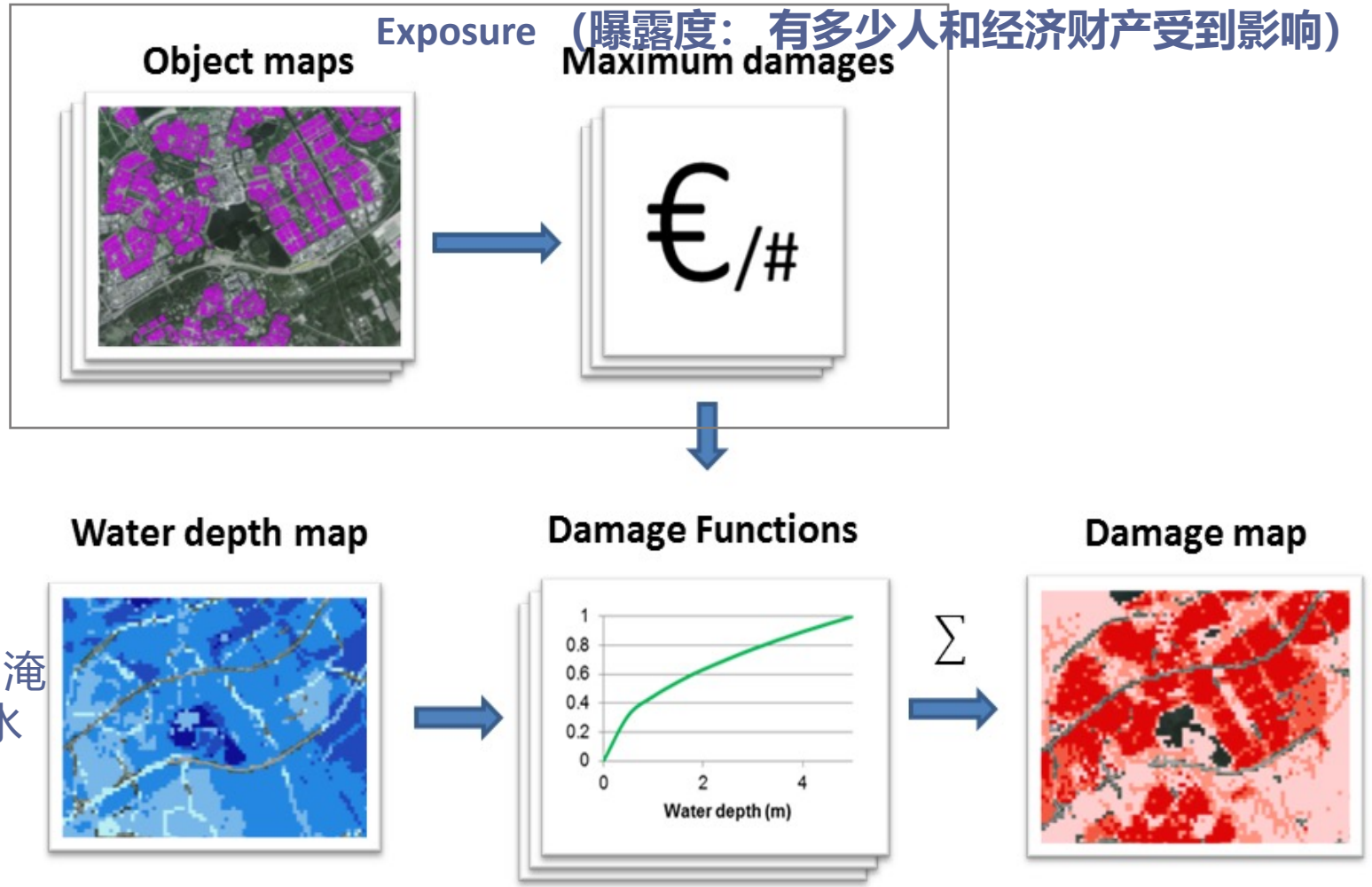
Academy

Flood simulation in NL

An example to show the routing process of flood simulation due to dike breach in the Netherlands

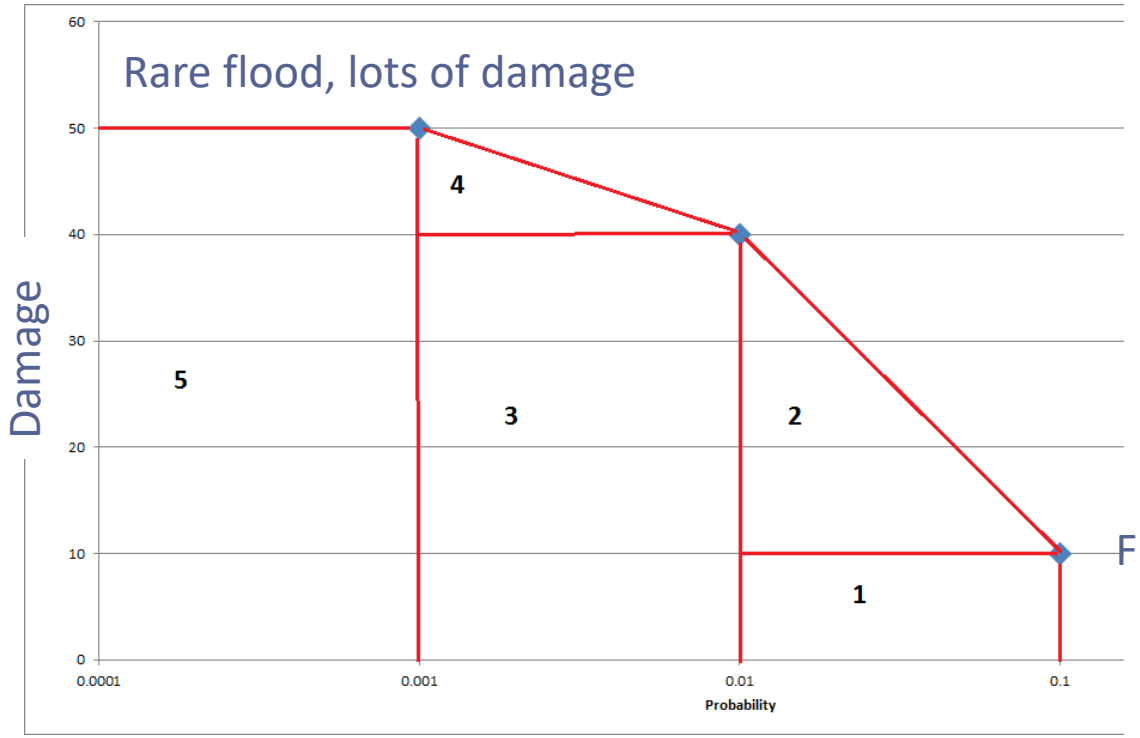
Damage modelling (灾害损失评估)

1. Flood model - > flood maps
2. Land use map -> maximum damage
3. Damage functions
4. Damage map



Total risk （利用风险曲线的计算）

- Combine many different events into maps (or aggregate damages) for different exceedance probabilities .
- Take the integral to get the expected annual damage
- In practice calculate the area under the graph.

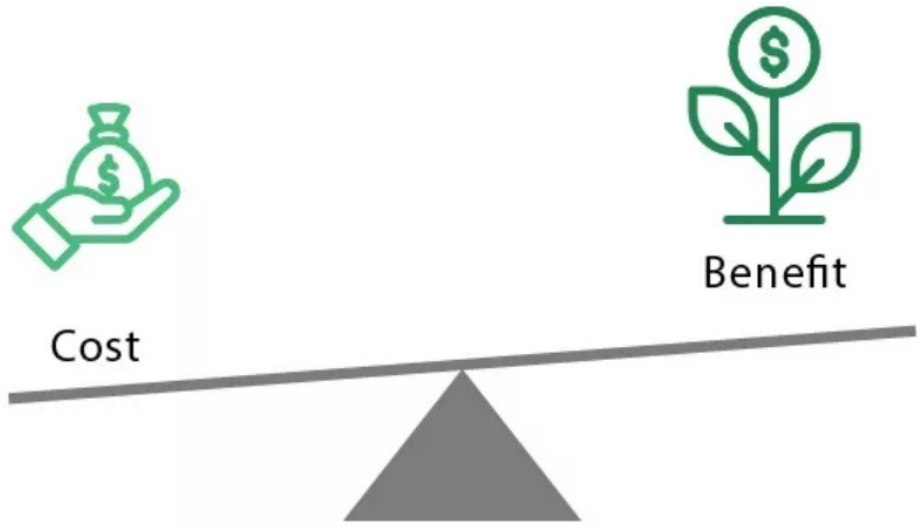


$$Risk = \int Damage(p)dp$$

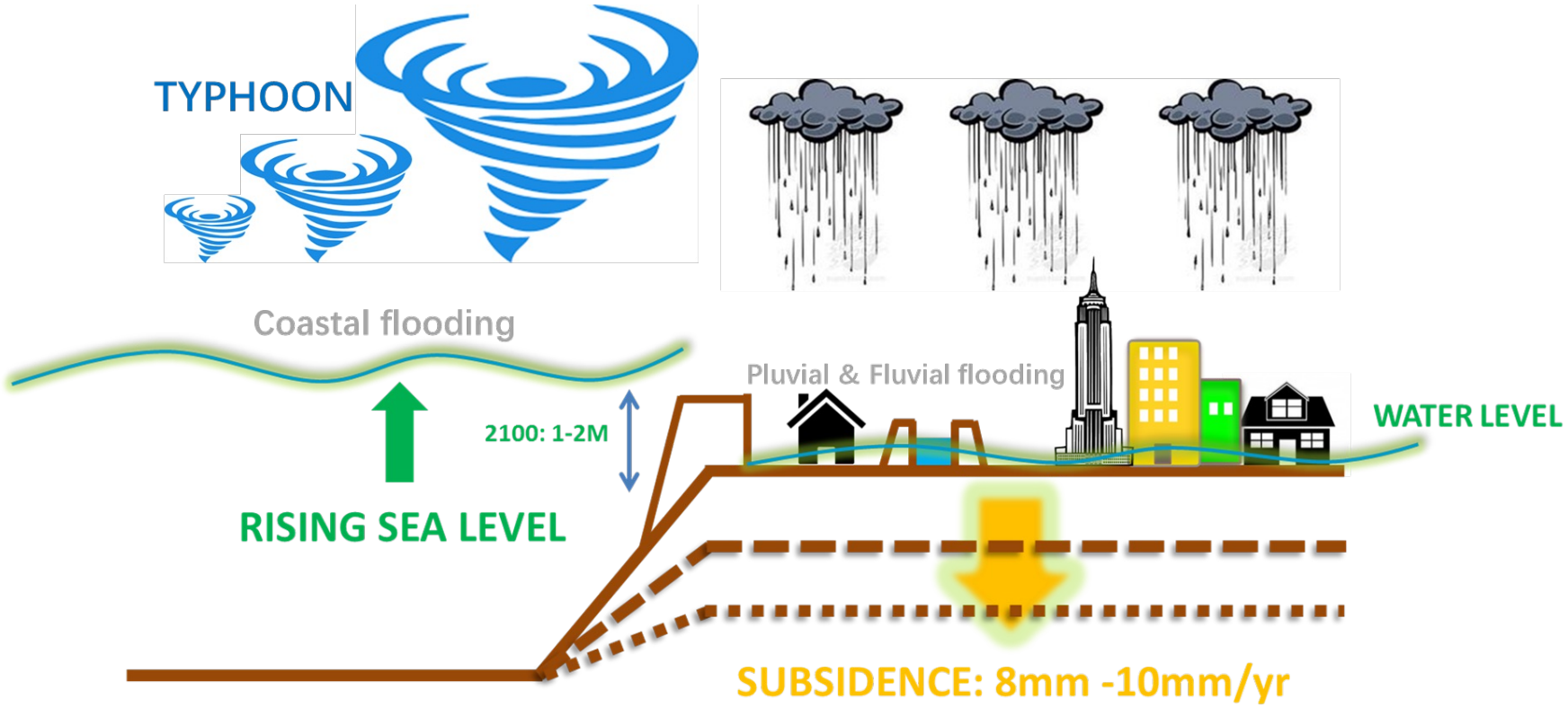
Evaluation of climate adaptation options

- To appraise and prioritize climate adaptation options （评估并且优先适应气候变化的措施）
- To optimize the allocation of resources （优化资源分配）

How much should be invested in which adaptation option(s) and at what time to create the highest benefit at reasonable costs and within the available budget?
（计算适应性措施所需要的财政资源，在什么时间点采取哪一个措施最有效率）



Example of compound flooding



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Case study

- Vlissingen, The Netherlands
- Shanghai, China

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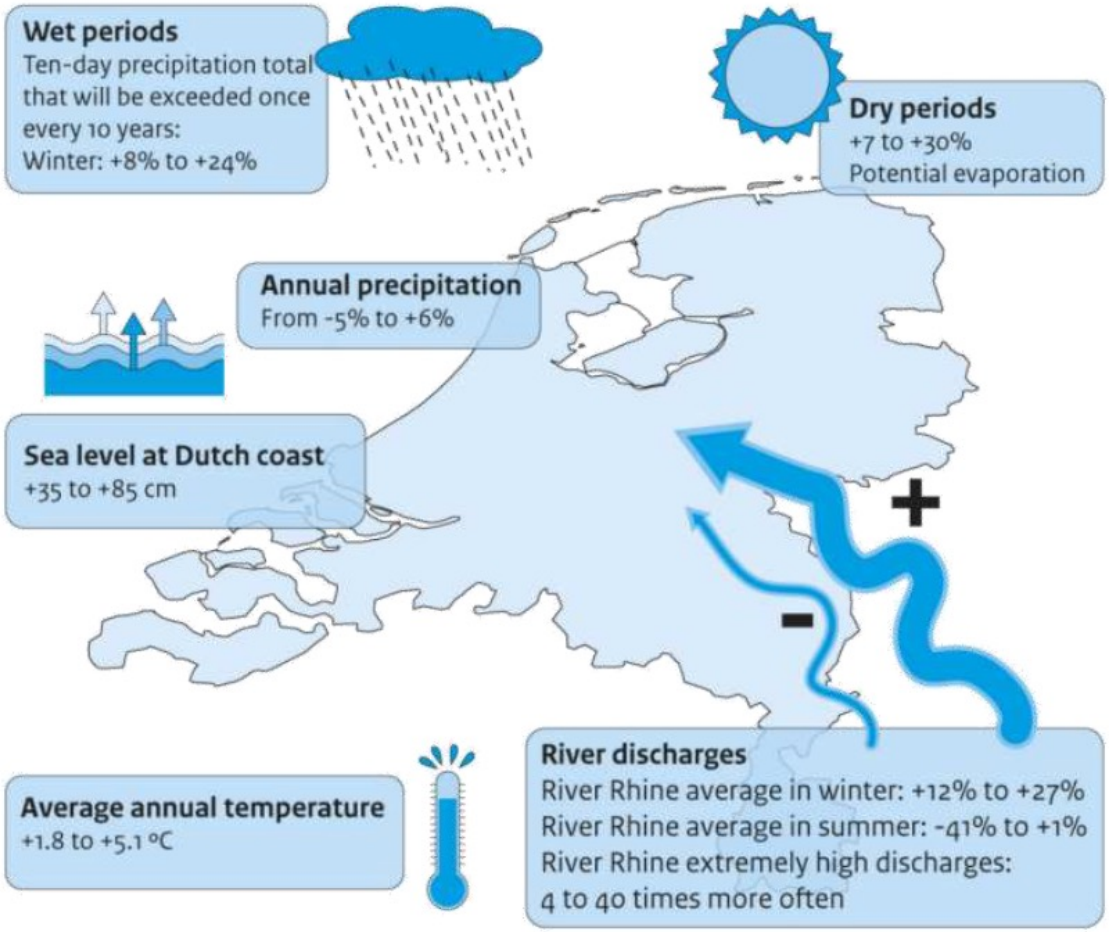
Climate change in the Netherlands



Source: KNMI 2014

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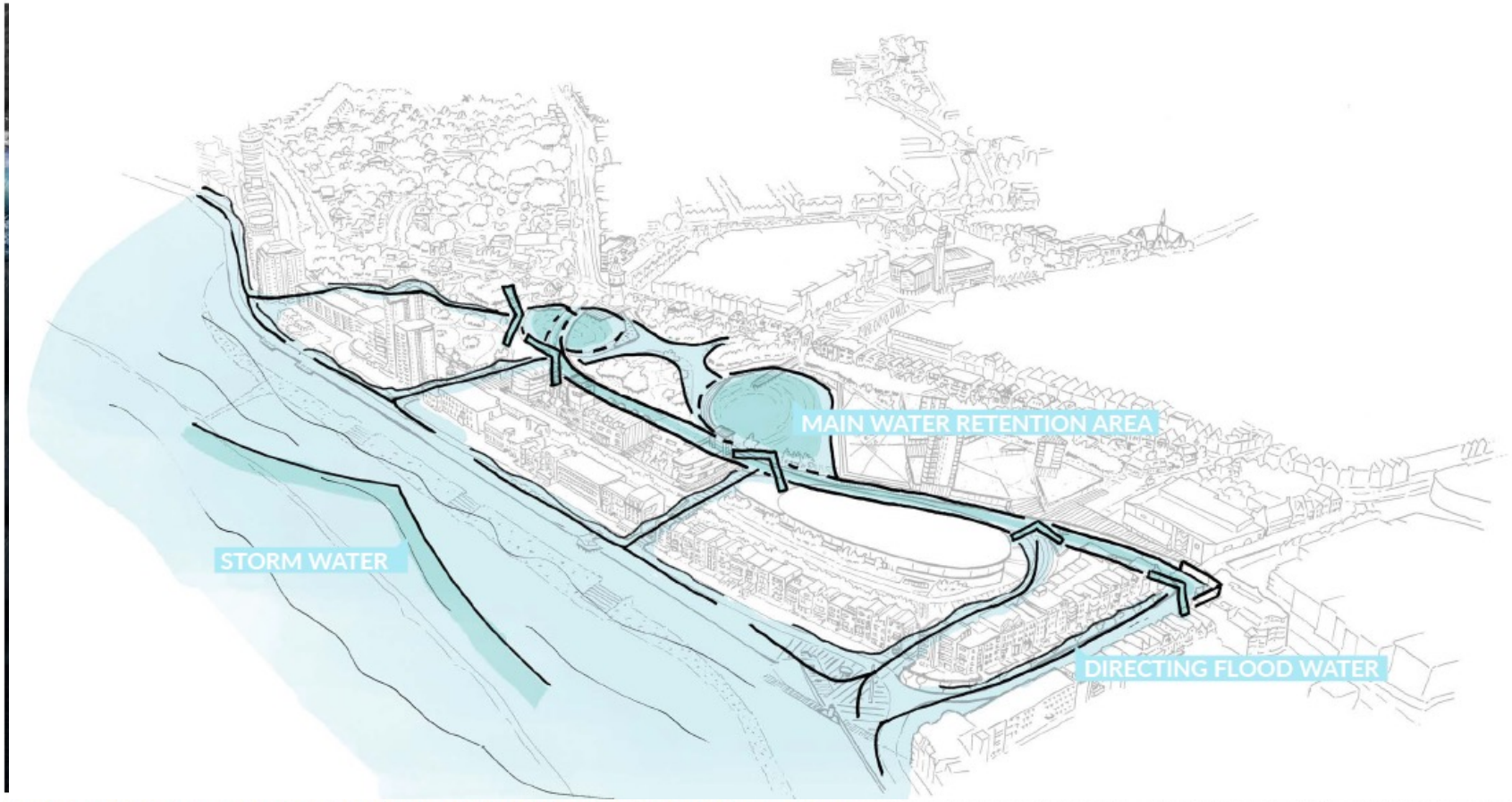
An example in Vlissingen, NL

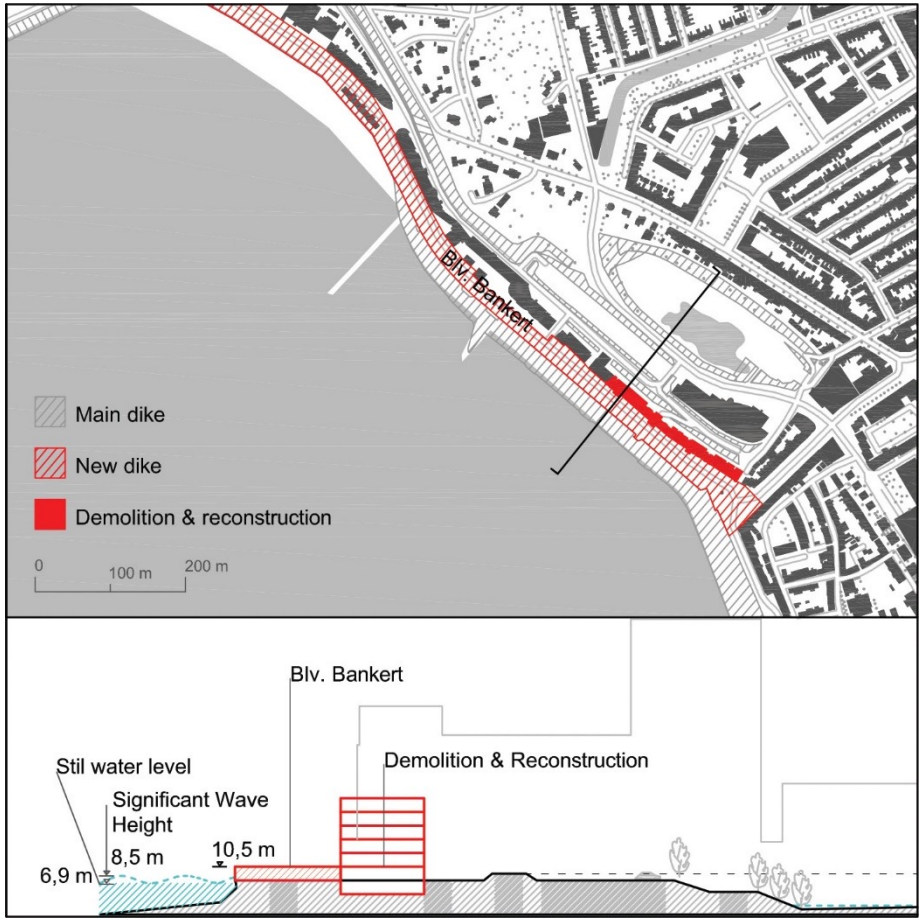
Adaptation measures （适应性措施）

- Increase height of dikes
  （加强加高海堤）
- Redirect and store the flood water
  （洪水引流以及存储）



The challenge for Vlissingen is to defend its urban area from flood water by redirecting and storing the flood water.

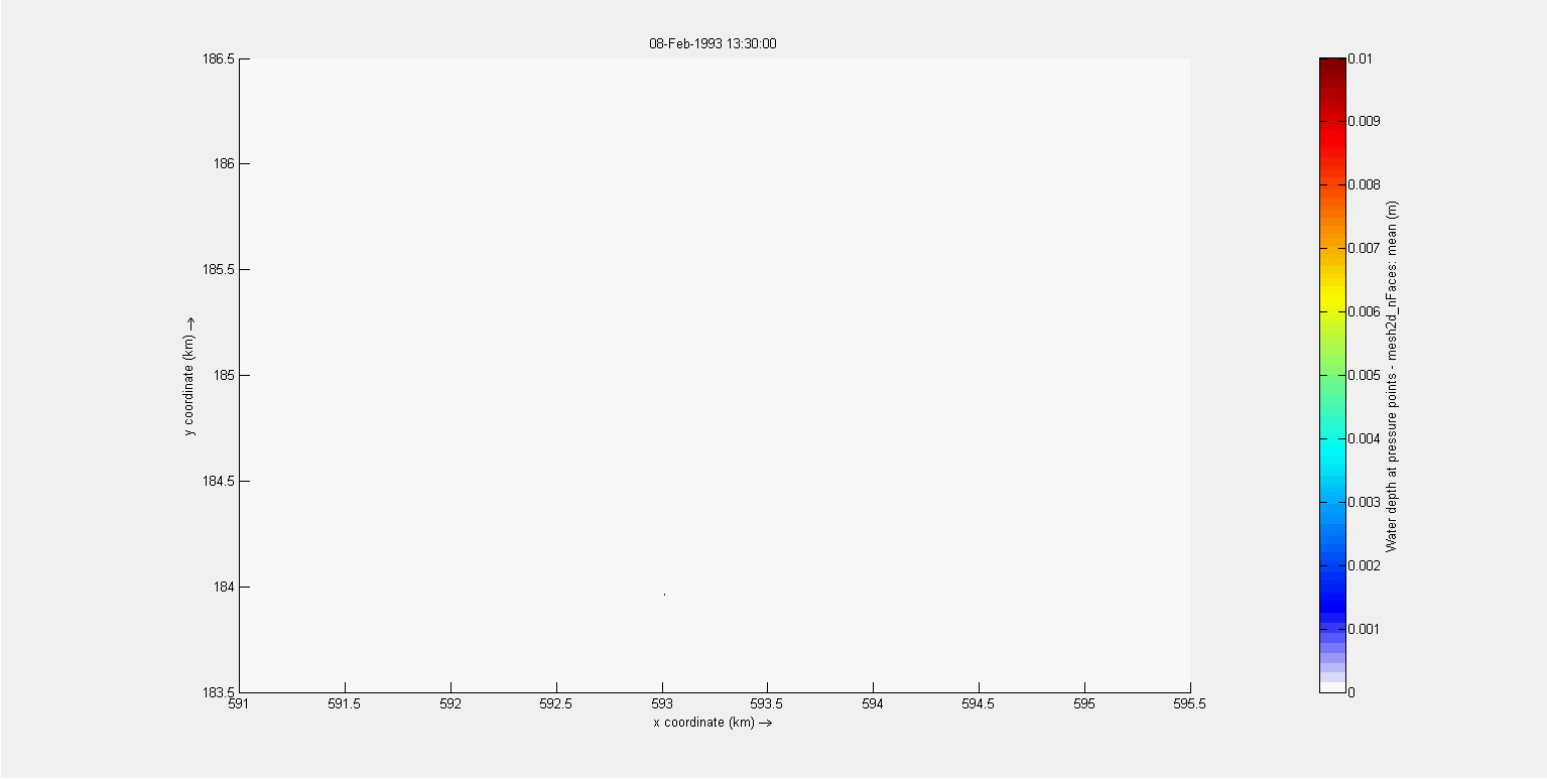
Vlissingen case study – two options



Spatial design scenarios: the Vlissings Model

Spatial design scenarios: the Overtopping Sump Model

Flood simulation



An example to show the flood simulation in vlisingen case, shown by the dynamics of inundation depth

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Vlissingen case

现状
baseline

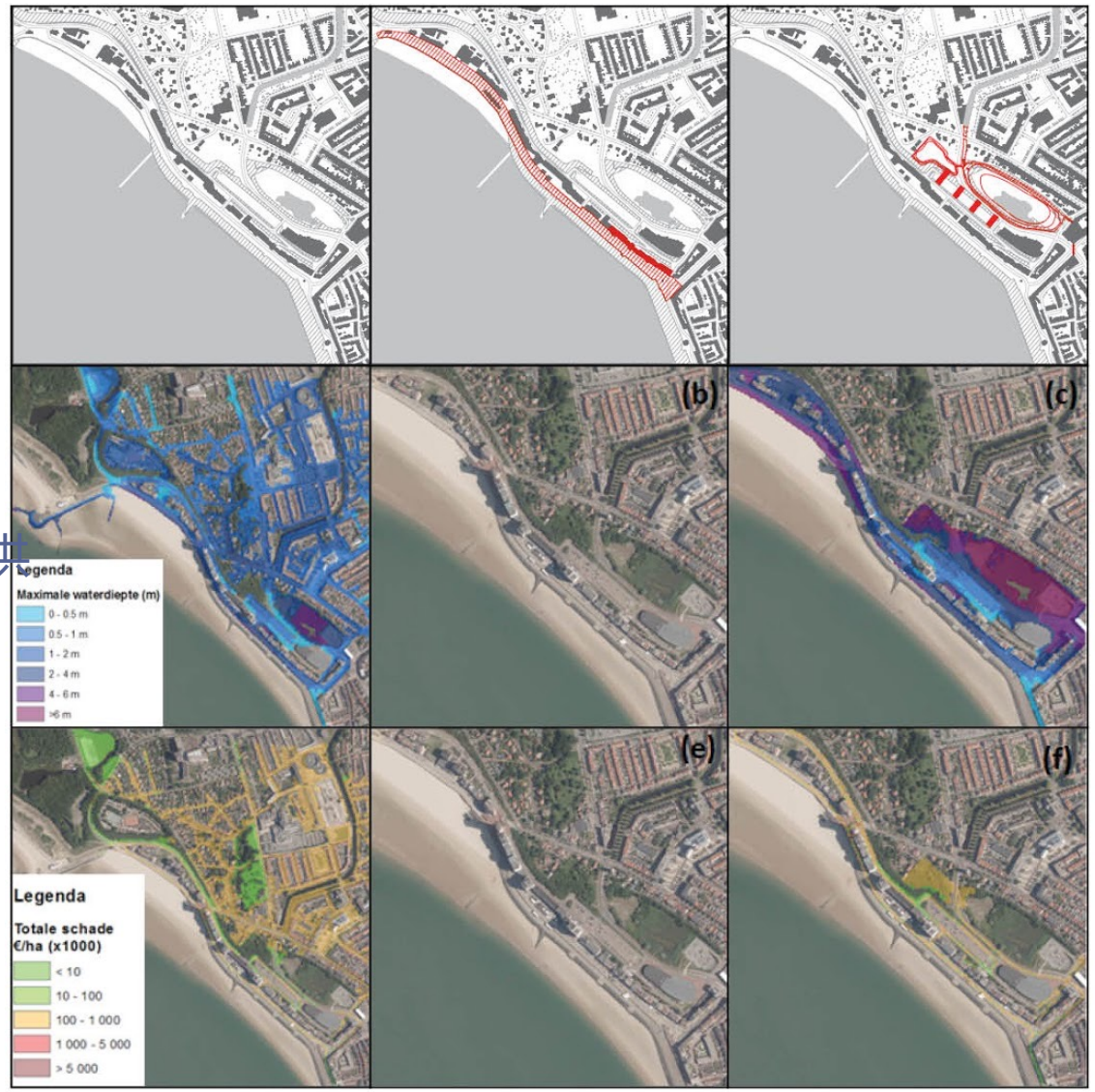
海堤加高3米的情景
dike heighten (+3m)

引流越堤洪水水量暂时存储到某一存储区域的情景
water storage area

Design
设计图

water depth洪水淹没图

Damage
淹没直接损失



CBA (cost-benefit analysis)

economic efficiency
利用成本-效益方法计算经济效率

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Result of damage assessment

Scenarios	Baseline	Strength dikes	Accept by storing water
Total damage [million euro]	53	0	8.4
Total fatality [person]	2	0	0
Total affected people [person]	805	0	42

CBA – (economic) benefit

	baseline	Vlissingen model	Overtopping sump
Total damage	53 million	0	8,4million
Total fatality [person]	2	0	0
Total affected people [person]	805	0	42
value of life		10 million	
investment to avoid one affected person		0,5million	
EAD [euro/year]	4755	0	2940
Benefit [euro/year]		4755	1815

assumption

Probability * damage = 1/10,000* damage value

Avoided EAD = damage (baseline) - damage(adapation)

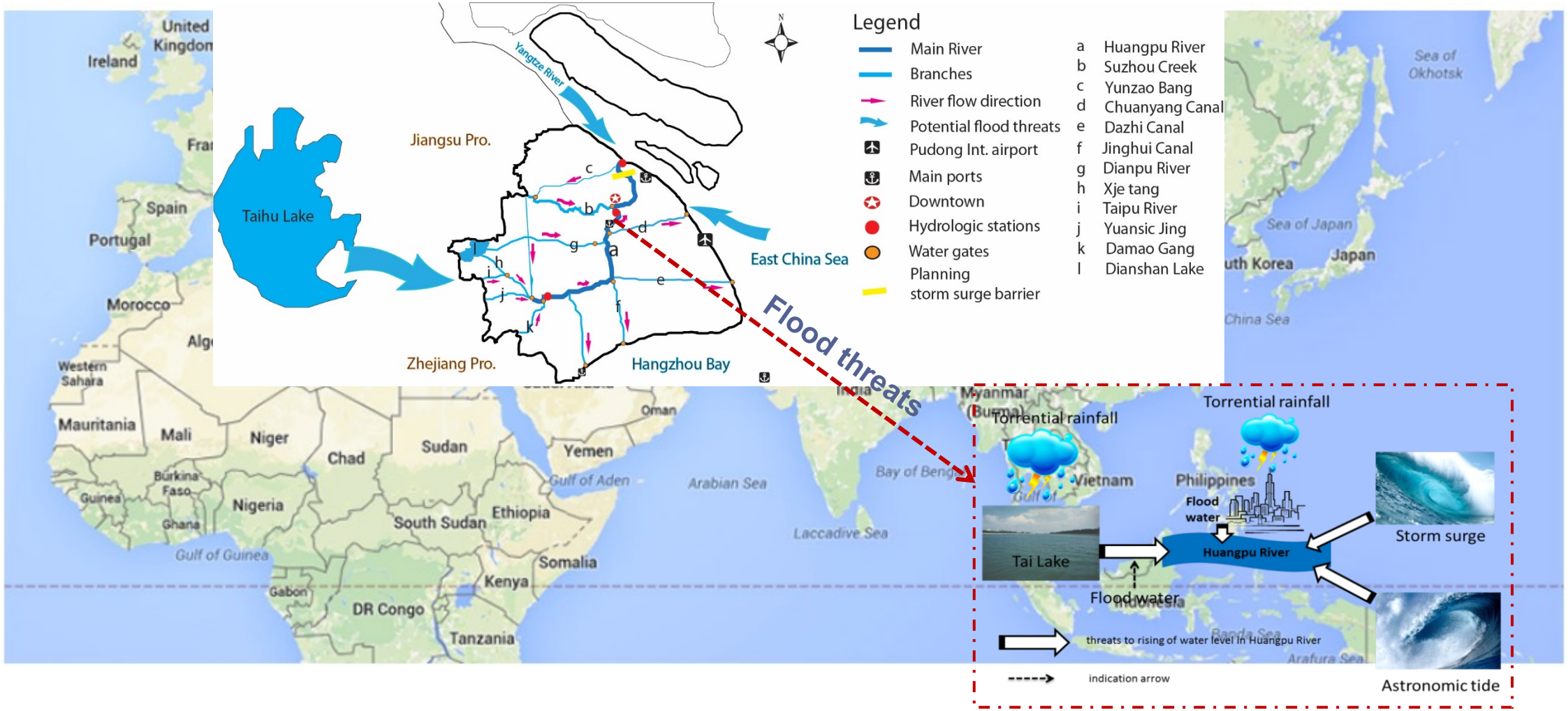
CBA - cost

- Initial investment
- Operation cost
- Repair and maintenance cost

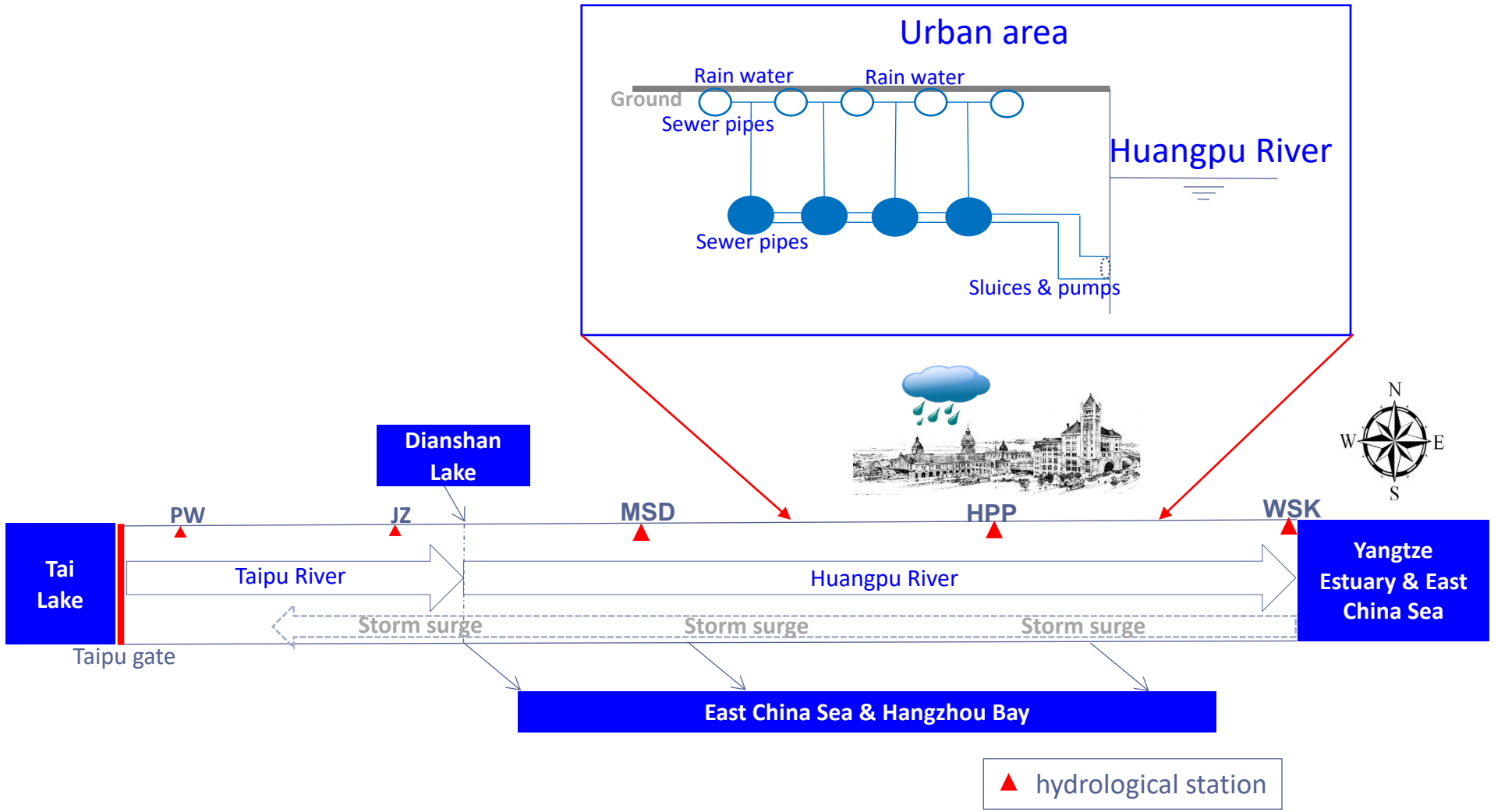
Table 1 Overview cost estimates the Netherlands (Kok, et al, 2008)

The Netherlands	
Dike (Millions € per km)	**Dike heightening (per m)** • 9 – 10.8 (rural) (Kok et al., 2008) • 18 – 21.6 (urban) (Kok et al., 2008) • 4 – 11 (rural) (Eijgenraam, 2006) • 6.9 (rural) (Fugro and Arcadis, 2006) • 13.8 (urban) (Arcadis and Fugro, 2006)
Beach Nourishment (€ per m^3 material)	• 2.3 – 6.7 (Stive, pers. comm., 2009) • 3 (Kok et al., 2008) • 2.85 (Arcadis and Fugro, 2006) • 3.72 (Foreshore nourishments) (RWS, 2009) • 7.55 (Beach nourishments) (RWS, 2009)
Maintenance	0.1 M€/km flood defence/year (AFPM, 2006)

Shanghai System Analysis



Schematization of Shanghai macro-water system



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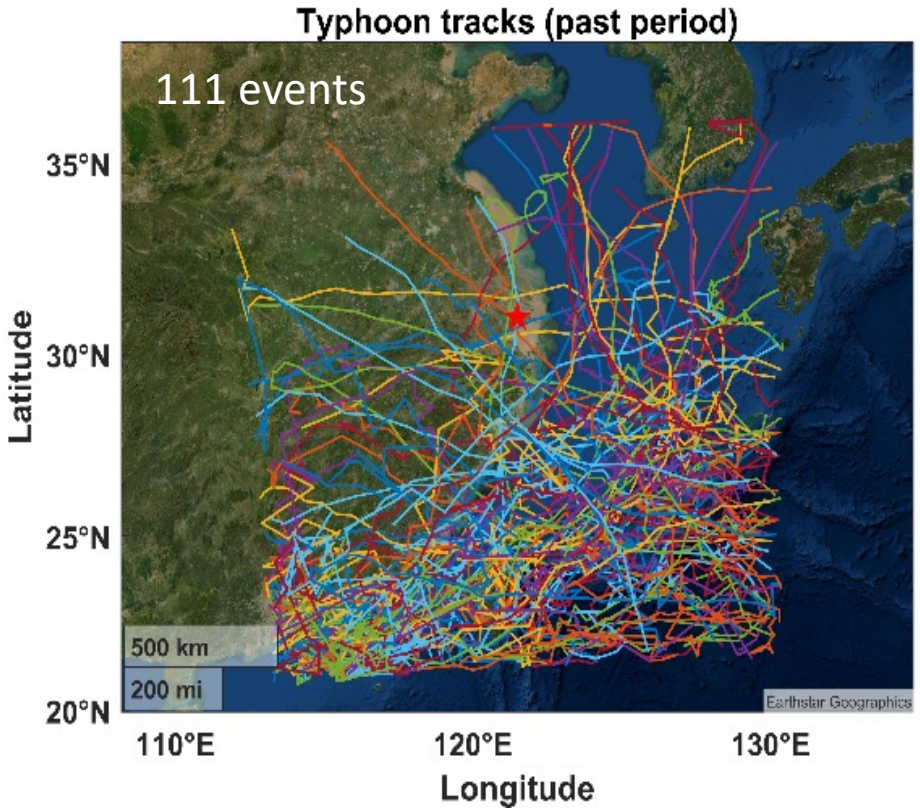
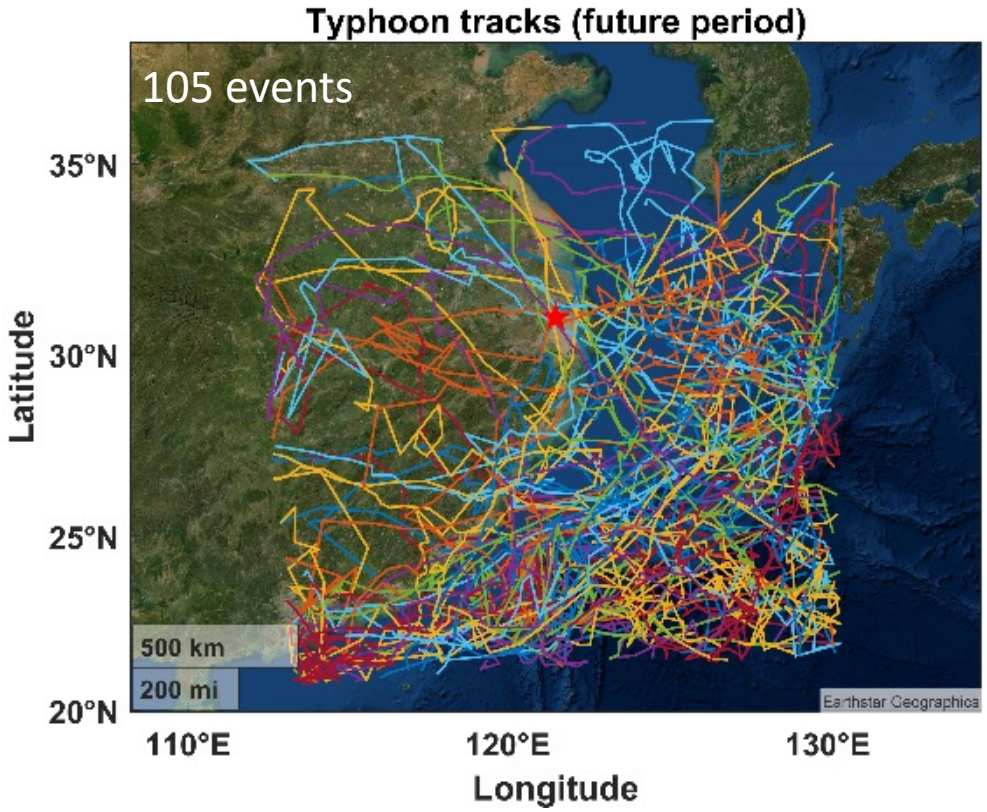
Climate model （气候模型）

- Hadley Centre model HadGEM2-ES （英国哈德莱中心的气候模型）
  - two 20-year time slices
    - Present time: 1981-2000 （以1981-2000年作为现状情景）
    - Future projection(2080-2099) under the RCP8.5 forcing scenario （在气候变化最高碳排放情景下未来20年的气候模式对台风的影响）

- 4km resolution of HadGEM2-ES simulation model created 111 and 103 typhoon events in the past period and future periods, respectively (shown in next slide). （模型最后生成过去时间的111场台风和未来20年时间段的103台风）

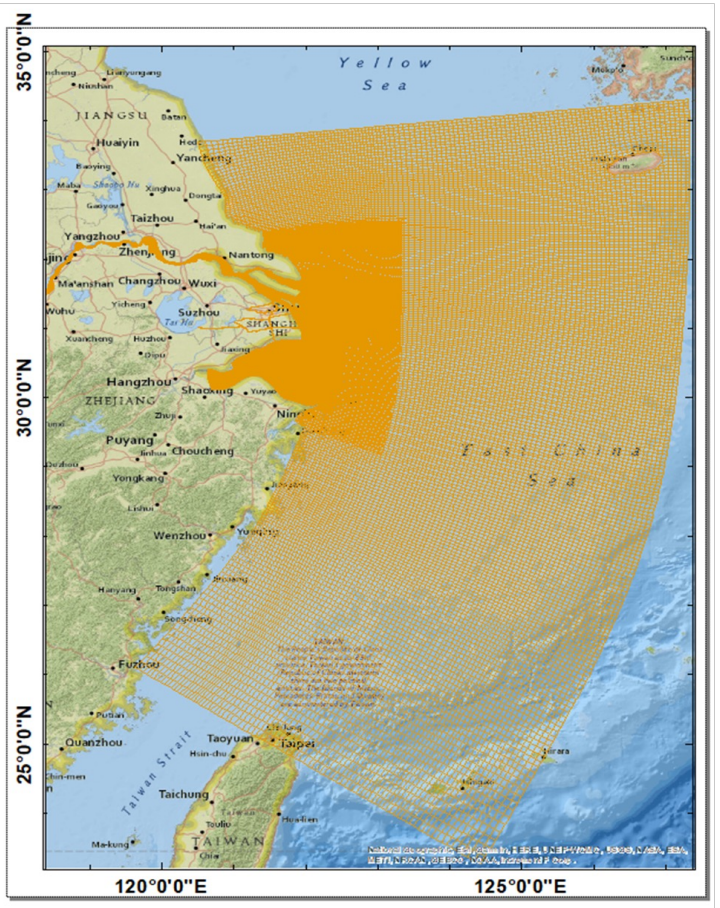
Simulated typhoon tracks: past and future



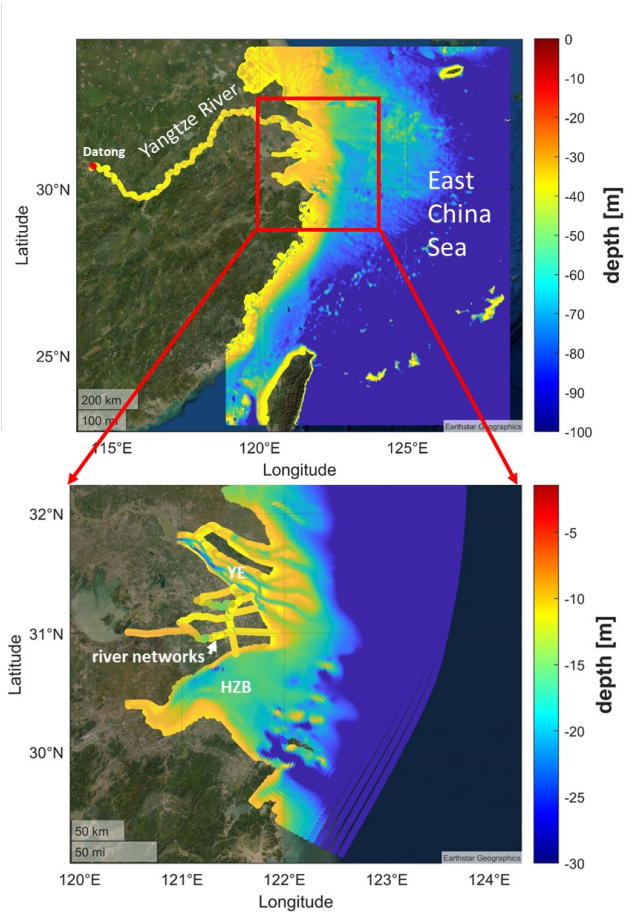


- Trajectories of the modelled typhoons in the past period 1980-2000 and under the RCP8.5 climate scenario in the future period of 2080-2099 （台风路径图）
- red star represents the location of Shanghai city （五角星代表研究区域）

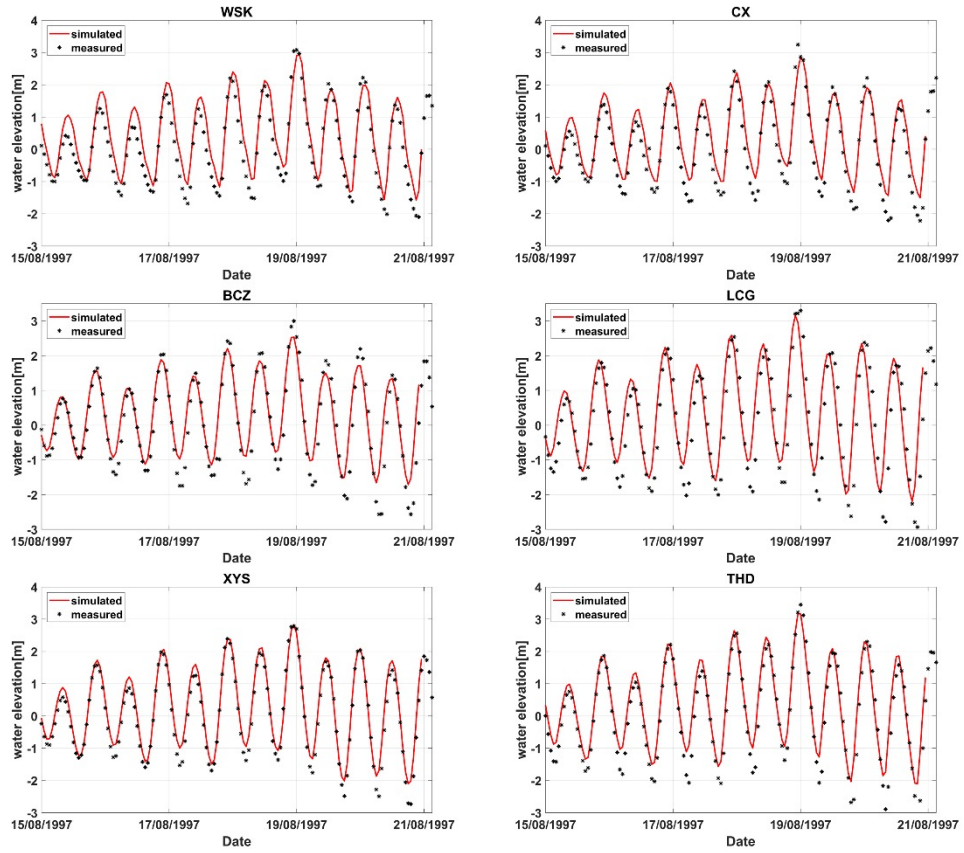
Hydrodynamic model (Delft3D-FM)



(a)



(b)

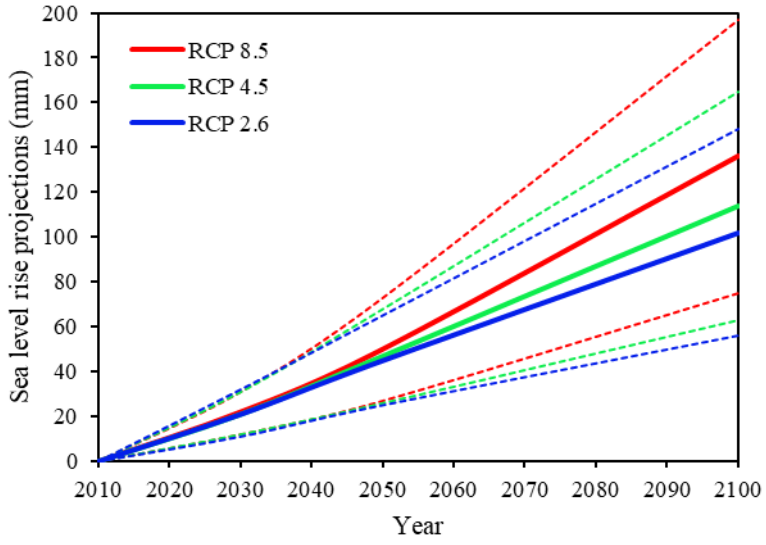


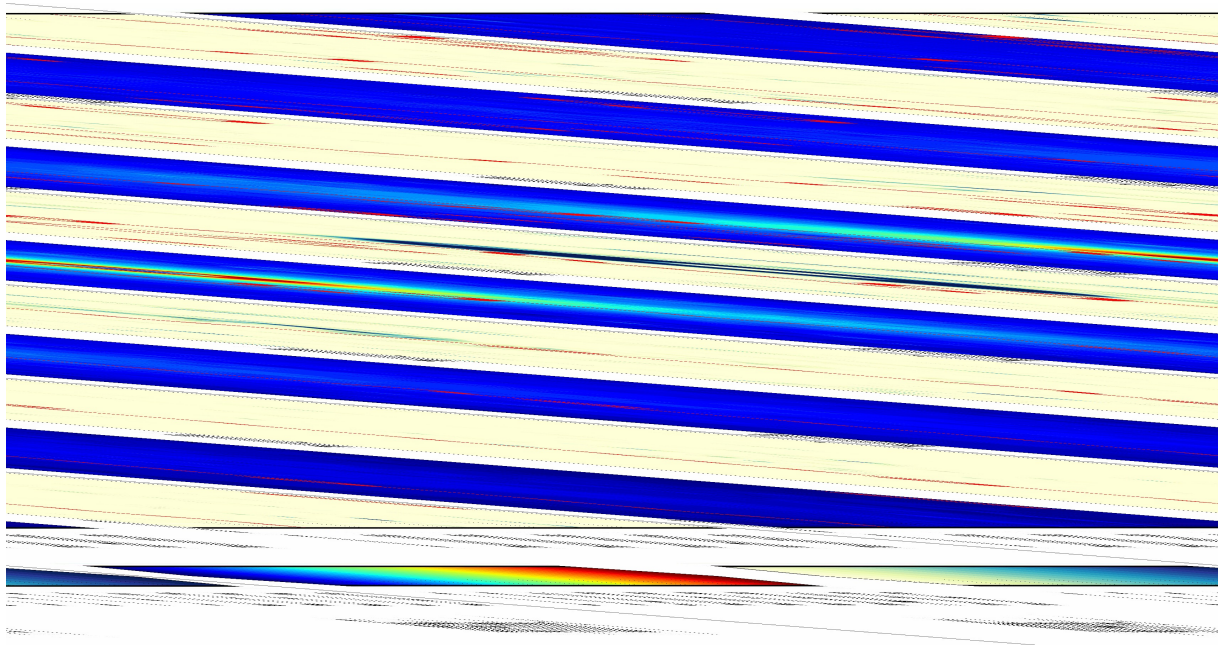
Validation: red lines indicate the model results , black points indicate measurements （验证结果）

沿海风暴潮模型 （a) 模型网格 (b)模型结果

IHS
Making cities work

Climate change - Sea lelvel rise (SLR) and climatology change



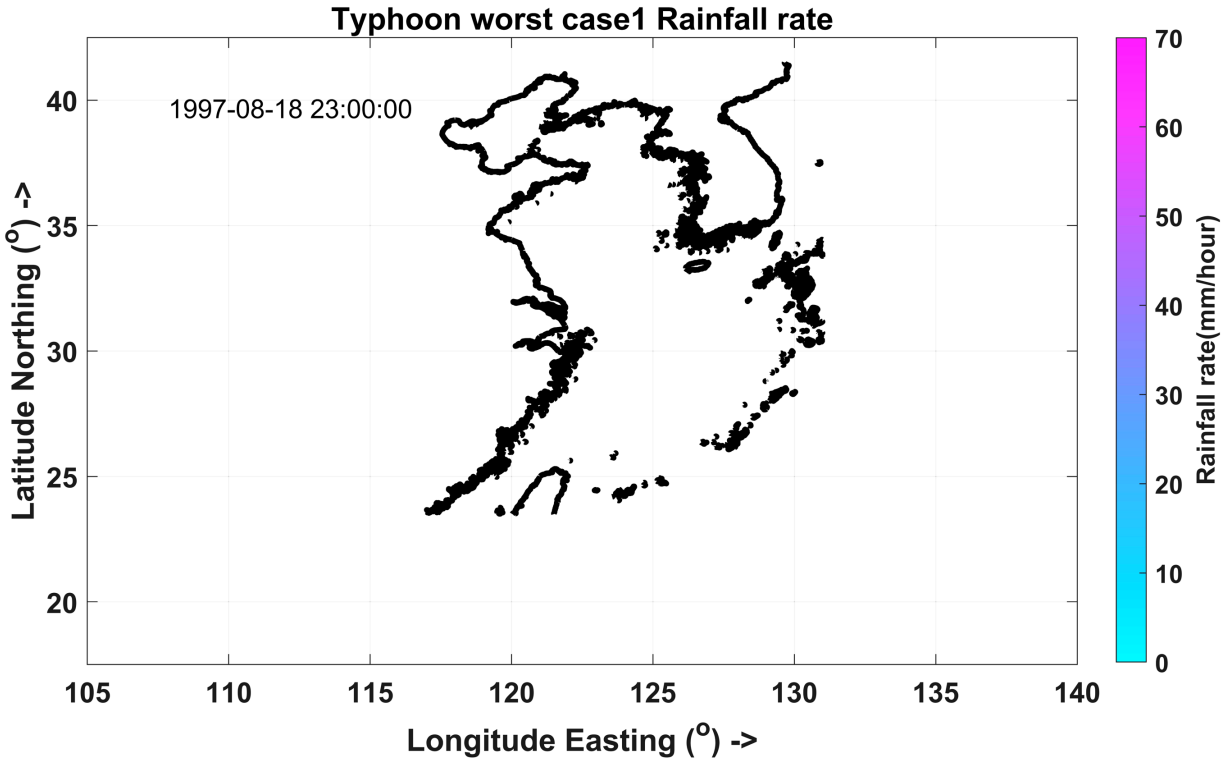


Ke, Q., Yin, J., Bricker, J.D. *et al.* An integrated framework of coastal flood modelling under the failures of sea dikes: a case study in Shanghai. *Nat Hazards* **109**, 671–703 (2021). https://doi.org/10.1007/s11069-021-04853-z

气候变化导致的海平面上升和台风强度变化的可视化

IHS
Making cities work

Typhoon-induced rainfall simulation (台风引起的降雨空间变化模拟)



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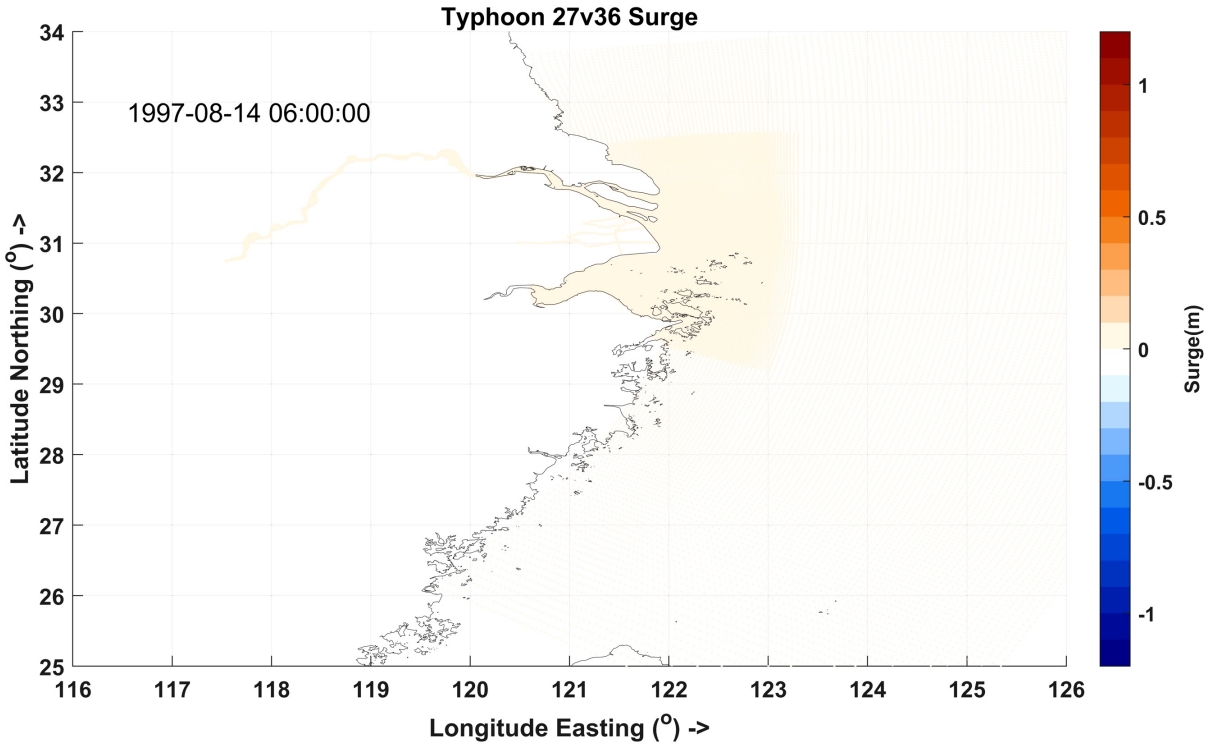
Making cities work

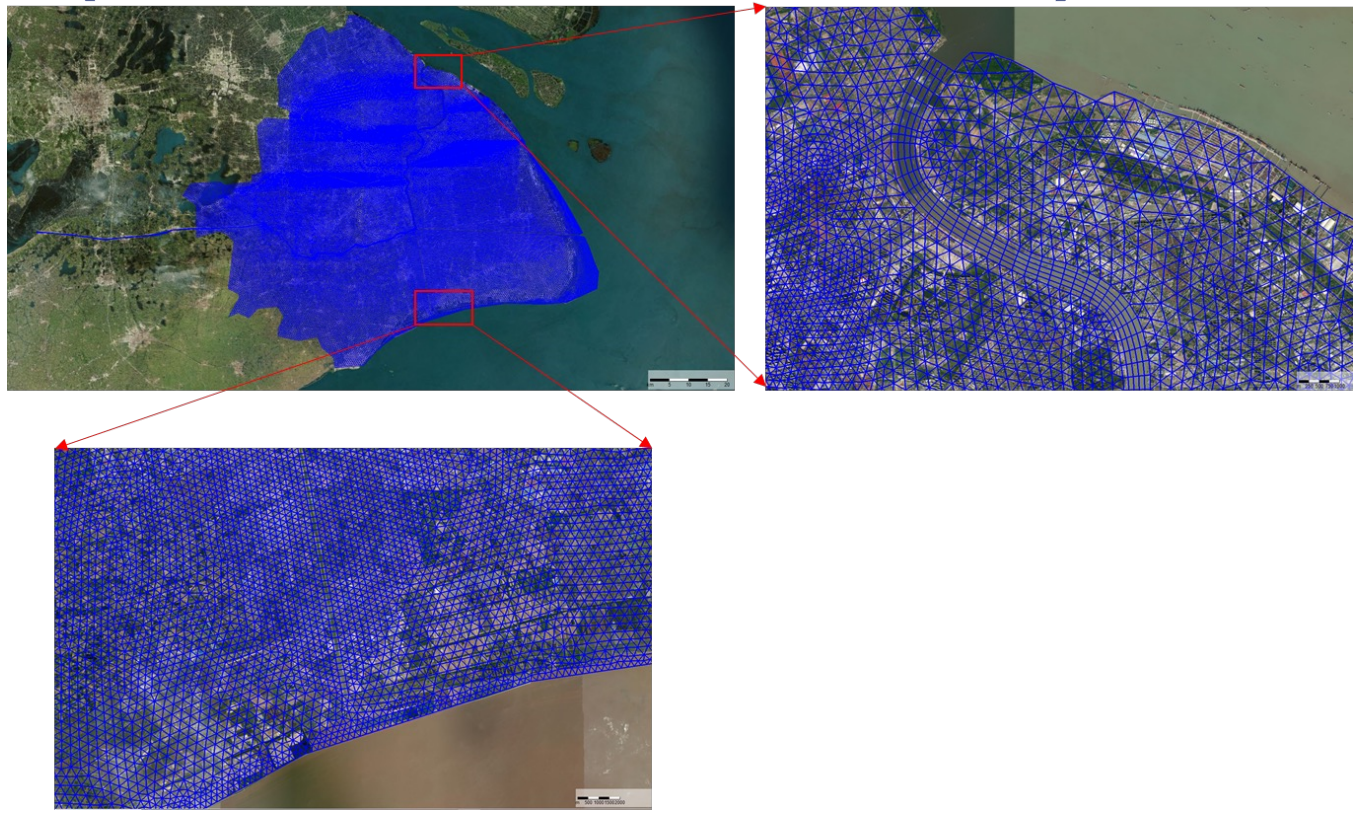
Storm surge simulation （风暴潮模拟）



Overland flood model （洪水淹没二维模型）

- Delft3D-FM
  - Grid cell resolution ~ 300m;
  - Topography: DTM
  - manning's roughness coefficient: 0.06 $sm^{-1/3}$

- driven by overtopping and breach discharges at the grid cells corresponding to the sea dike （越堤海水和溃堤引起的洪水）

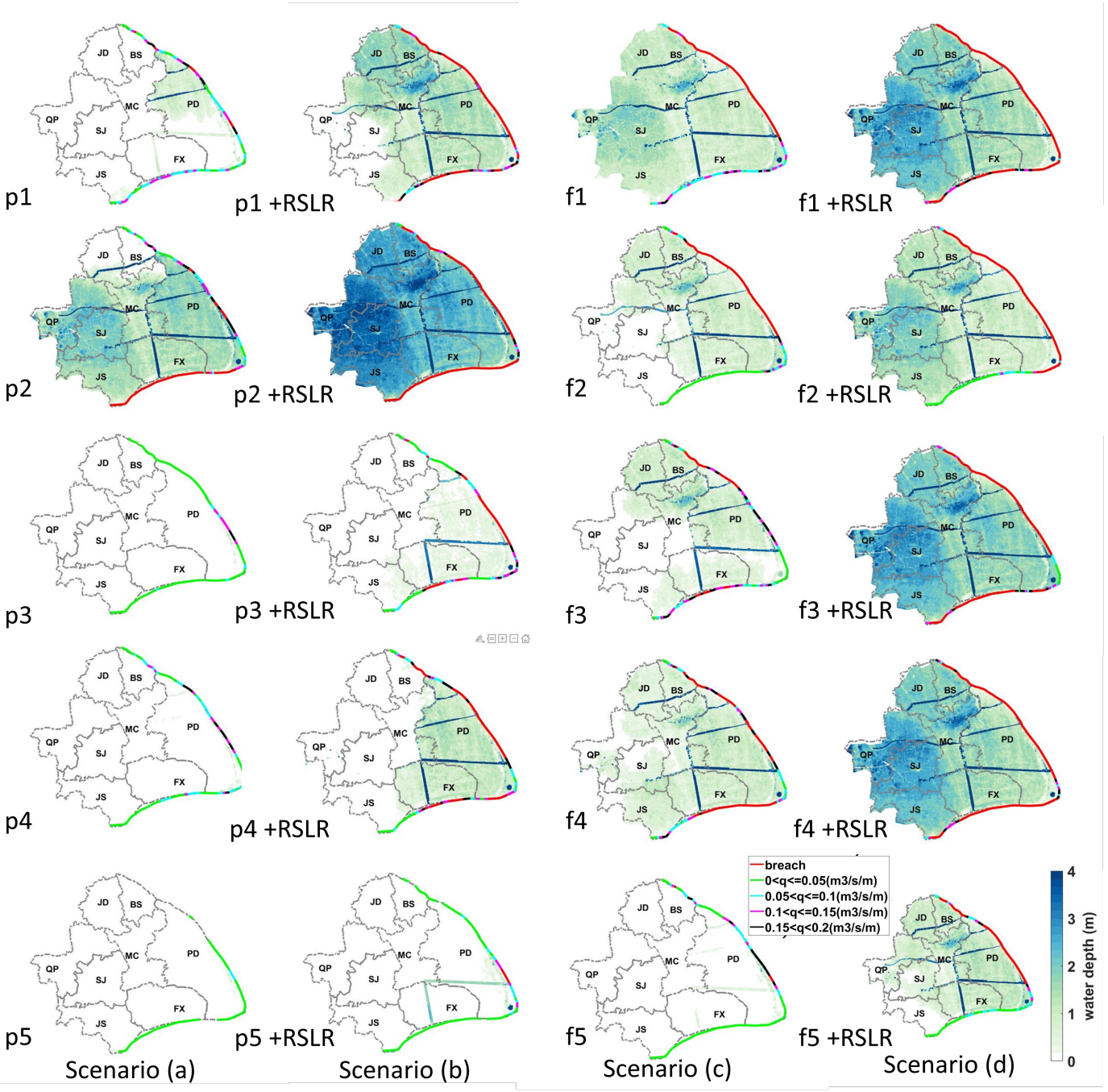


domain of overland flood model with triangular and curvilinear grid cells

模型中二维网格变化

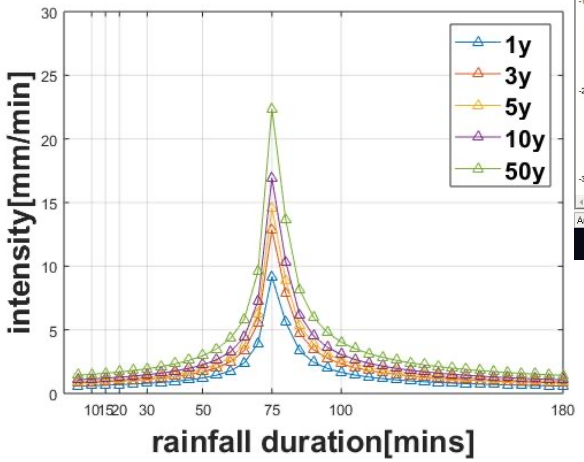
Flood maps

- Maximum overtopping discharge rates ($m^3/s/m$) along the coast
- Scenario (a): Breaching occurred during two cases (out of five) in past climate
- Scenario (d): all five typhoons cause large breach sections



IHS
Making cities work

1D drainage by SOBEK （基于排水管网的内涝模型）



a section of profile of pipeline and manholes system

Assumption : all the rainfall water goes into the pipeline;
water can flow out from the manholes

此次模拟假设所有降雨都通过排水管道，进而由于排水能力不足导致的积水

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Reflection and discussion

- An integrated framework of coastal flood modelling for areas with coastal dikes considering the combined effects of SLR, land subsidence and increasing TC intensity should be developed （沿海城市建立台风模型，风暴潮模型和洪水淹没模型的耦合模型）, while it requires multiple data and quality of data also matters (气候变化数据、台风数据、水文数据、防洪设施的数据质量会影响风险评估结果)
- TC climatology change and RSLR increases the flood hazard to which coastal cities will be exposed in the future. RSLR is likely to have larger effect than TC climatology change on dike breach length along the Shanghai coast （以上海为例相对海平面上升和台风强度都大大增加未来洪水风险，相对海平面上升的作用更大)

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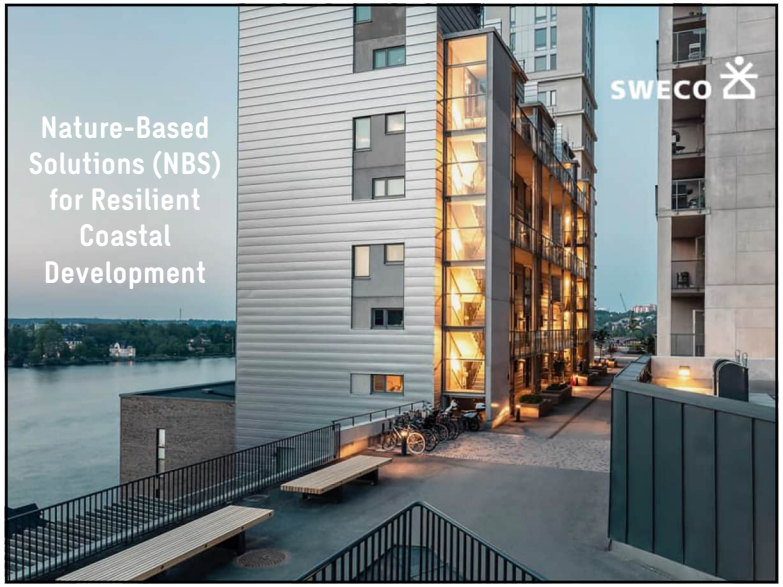
Thank you! Questions?


Nature-Based Solutions (NBS) for Resilient Coastal Development
SWECO

1


About Sweco:
欧洲领先的建筑和工程咨询公司
Europe's leading architecture and engineering consultancy
• Gunnar Nordström带着对建筑和工程公司相结合的愿景于1958年成立Sweco。
• Founded in 1958, Sweco is based on Gunnar Nordström's vision of a combined architecture and engineering company.
• 公司理念是将不同的角度结合起来，解决时代的挑战。
• The idea is to bring different perspectives together to solve the challenges of our time.

2


SWECO
#1
欧洲第一
On the European market
SEK
24 bn
2022年净销售额
Net sales 2022
#4
建筑行业全球第四
Global architectural practice
21,000
众多专业领域全职员工
Full-time employees, with as many different perspectives
15
分布在欧洲15个国家
Markets in Europe
100,000+
10万多个项目
分布全球70个国家
Projects in more than 70 markets worldwide
可持续发展
是我们业务的核心
Sustainability is at the core of our business

3

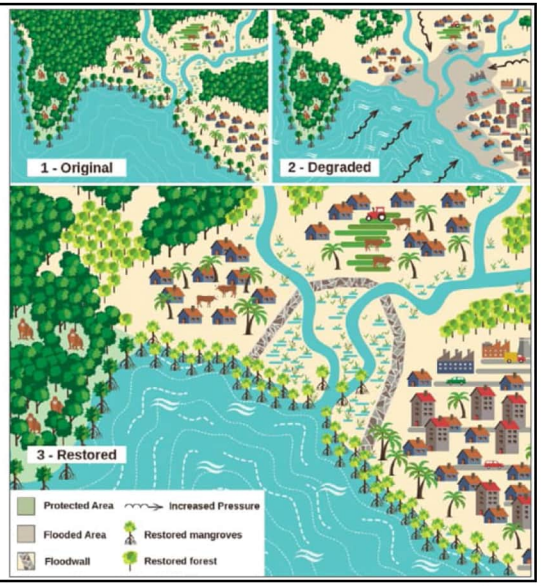

SWECO
三个主要服务领域 Our three service segments:
• Architecture
• Sustainable buildings
• City planning
• Climate and environment assessment
• Parametric design
• Renewable energy
• Electrification
• Environmental impact assessment
• Efficient logistics and processes
• Water treatment & water protection
• Railway and rail-bound traffic design
• Public transportation planning
• Cycling in cities
• Traffic and urban planning
建筑和城市区域
Buildings and urban districts
• 建筑
• 可持续建筑
• 城市规划
• 气候与环境评估
• 参数化设计
水、能源和工业
Water, energy and industry
• 可再生能源
• 电气化
• 环境影响评估
• 高效的物流和流程
• 水处理和水保护
交通等基础设施
Transport infrastructure
• 铁路和铁路交通设计
• 公共交通规划
• 在城市骑自行车
• 交通与城市规划

4

INTERNATIONAL UNION FOR CONSERVATION OF NATURE

9

Nature-based Solutions



10

SWECO

COASTAL CITY X – THE SUSTAINABLE CITY BY THE SEA

Click on the symbols to find out how your city can adapt to rising sea levels and increased precipitation.

11

SWECO

Home

Drinking water

In Sweden, we have good access to fresh water in our lakes, streams and groundwater reservoirs. The challenge for the future is to maintain a good quality of water, which means protecting water sources from pollution, saltwater intrusion and harmful microorganisms.

- The purification processes may need to be upgraded
- Waterworks need to be protected against flooding from watercourses and rising seas
- Strategic planning can be used to secure and improve the drinking water supply

Examples of projects carried out by Sweco

12

Water quality

The water quality in our seas, lakes and streams can be affected by increased precipitation and rising sea levels. Even the water quality at beaches close to urban areas may be affected.

We can prepare by taking action to improve water quality and studying the effects on aquatic ecosystems. By integrating water quality into development and urban planning, solutions with multiple positive effects can be created at optimized costs.

Examples of projects carried out by Sweco

13

Wastewater

Wastewater treatment plants and sewer systems may need to be protected against rising water levels in seas, lakes and streams or worsening beach erosion.

Measures can be taken to reduce the risk of flooding and downtime on the pipeline network in connection with heavy rainfall.

There is potential to make better use of the energy and nutrient content of wastewater.

Examples of projects carried out by Sweco

14

Stormwater

Runoff from impervious surfaces can be more than ten times higher than from natural areas. To reduce the risk of flooding and improve water quality, stormwater can be delayed and treated locally.

The amount of stormwater may increase with climate change.

In urban planning and development, it is important to designate locations that are suitable for delaying, purifying and discharging stormwater (Combined Green and Grey Infrastructure).

Examples of projects carried out by Sweco

15

Rivers and streams

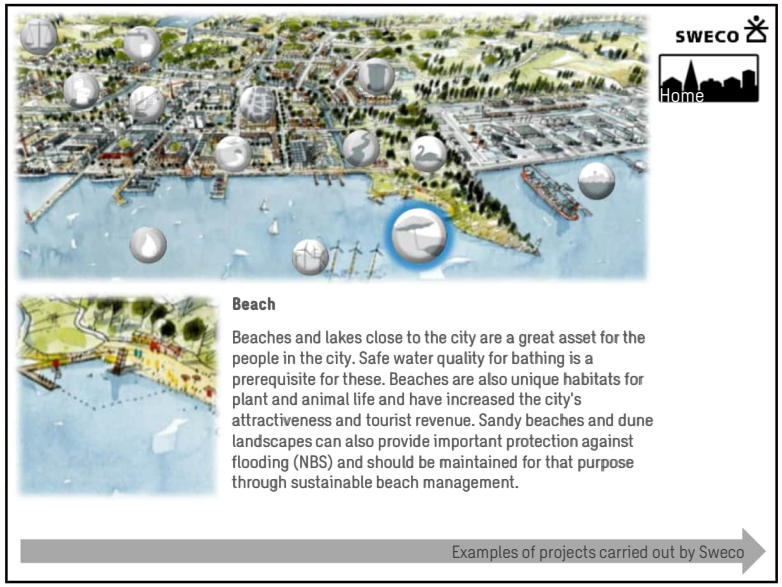
Many coastal cities have bodies of water that run through or near the city. Models can be used to assess flood risks and the effects of measures in waterways.

Changed precipitation patterns can lead to increased water flow, while the watercourse can be affected by rising lake or sea levels.

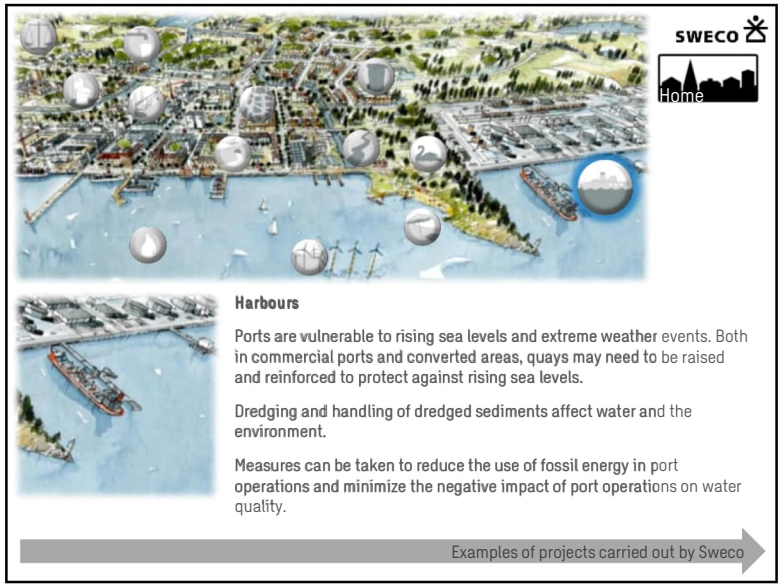
By seeing the watercourse as a natural solution (NBS) to problems and access in urban planning, added value is created.

Examples of projects carried out by Sweco

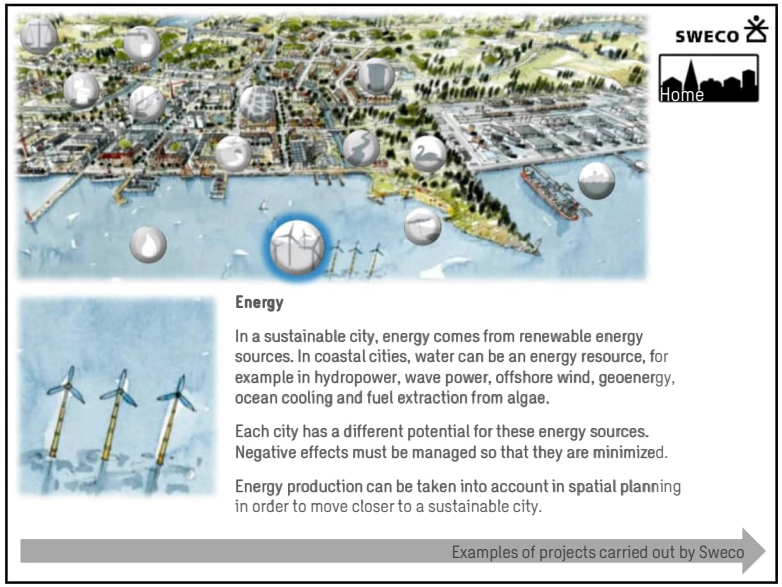
16


SWECO
Home
Beach
Beaches and lakes close to the city are a great asset for the people in the city. Safe water quality for bathing is a prerequisite for these. Beaches are also unique habitats for plant and animal life and have increased the city's attractiveness and tourist revenue. Sandy beaches and dune landscapes can also provide important protection against flooding (NBS) and should be maintained for that purpose through sustainable beach management.
Examples of projects carried out by Sweco

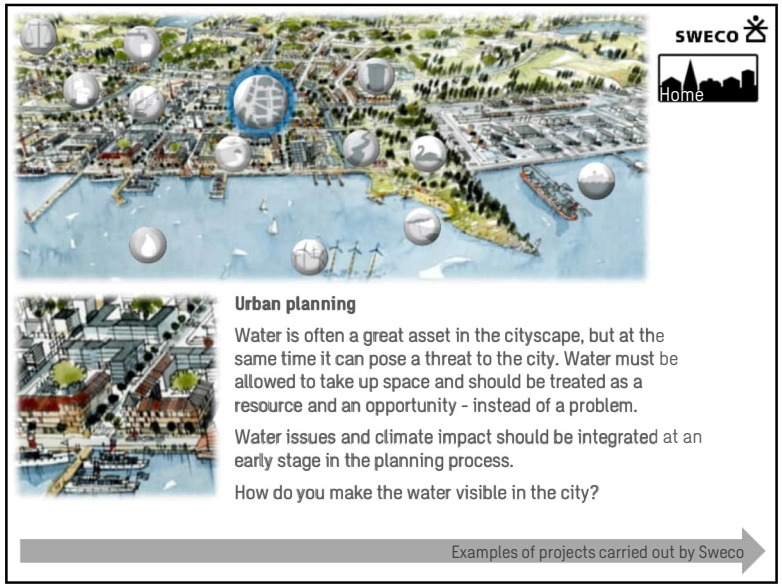
17


SWECO
Home
Harbours
Ports are vulnerable to rising sea levels and extreme weather events. Both in commercial ports and converted areas, quays may need to be raised and reinforced to protect against rising sea levels.
Dredging and handling of dredged sediments affect water and the environment.
Measures can be taken to reduce the use of fossil energy in port operations and minimize the negative impact of port operations on water quality.
Examples of projects carried out by Sweco

18


SWECO
Home
Energy
In a sustainable city, energy comes from renewable energy sources. In coastal cities, water can be an energy resource, for example in hydropower, wave power, offshore wind, geoenergy, ocean cooling and fuel extraction from algae.
Each city has a different potential for these energy sources. Negative effects must be managed so that they are minimized.
Energy production can be taken into account in spatial planning in order to move closer to a sustainable city.
Examples of projects carried out by Sweco

19


SWECO
Home
Urban planning
Water is often a great asset in the cityscape, but at the same time it can pose a threat to the city. Water must be allowed to take up space and should be treated as a resource and an opportunity - instead of a problem.
Water issues and climate impact should be integrated at an early stage in the planning process.
How do you make the water visible in the city?
Examples of projects carried out by Sweco

20

Urban Development

Climate change can lead to increased risks from urban development. It should be decided in a well-thought-out way what ground levels are acceptable for the development of new areas. Well-thought-out plans for protection and measures against increased precipitation, rising sea levels and rising groundwater levels should be developed.

In the case of new development, you also have the best opportunities to choose sustainable solutions right from the start.

Examples of projects carried out by Sweco

21

Legislation

Climate adaptation often means that work is carried out in water, such as dredging, construction of protection against flooding or erosion, land drainage or construction/alteration of facilities in water areas.

These works require a permit and often an EIA.

In the event of flooding, claims for damages sometimes arise and then extensive work is often required to investigate the question of guilt.

Examples of projects carried out by Sweco

22

Waste

Sustainable waste management practices are fundamental for society to function well and people to feel good. Waste management is no longer seen as an end station, but our residual products are treated as a resource. Nevertheless, some waste will continue to need to be taken out of the cycle and stored in safe landfills.

Landfilling and storage can be affected by rising sea and groundwater levels, as well as erosion and heavy rainfall.

Examples of projects carried out by Sweco

23

Natural environment

In the urban environment, there are often elements of natural environments and parks that are an important component in the city being an attractive place to live and work in.

There is great potential here where you can take advantage of nature's own solutions for, for example, flood and erosion protection as well as water quality improvement. These are so-called nature-based solutions that provides ecosystem services.

These environments are often squeezed in new developments and risk being flooded or eroded into the sea in the future.

Examples of projects carried out by Sweco

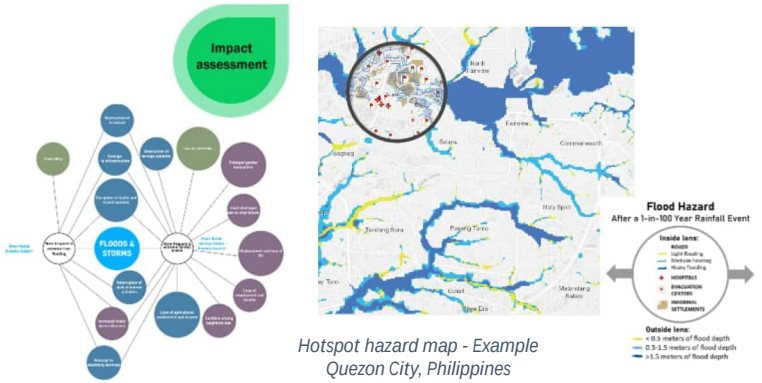
24

The Rapid Climate Risk Assessment (RCRA)

1. **Climate Hazard Assessment**
   - Determine the relevant climate hazards in a city
   - Select relevant climate indicators
   - Analyze historical trends and events and future projections for the hazards
   - Hazard maps
2. Climate Impact Assessment
   - Assess the different impacts
   - Prioritize the identified impacts with city stakeholders
3. Climate Risk Assessment
   - Identify key climate risks
   - Summarize and communicate key climate risks
   - Validation with local stakeholders

25

The Rapid Climate Risk Assessment (RCRA)



Hotspot hazard map - Example
Quezon City, Philippines

26

SymbioCity Approach

1. Define and organize the process
2. Diagnose current conditions
3. Specify objectives, indicators and targets
4. Develop alternative proposals
5. Analyse impacts based on objectives
6. Implementation and follow up

27

28

Caofeidian Eco-City, Tangshan China

Sweco has had an extensive and cross-sectoral assignment in the planning of a new eco-city for 1.2 million inhabitants, designed according to the SymbioCity concept developed by Sweco and Sida, which means that sustainable systems are implemented from the start.

The location of the city is a low-lying area of land that must be protected from extreme high tides.

The city is built in and around water with artificial lagoons and an extensive canal system, like a modern Venice.

The coastal protection is designed as an embankment to the sea after the Dutch model and with large gates similar to the Thames barrier in London. The embankments also create recreational areas with attractive views of both the sea and the city.

29

Stormwater strategy for Stockholm Royal Seaport

Stockholm Royal Seaport is one of Europe's most extensive urban development areas.

A total of 10,000 new homes and 30,000 new workplaces are planned, which will be combined with a modern port and other strategic infrastructure.

Stormwater management must be adapted to a changing climate, be used for irrigation of vegetation and contribute to biodiversity and aesthetic courtyard environments.
The result was large plant beds with a specially mixed soil with both good permeability and good water retention.

30

Action plan for protection against rising sea levels on the Falsterbo Peninsula

The peninsula Falsterbonäset in southern Sweden is mostly located at levels below +3 m.
Sweco has developed an action plan that is divided into three stages until the year 2100.

Measures proposed:

- Beach replenishment
- Levees
- Reinforcement of natural embankments

'The total value of the peninsula's real estate amounts to SEK 60 billion."
Hans Hanson, professor LTH

31

Port of Gothenburg

Over the years, Sweco has carried out a large number of assignments at the Port of Gothenburg, which is the largest port in Scandinavia.

The port has a clear environmental profile and has been awarded the prestigious Energy Globe Award in 2011 and the Sustainable Shipping Award in 2011.

Examples of environmental initiatives:

-
- Electrical connection of vessels at the quayside
- Eco-labelled electricity
- Gas recovery during ship loading
- Rail shuttles with electric trains for freight transport
- Sustained and safe disposal of con**taminated dred**ged material

32

Project management and coordination, testing of offshore wind power

Blekinge Offshore AB plans to build a wind farm, Blekinge Offshore, with a maximum of 700 wind turbines in Hanö Bay.

Sweco has led and coordinated the review process, which has entailed:

- Consultation paper and conduct of consultations
- EIA incl. associated specialist investigations
- Complete permit application
- Response to comments received from authorities and other interested parties

33

Climate risk assessment as baseline for future urban planning, Karlshamn

Sweco has interpreted climate predictions and analysed possible consequences for important societal functions such as:

- Changes in stormwater volumes Increased overflow in the sewer system
- Risk of water scarcity
- Flooding of essential services
- The substrate allows development to take place safely for rising sea and groundwater levels as well as extreme rainfall.

"Long-term planning is flexible planning."
Sebastian Irminger-Street, project manager

34

Måned 2023

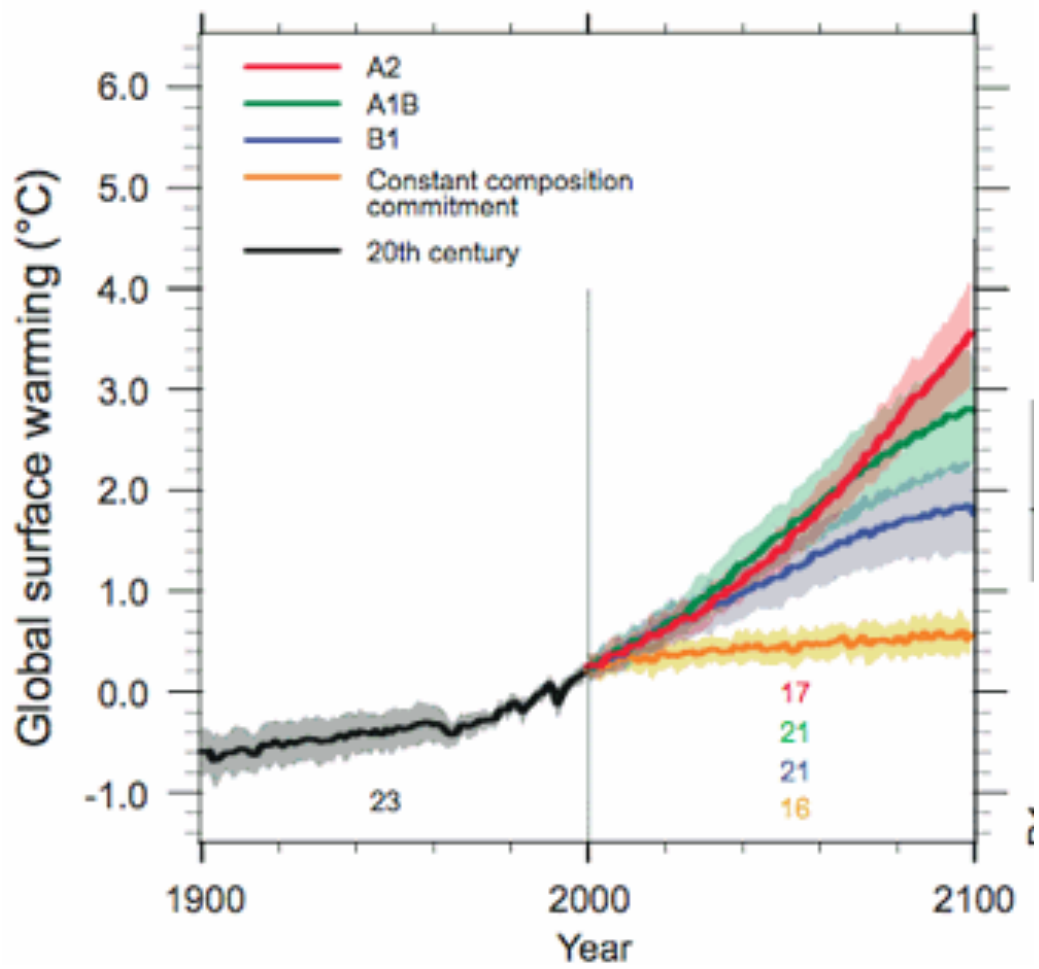
The Technical and Environmental Administration
Mobility, Climate Action and City Structures

Climate adaptation in Copenhagen

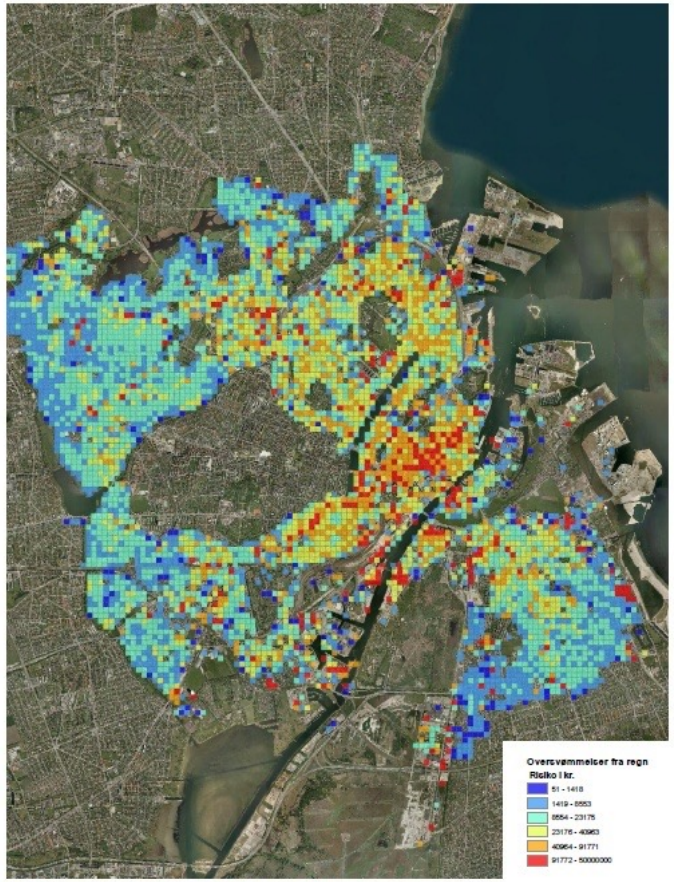
The City of Copenhagen – Denmarks biggest municipality

Climate change

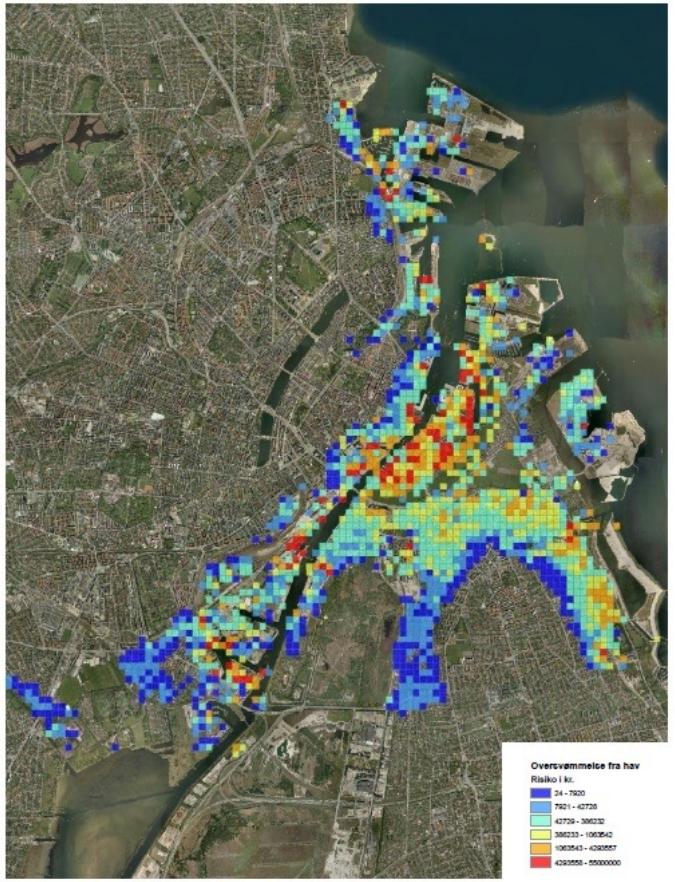
- 30% more rain over the next 100 years
- More frequent and heavyer cloudburst
- 1 meter higher sealevel in 100 years



Risk asessment

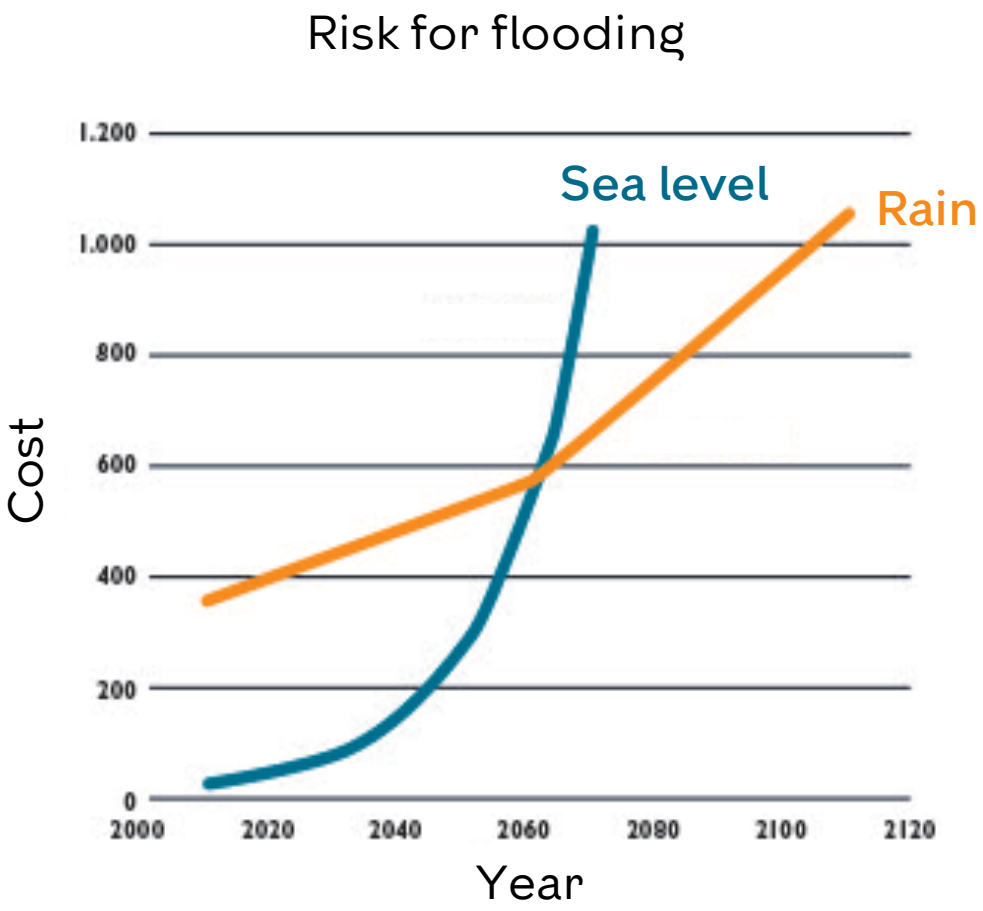


Risk map for flooding caused by rain in 2110



Risk map for storm surges from the sea in 2110

The adaptation plan



2 July 2011

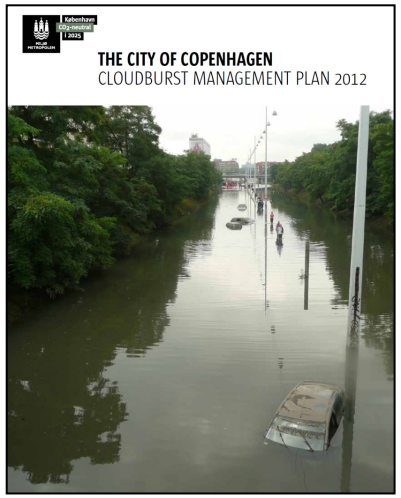
Time line of adaptation proces in Copenhagen

August 2011

Plan approved by City Council

December 2012

Plan approved by City Council

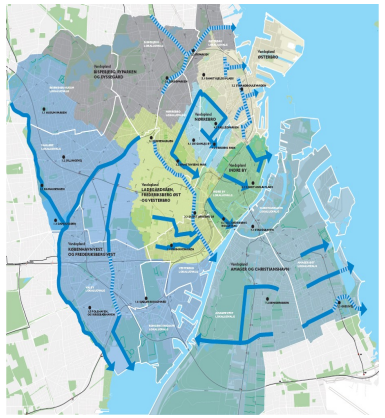


2013-2014

Preparation af plan for each water catchment area

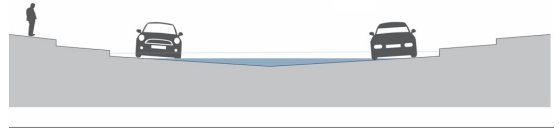
November 2015

Political decision for implementation

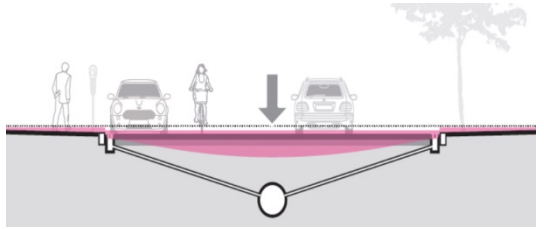


5 types of solutions

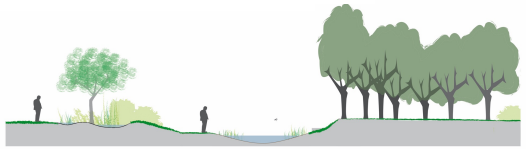
1. Cloudburst boulevards – transporting water



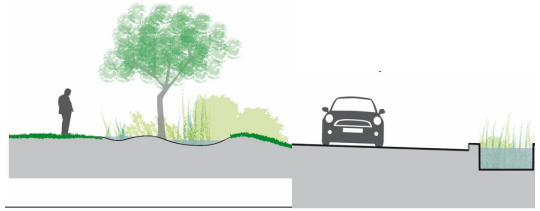
2. Pipes transportation under ground



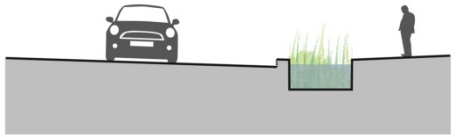
3. Retention boulevards – delaying water



4. Central delays – for storing water



5. Green roads – transport and delay of water on small roads



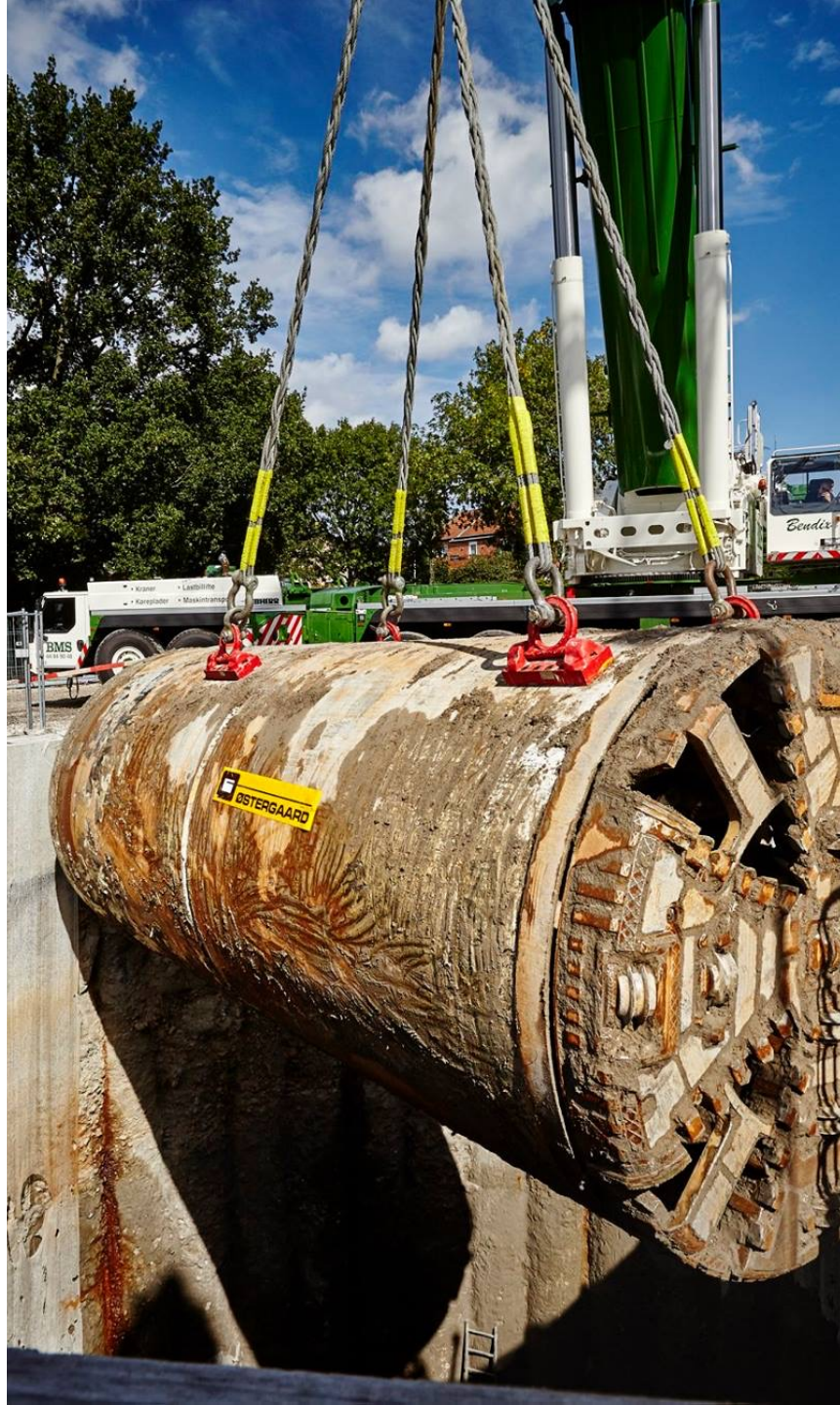
City of Copenhagen

- Climate adaptation planing
- Surface projects
- Coordination of projects
- Greening
- UHI and other climate issues

City of Copenhagen

HOFOR

- Hydraulic calculation
- Sewage system
- Pipe construction
- Green roads
- Financing of rainwater handling



Cobenefits of adaptation

- Recreational value
- Biodiversity
- Meeting places
- Improved microclimate (UHI)
- Synergy with urban renewal
- Architecture
- Attractive city
- Rainwater recycling

Cloudburst project at Taasinge Plads

Retention and infiltration of rainwater at the square

Cloudburst project at Husum Vænge

Retention of rainwater in the park

Cloudburst project at Skt. Kjelds Plads

Retention, infiltration and transport of rainwater

Cloudburst project at Karens Minde

Retention of rainwater in green area

Cloudburst project at Enghave park

Retention of rainwater in the park

Cloudburst project at Enghave park

Retention of rainwater in the park

Cloudburst project at Scandiagade

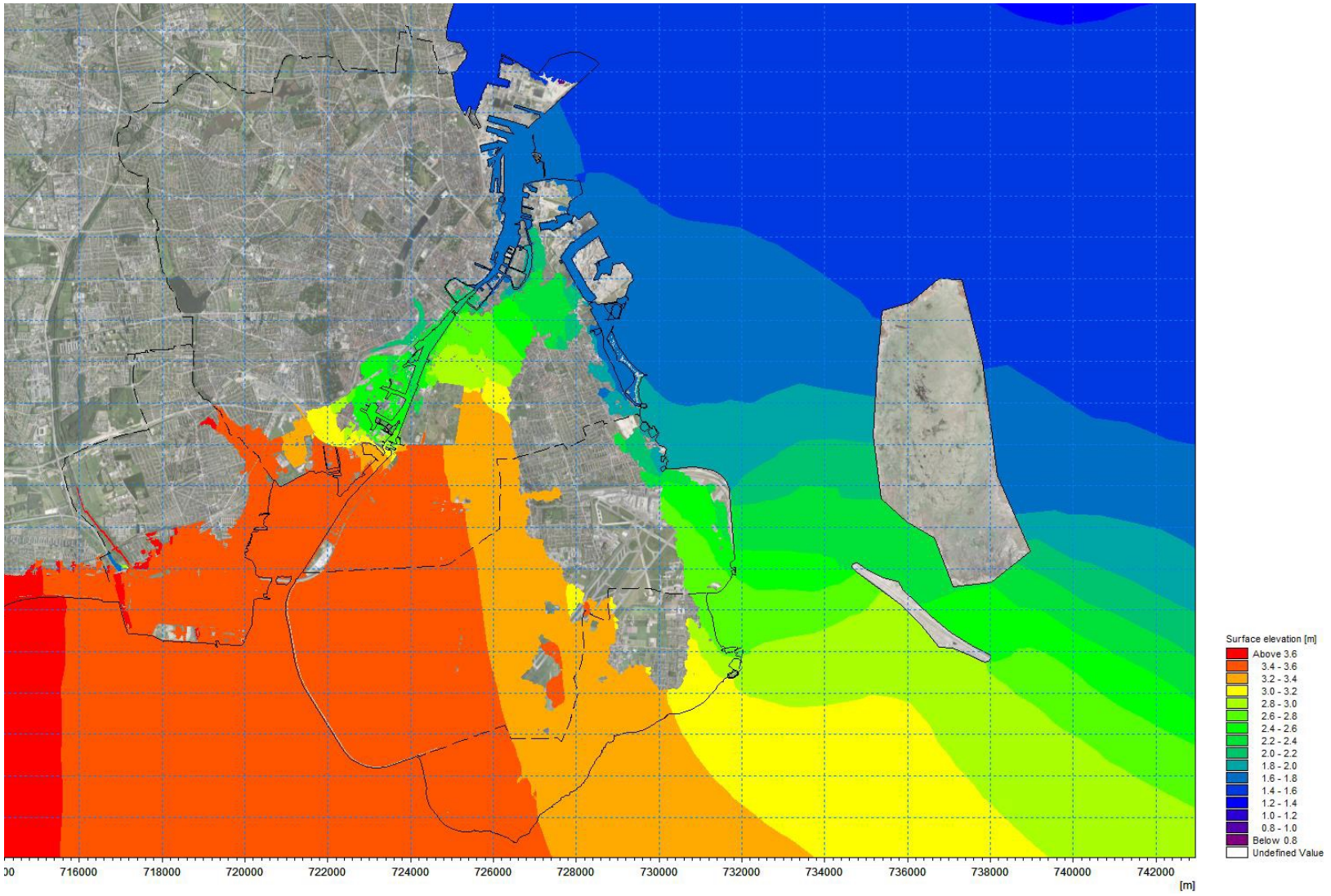
Eight sunken gardens with different themes – total volume of 1,500 m3

Cloudburst project at Remiseparken

Storm surge

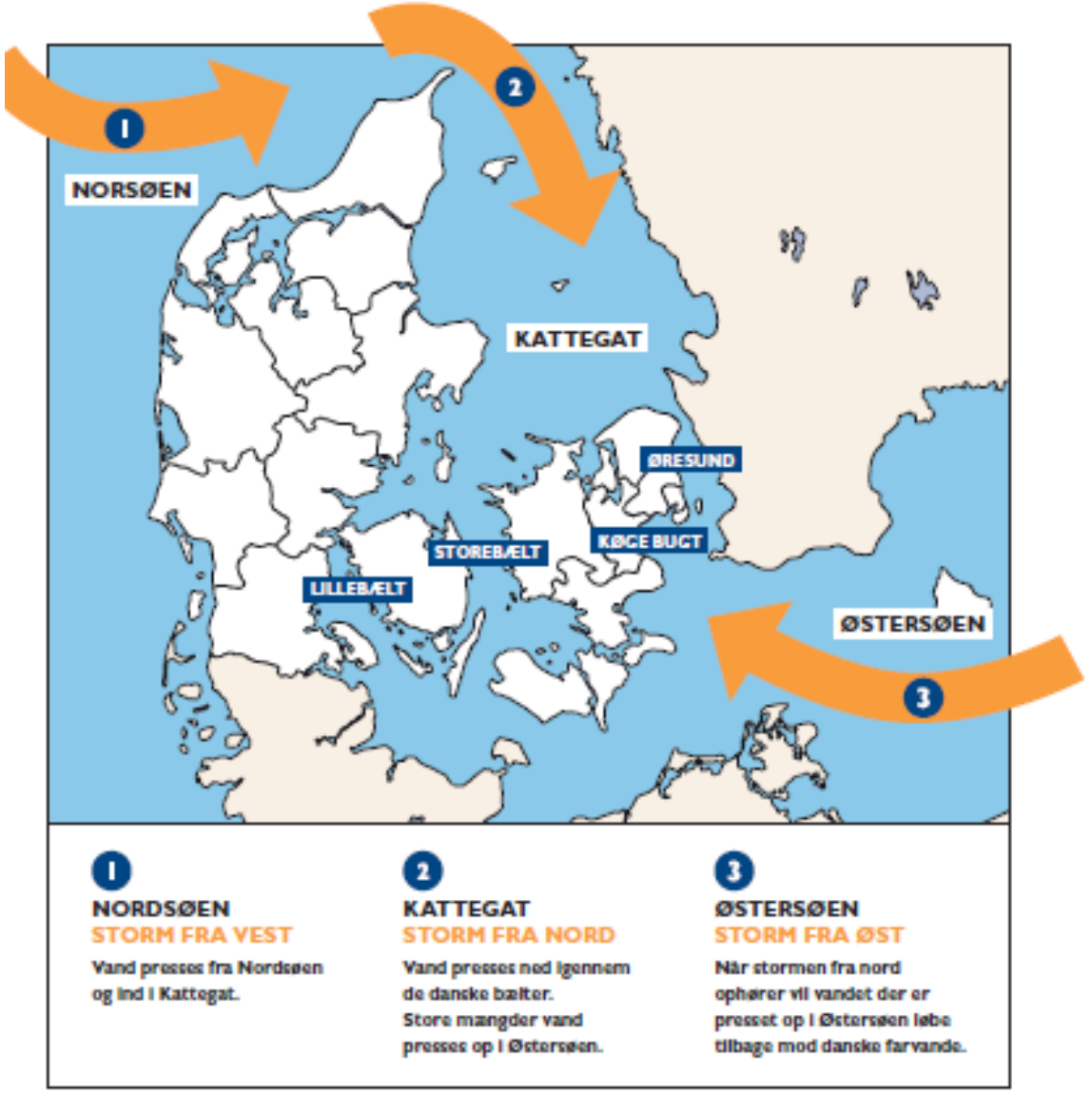
Storm surge

- 1000 years storm surge
- From south
- 3,76 meters at Avedøre

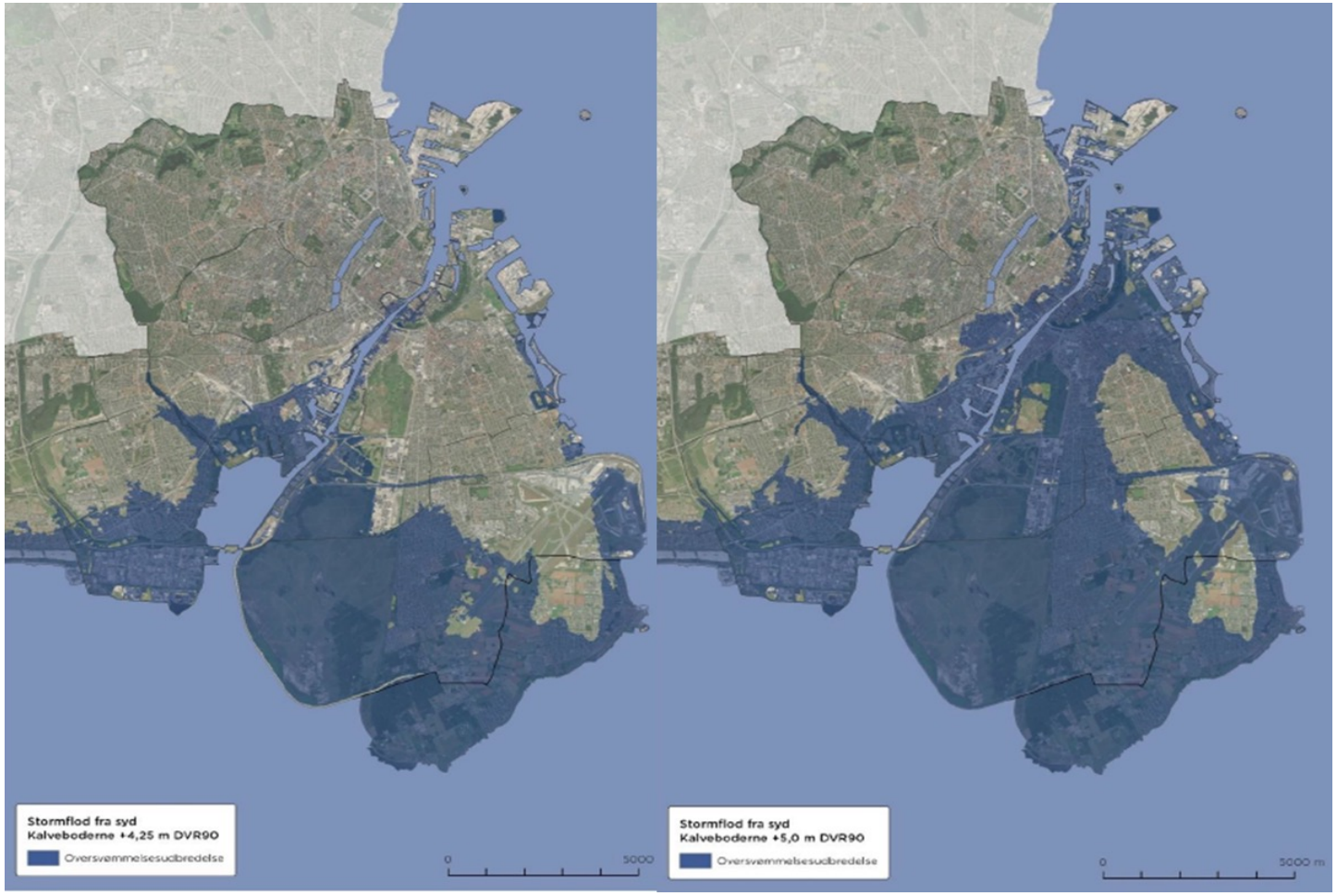


Storms in the Baltic

- Storm from the north – presses water into the Baltic
- Storm from the South/East pushes water out of the Baltic
- Dangerous combination:
- A storm from the North, and a wind change to the South/East.



The challenge – today and in the future (2100)



Main solution: An external barrier

Summing up:

Storm Surge Plan politically adopted the 22nd of June 2017

- Main strategy: outer protection scheme
- Protection-level: 1000-year storm surge in 2100.
- Protection schemes against storm surges from south (now) – based on socioeconomic calculations
- Project running in 2020 focusing on storm surges from south

Lynetteholmen

Storm flood protection as part of urban development

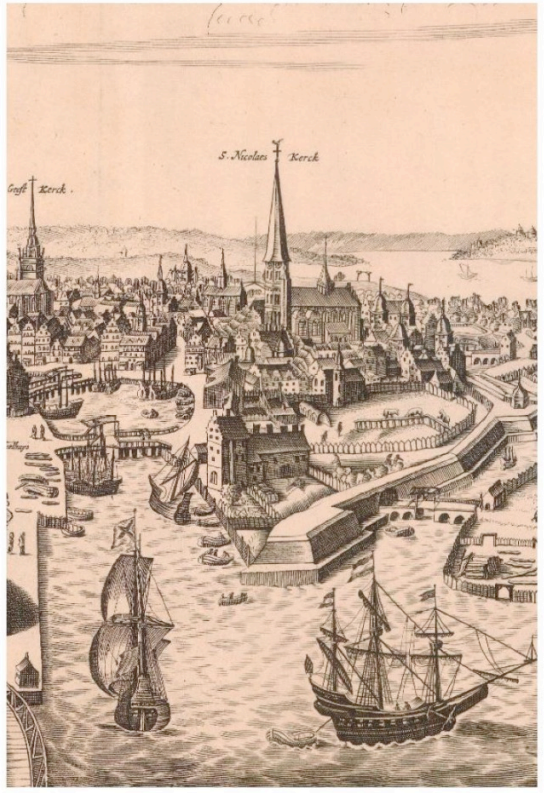
- A new island
- Harbor tunnel
- Subway
- Housing
- Park
- Storm surge protection

Lynetteholmen – securing the northern part

- Storm surge management plan – securing the city with an outer protection
- Lynetteholmen is an artificial island and part of this protection. Size 2.8 km^2
- Construction started at the end of 2021 – and continue until 2070. A flood gate will be added at some point
- Purpose:
  - Contributes to securing northern Copenhagen from a storm surge
  - New urban development – up to 35.000 new residents.
  - Soil deposit
  - Can contribute to financing investments in ring road and more metro

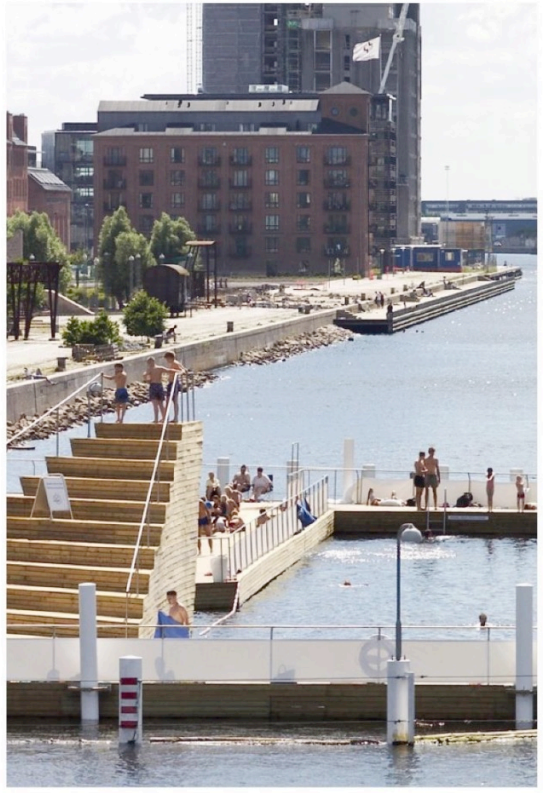
The historical perspective

The development of the edges of Copenhagen



BEFÆSTET KANT

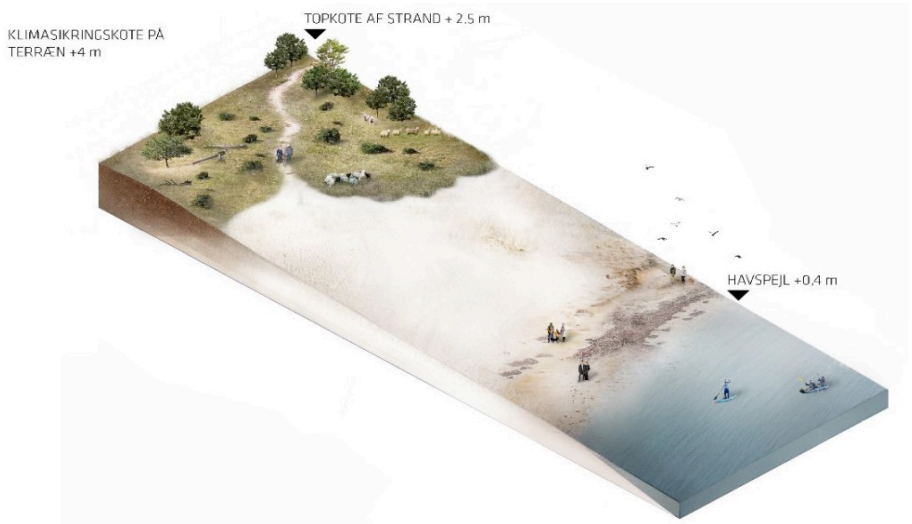
INDUSTRIEL KANT



POSTINDUSTRIEL KANT

NATURBASERET KLIMASIKRET KANT

Nature based solutions



ÅR 2070

- Topkote af kysten kan reduceres til koter varierende fra +2,5 m til +3,7 m afhængig af kysttypen og med et bagland på +4,0 m
- København får bynær natur med høj biodiversitet og stor rekreativ værdi.
- Stranden og den landskabelige klimasikring skaber og sikrer adgang til Øresund.
- Den nye bydel får mulighed for landskabelige kvaliteter og naturværdi allerede i anlægsperioden, hvor jordopfyldning stadig pågår.

ÅR 2200

- Topkote af kysten kan forhøjes til +4,0 m og med et bagland på +4,0 m
- København får bynær natur med høj biodiversitet og stor rekreativ værdi.
- Stranden og den landskabelige klimasikring skaber og sikrer adgang til Øresund.
- Den nye bydel får mulighed for landskabelige kvaliteter og naturværdi allerede i anlægsperioden, hvor jordopfyldning stadig pågår.

Challenges:

Urban development
– 35.000 new residents

Transport issues?
Metro line

Transport issues?
New coastal ring road

Construction issues:
Possibleremoval of waste water treatment plant

Environmental issues:
Impact on flow in Øresund

Environmental issues:
inflow of water in Copenhagen harbour

Construction issues:
Transport of soil for construction of island

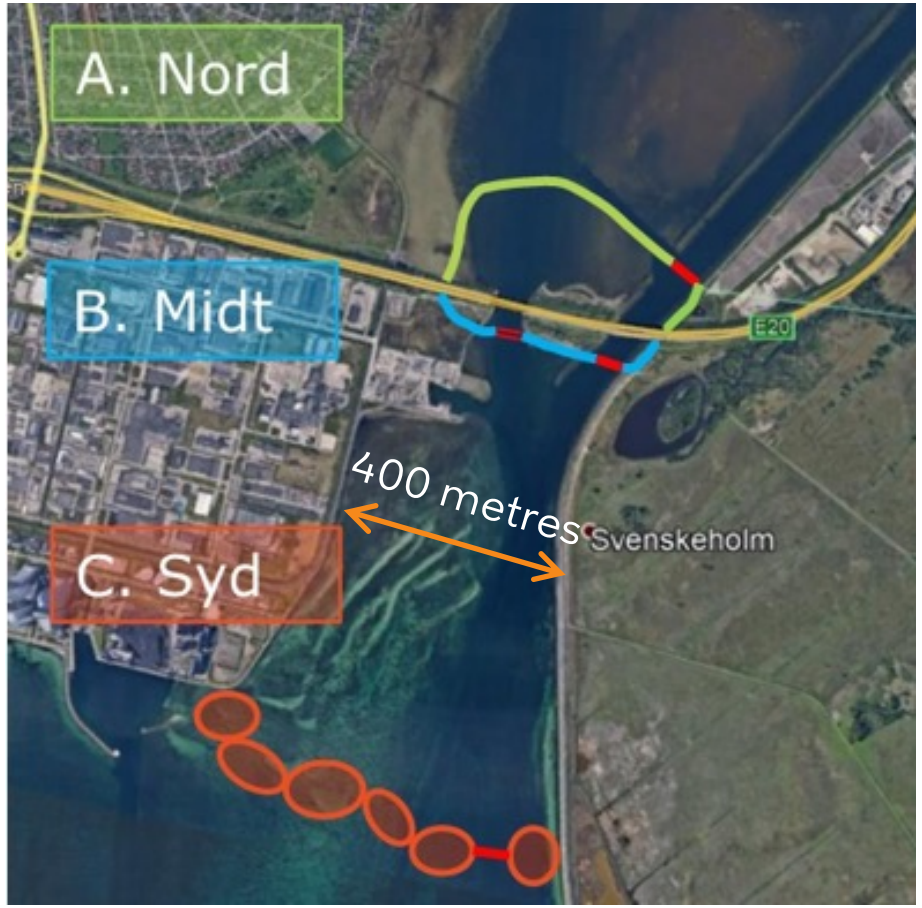
Construction issues:
Polluted soil removed from seabed

Southern Protection

- Much greater risk than storm surge from north.
- Damages can reach 4.5 billion Euro
- Joint project between Copenhagen and neighbouring municipalities
  - New flood mapping and scale of storm surges from the south. Calculation of socioeconomic consequences of storm surge protection Composition of contributory models of financing related to a southern protection scheme.
  - Screening of potential solutions for storm surge barriers, including potential location for solution (Natura 2000 area)

Potential solutions (first screening)

- Solutions stretches from being very technical to more nature-based, fx:
  - Dikes and gates
  - Or an array of islands (south) and a gate
- Only first screening!
- Located in a nature protection area (Natura 2000)



Socioeconomic analysis

Analysis included: direct losses + indirect losses

- Infrastructure companies:
  - Physical damages on infrastructure
  - Operating losses
- Road users:
  - Inconvenience of delays (for flight passengers, road users, travelers in public transportation)
- Others (owners of buildings, electricity infrastructure etc.)
  - Physical damages on buildings and infrastructure
  - Rehousing
  - Illness
  - Operating losses

Forward-looking approach: Integrated solution – involves 5 municipalities

Lessons learned and needs

- Multidisciplinary collaboration is essential
- Projects have a high complexity
- Challenges existing practices - and existing legislation
- Need for innovative solutions
- Knowledge of hydraulic connections between projects is crucial to the framing of each project
- Urban space potential depend on knowledge of water management.


Thanks for your attention