Planning adaptively for sea level rise, supported by quick-scan tools

Webinar November 19th, 2019

FIU Institute of Water and Environment
Florida International University

Deltares USA

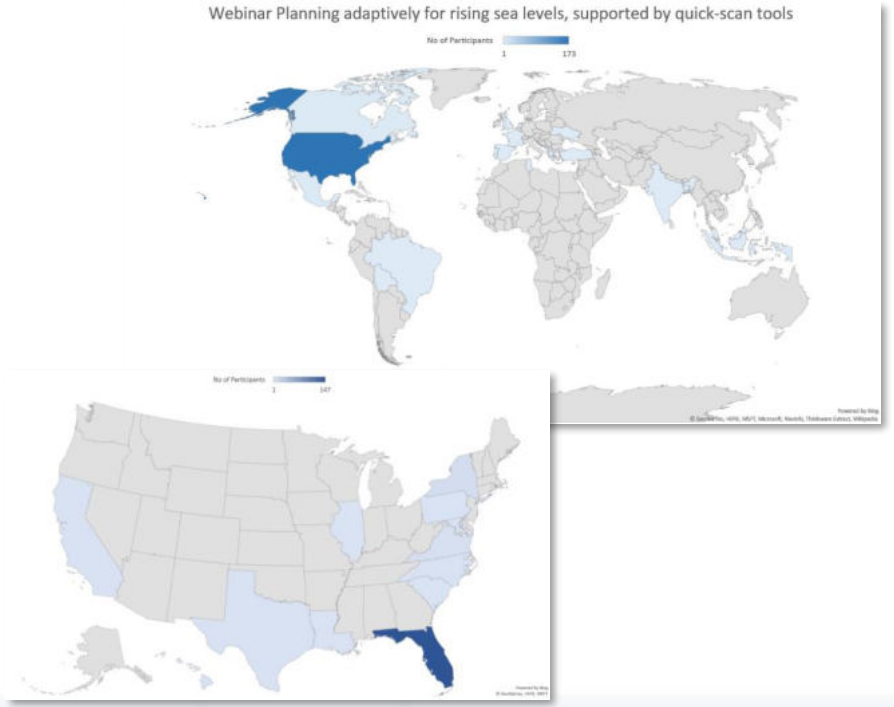
South Florida Water Management District

Deltares
Enabling Delta Life

FIU Sea Level Solutions Center
Florida International University

Introduction | This webinar

- > 200 registrations
- 17 countries
- 173 US, 13 states
- 147 Florida
- Governments, NGO's, consultants, universities, small businesses



Introduction | Speakers

- **Dr. Jayantha Obeysekera**, Research Professor and Director of the Sea Level Solutions Center, Florida International University

- **Akintunde Owosina**, P.E., Chief Hydrology and Hydraulics Bureau. South Florida Water Management District

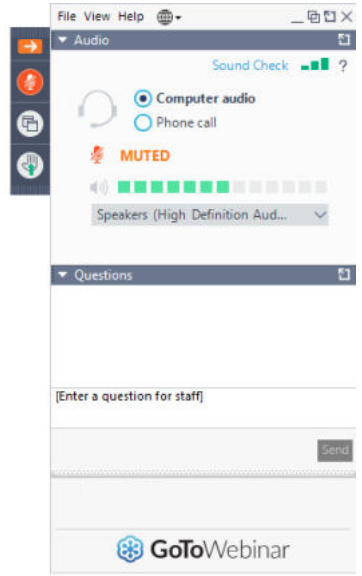
- **Dr. Marjolijn Haasnoot**, Adaptive planning and water management specialist, developer of the Dynamic Adaptive Policy Pathways, Deltares

- **Dr. Kathryn Roscoe**, flood risk and adaptation specialist and regional coordinator USA & Canada, Deltares

- **Dr. Claire Jeuken**, nature-based solutions and flood risk adaptation expert, Deltares USA

Introduction | Webinar outline

1. Introduction to adaptive planning
2. Dynamic Adaptive Policy Pathways (DAPP)
3. Tools supporting the DAPP approach
4. Discussion



#daretoask

Webinar outline | next presenter

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Introduction to adaptive planning | Background

Project: Development of Short- and Long-Term Strategies for Resiliency with respect to Coastal Flooding in Miami-Dade County

- **Funded by** Florida Department of Environmental Protection
  (Florida Coastal Management Program)
- **Collaborators:**
  - South Florida Water Management District
  - Deltares USA
  - FIU Sea Level Solutions Center
  - Miami Dade County (Office of Resilience and Emergency Management)
  - City of Miami

Introduction | We need a new paradigm for Resiliency Planning

Five Principles of Resiliency in coping with extremes:

1. Adopt a system's approach;
2. Look at beyond-design events;
3. Build and prepare infrastructure according to 'remain functioning'
4. Increase recovery capacity by looking at social and financial capital; and
5. Remain resilient into the future

Implications:

- **Plan for future** and not the present – projections can be deeply uncertain
- **Price tag** can be very high, and financing can be challenging
- **Smart phasing** of adaptation strategies is desirable

De Bruijn et al. (2017)

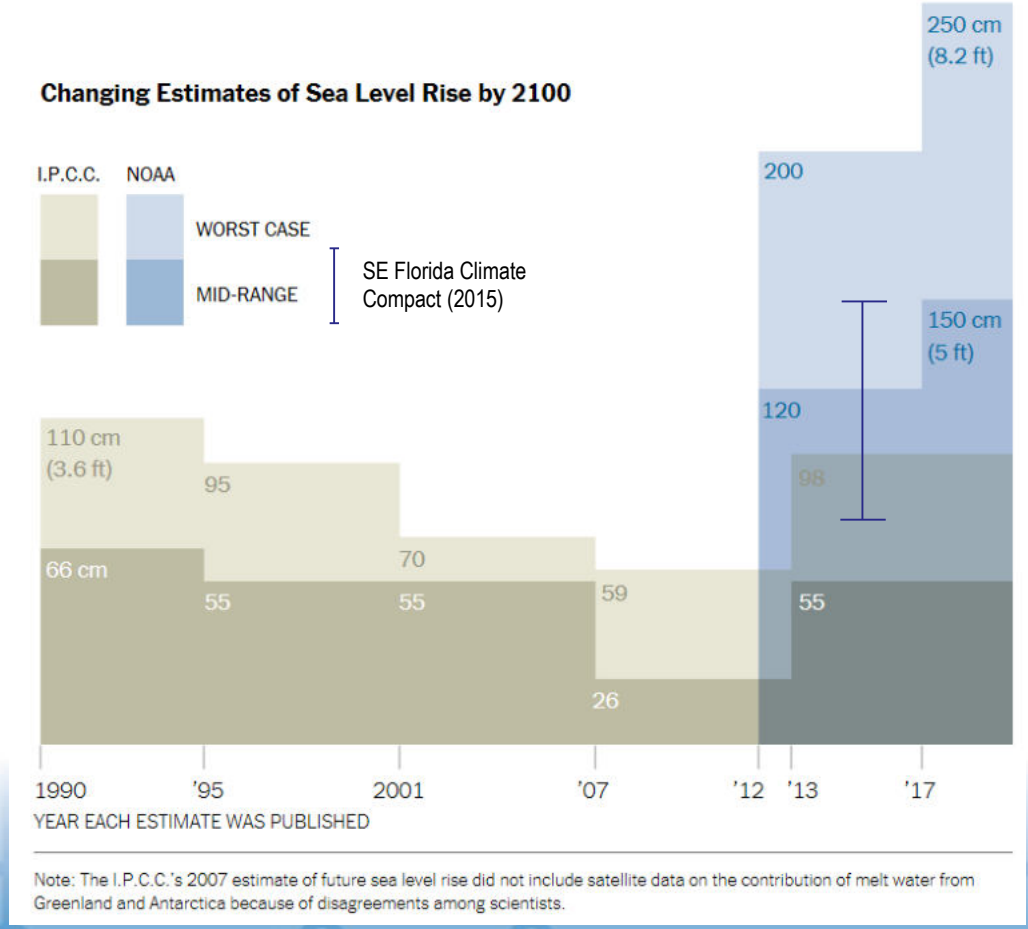
Introduction| Sea level rise projections for 2100

Larger bandwidth
Uncertainty increased
→ Deep uncertainty

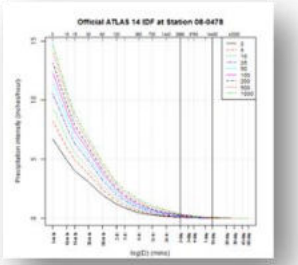
The New York Times

Rising Seas Will Erase More Cities by 2050, New Research Shows

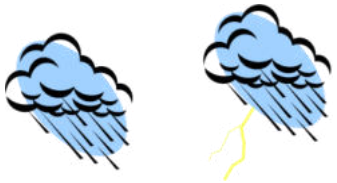
By Denise Lu and Christopher Flavelle Oct. 29, 2019

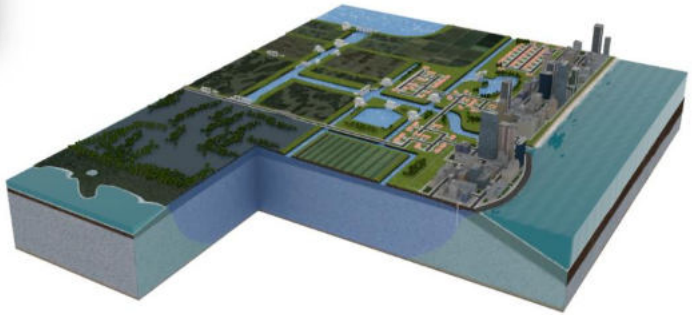


Introduction | Uncertainties in “Shocks” and “Stresses”



Rainfall
Extremes:
IDF Curves

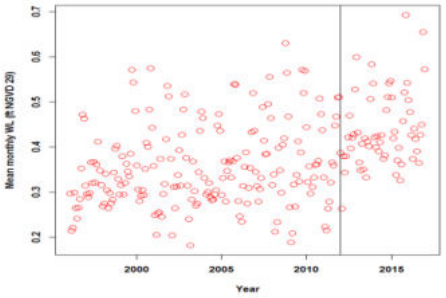




Future
Storminess?

Fig. 2. Diagram illustrating the contributions to sea level due to tides, storm surge and wind-generated waves.

SLR: Which Scenario?

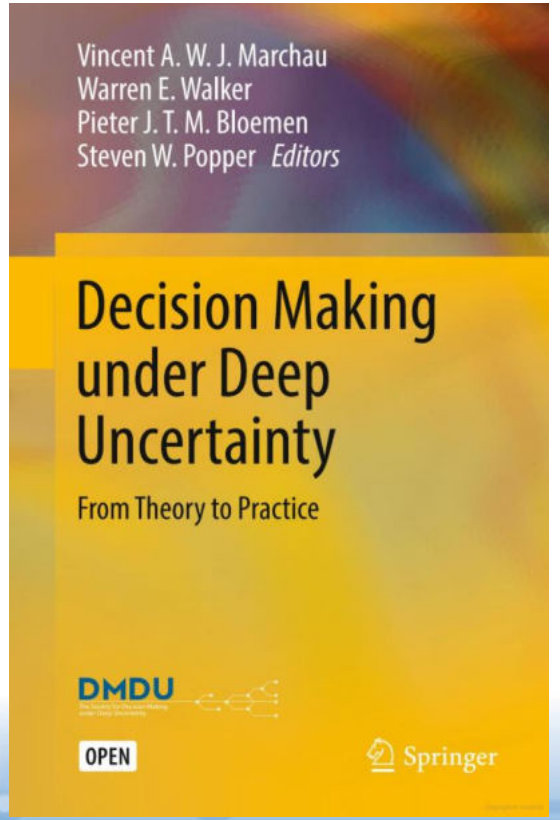


Ocean Dynamics, Gravitational Effects

Socio-economic trends?
TheBalance.com

Selected Methods of DMDU:

- Robust Decision Making (RBM) pioneered by RAND
- Decision Scaling or Stress Test ("bottom-up approach")
- Dynamic Adaptive Policy Pathways (DAPP) developed by Deltares and TU Delft, The Netherlands

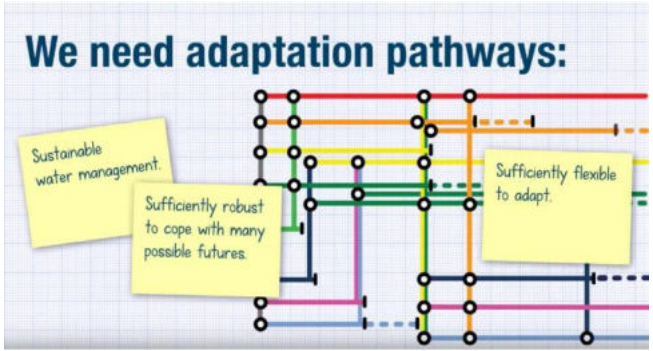


https://link.springer.com/book/10.1007/978-3-030-05252-2

Dynamic Adaptive Policy pathways (DAPP) | Introduction

Decisions are made over time in dynamic interaction with the system and cannot be considered independently

- DAPP explicitly includes decision making over time and sequences of decisions (pathways) under uncertainty.
- Supports planners to design a dynamic adaptive plans: short-term actions, long-term options, adaptation signals.



"Different roads leading to Rome"

Haasnoot et al. (2013) Glob. Env. Change. 10.1016/j.gloenvcha.2012.12.006

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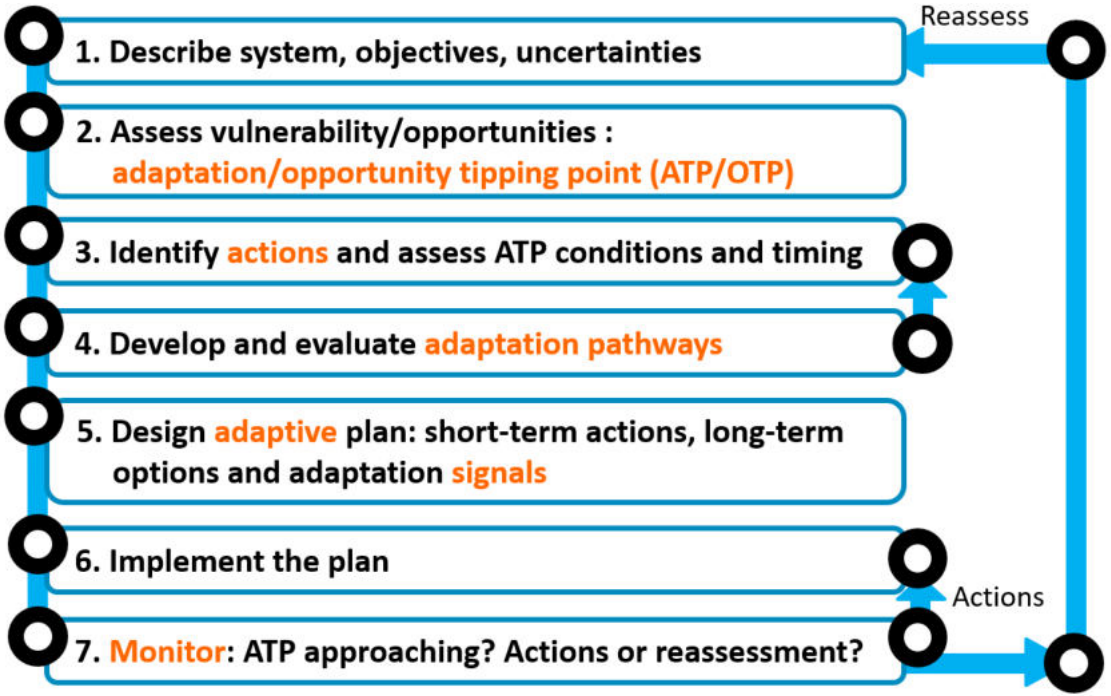
Adaptive pathways planning using DAPP

A **systematic framework t**hat helps focus on important planning and decision **questions** under deep uncertainty:

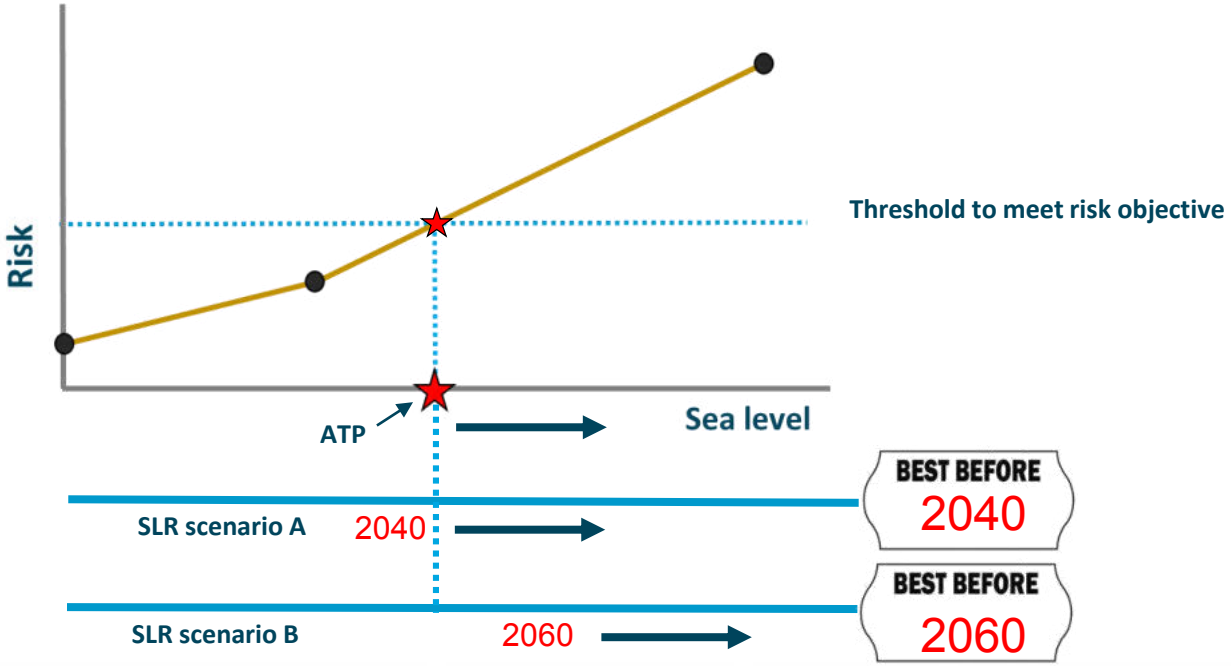
- What low-regret actions can we take now that contribute to future goals?
- What actions can we postpone? How to prioritize?
- What robust and flexible strategies perform well over a wide range of futures?

Systematic framework of DAPP

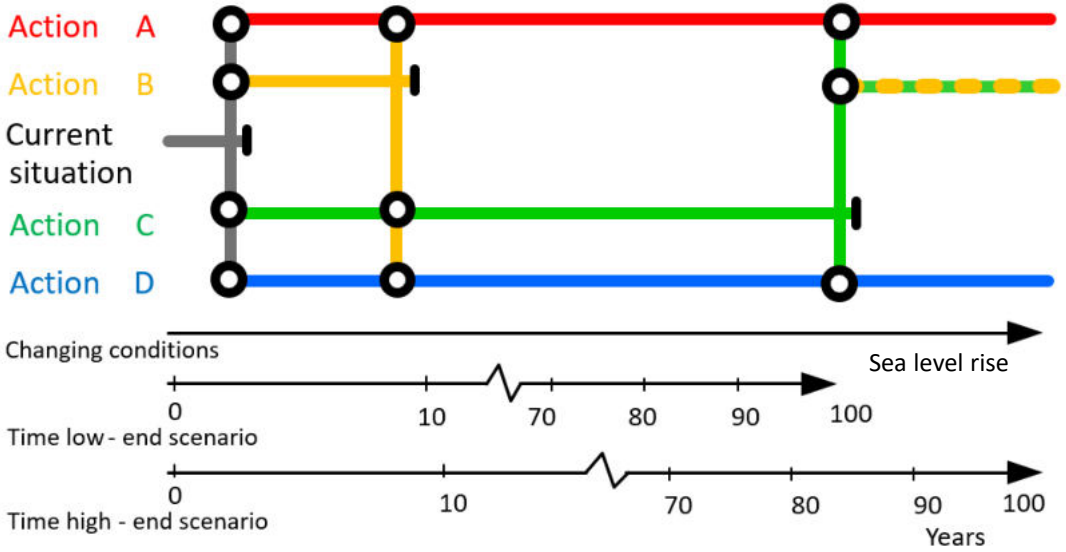
Key features:



Adaptation Tipping Points (ATP)



Adaptation pathways maps



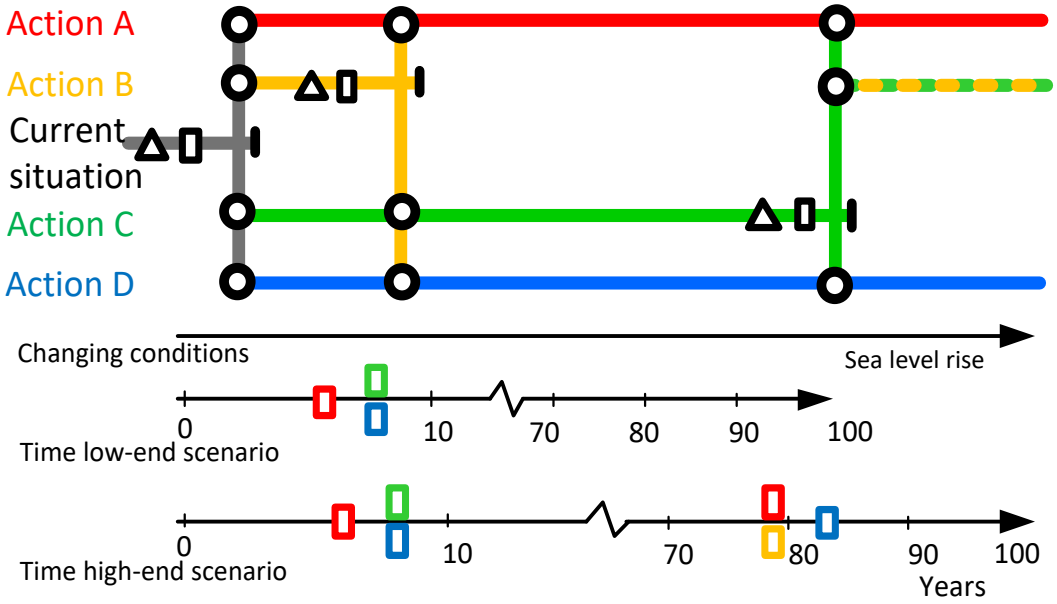
Time horizon 100 years

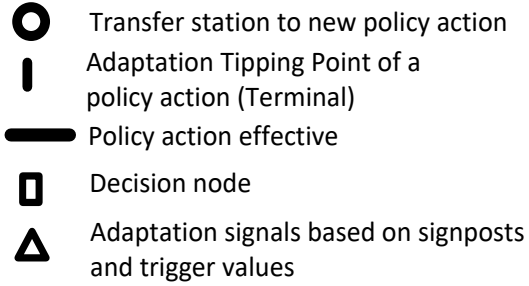
Pathway	Costs	Benefits	Co-benefits
1	+++	+	0
2	+++++	0	0
3	+++	0	0
4	+++	0	0
5	0	0	-
6	++++	0	-
7	+++	0	-
8	+	+	---
9	++	+	---

Transfer station to new policy action
Adaptation Tipping Point of a policy action (Terminal)
Policy action effective

The maps (left) show different possible sequences of decisions to achieve objectives. A scorecard (right) helps to evaluate the pathways and decisions.

Adaptation pathways maps





Haasnoot et al. 2013; Haasnoot et al. 2018 Glob. Env. Change, Haasnoot et al. 2019

http://pathways.deltares.nl

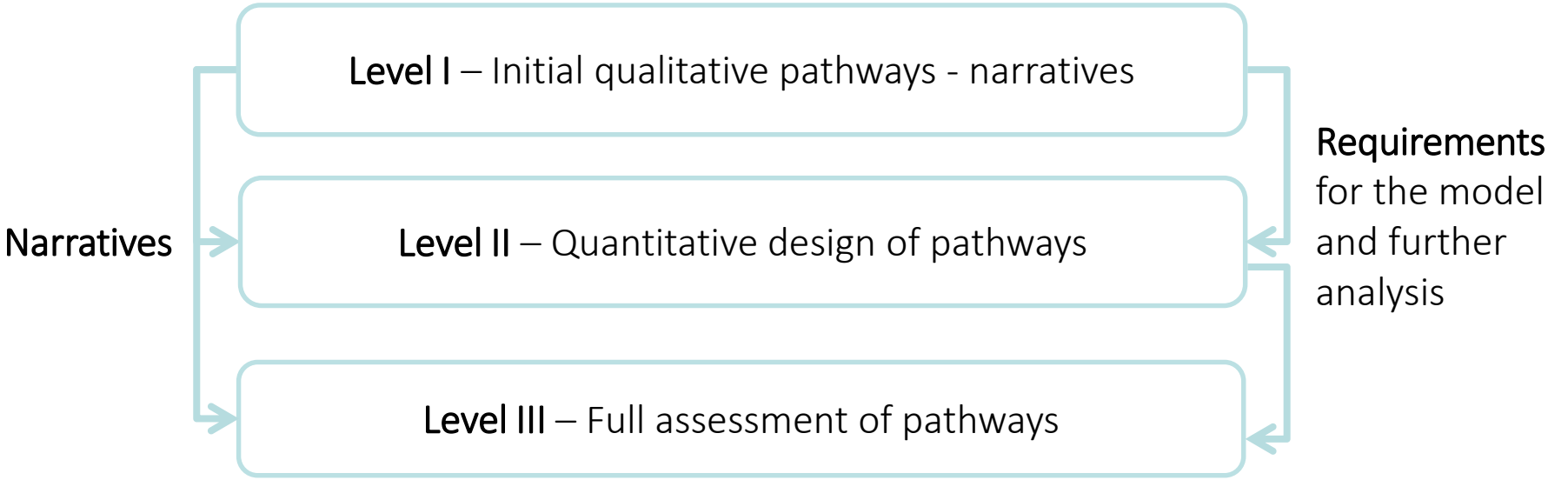
A phased approach to pathways

Awareness raising:

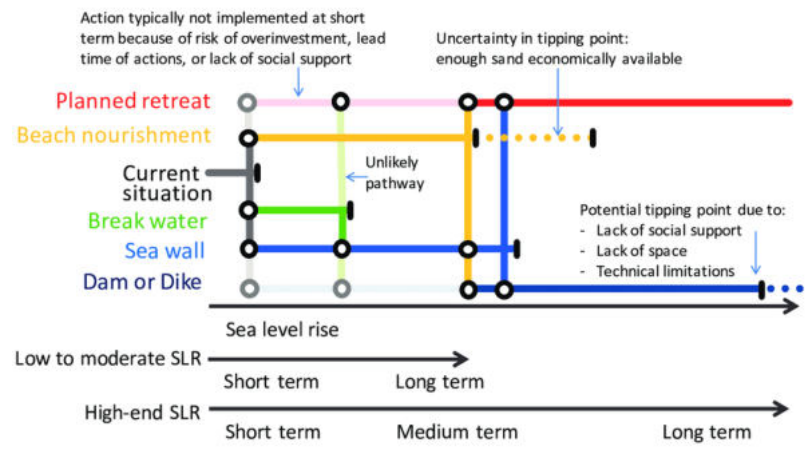
- Serious gaming.
- Introduction to adaptive planning method.

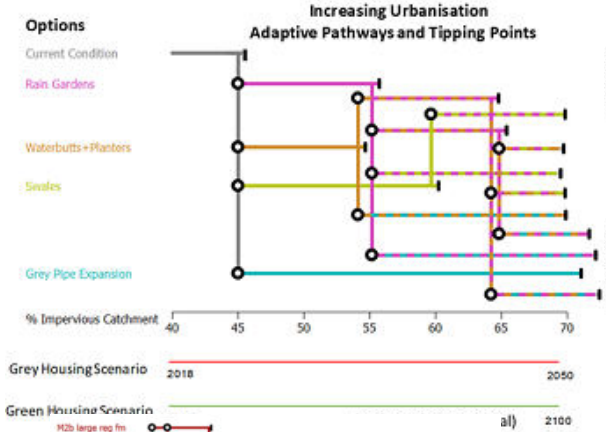
http://deltagame.deltares.nl

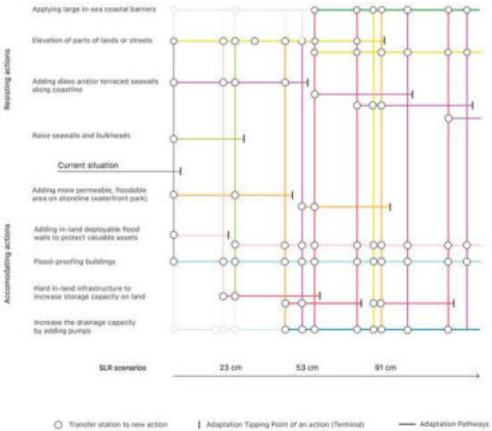
A phased approach to pathways

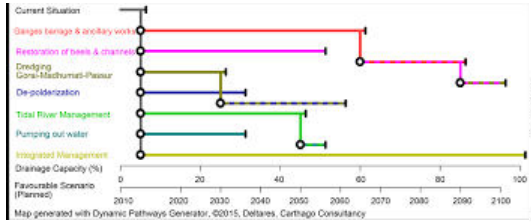


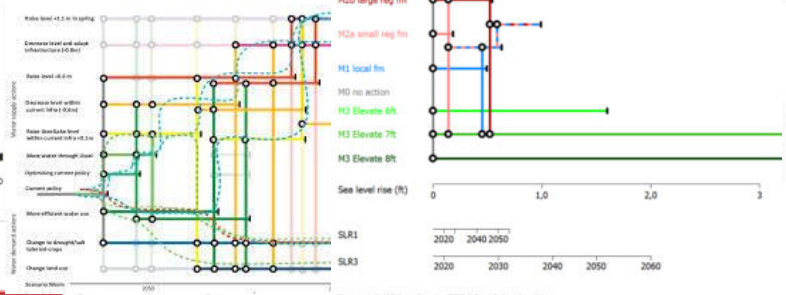
Where have pathways studies been applied?

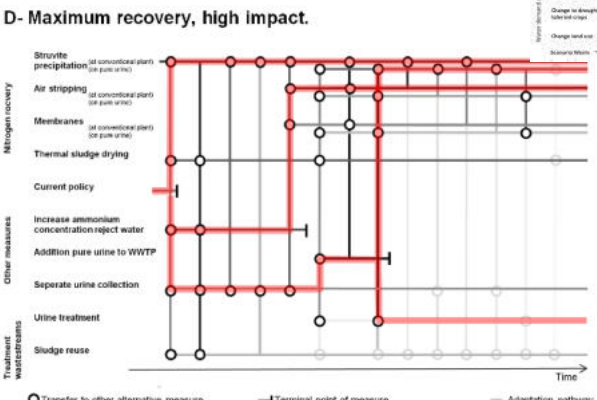

Action typically not implemented at short term because of risk of overinvestment, lead time of actions, or lack of social support
Uncertainty in tipping point: enough sand economically available
Planned retreat
Beach nourishment
Current situation
Break water
Sea wall
Dam or Dike
Unlikely pathway
Potential tipping point due to:
- Lack of social support
- Lack of space
- Technical limitations
Sea level rise
Low to moderate SLR
Short term
Long term
High-end SLR
Short term
Medium term
Long term

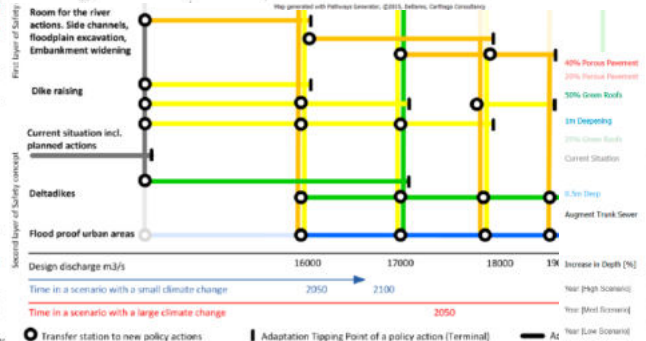

Options
Current Condition
Rain Gardens
Waterbutts+Planters
Swales
Grey Pipe Expansion
Increasing Urbanisation
Adaptive Pathways and Tipping Points
% Impervious Catchment
40
45
50
55
60
65
70
Grey Housing Scenario
2018
2050
Green Housing Scenario
2100

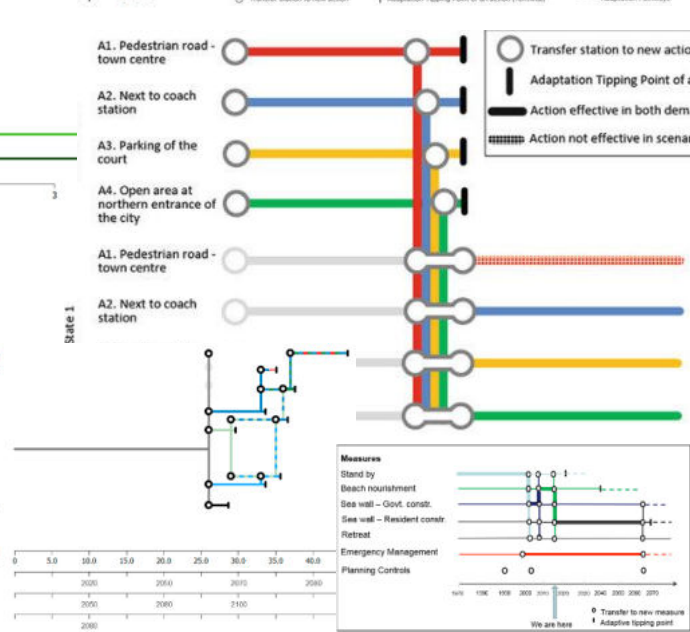

Applying large in-sea coastal barriers
Elevation of parts of lands or streets
Adding dikes and/or terraced seawalls along coastline
Raise seawalls and bulkheads
Current situation
Adding more permeable, floodable area on shoreline (waterfront park)
Adding in-land deployable flood walls to protect valuable assets
Flood-proofing buildings
Hard in-land infrastructure to increase storage capacity on land
Increase the drainage capacity by adding pumps
Retreating actions
Accomodating actions
SLR scenarios
23 cm
53 cm
91 cm


Current Situation
Ganges barrage & ancillary works
Restoration of beels & channels
Dredging Gorai-Madhumati-Passur
De-polderization
Tidal River Management
Pumping out water
Integrated Management
Drainage Capacity (%)
Favourable Scenario (Planned)
0
20
40
60
80
100
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Map generated with Dynamic Pathways Generator, ©2015, Deltares, Carthago Consultancy


Water supply actions
Water demand actions
M2b large reg fm
M2a small reg fm
M1 local fm
M0 no action
M3 Elevate 6ft
M3 Elevate 7ft
M3 Elevate 8ft
Sea level rise (ft)
0
1,0
2,0
3
SLR1
SLR3
2020
2040 2050
2020
2030
2040
2050
2060

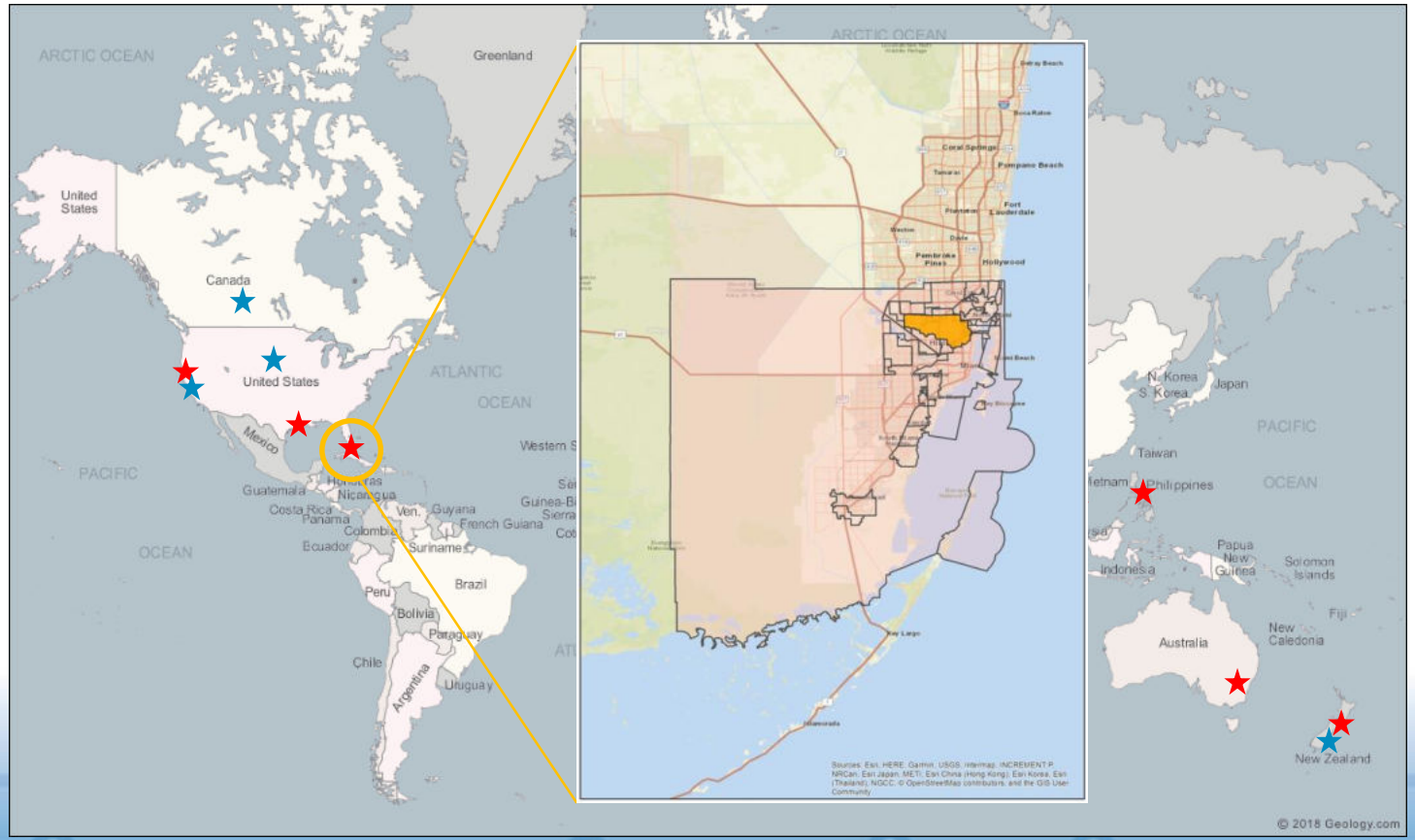

D- Maximum recovery, high impact.
Nitrogen recovery
Other measures
Treatment wastestreams
Struvite precipitation
Air stripping
Membranes
Thermal sludge drying
Current policy
Increase ammonium concentration reject water
Addition pure urine to WWTP
Seperate urine collection
Urine treatment
Sludge reuse
Time


First layer of Safety
Second layer of Safety concept
Room for the river actions. Side channels, floodplain excavation, Embankment widening
Dike raising
Current situation incl. planned actions
Deltadikes
Flood proof urban areas
Design discharge m3/s
16000
17000
18000
Time in a scenario with a small climate change
2050
2100
Time in a scenario with a large climate change
2050
40% Porous Pavement
50% Green Roofs
1m Deepening
Current Situation
Augment Trunk Sewer
Increase in Depth (%)
Year (High Scenario)
Year (Mid Scenario)
Year (Low Scenario)
Transfer station to new policy actions
Adaptation Tipping Point of a policy action (Terminal)


Transfer station to new action
Adaptation Tipping Point of an action (Terminal)
Adaptation Pathways
A1. Pedestrian road - town centre
A2. Next to coach station
A3. Parking of the court
A4. Open area at northern entrance of the city
A1. Pedestrian road - town centre
A2. Next to coach station
State 1
Transfer station to new actio
Adaptation Tipping Point of
Action effective in both dem
Action not effective in scenar
Measures
Stand by
Beach nourishment
Sea wall – Govt. constr.
Sea wall – Resident constr.
Retreat
Emergency Management
Planning Controls
We are here
Transfer to new measure
Adaptive tipping point

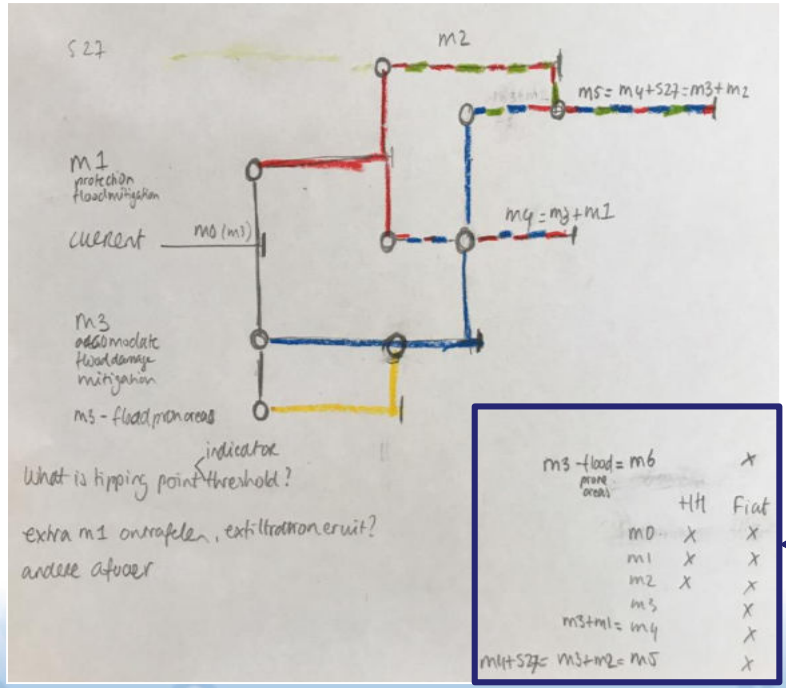
Where have pathways studies been applied?

Application to Miami C7 basin (2017)

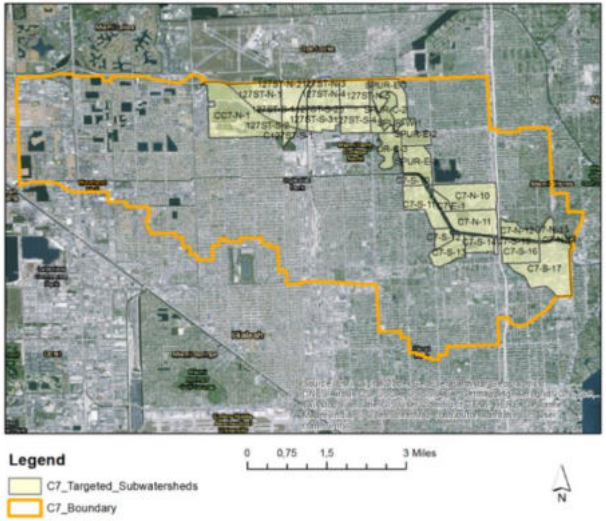


Level I - Workshop to explore pathways

Level I - Initial analysis



To be modeled



Measures

- **M0 –** No action
- **M1** – Local flood mitigation: flood walls, exfiltration trenches, flap gates, and local pumps
- **M2** – Regional flood mitigation: forward pumps at S-27 coastal structure (small & large pumps)
- **M3** - Land-use mitigation: raise roads and buildings to 6, 7 or 8 feet elevation

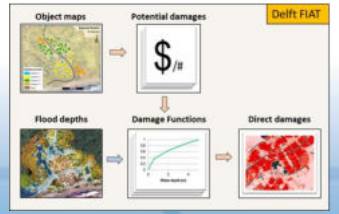
Level II – quantitative analyses

Dynamic Adaptive Policy Pathways (DAPP)

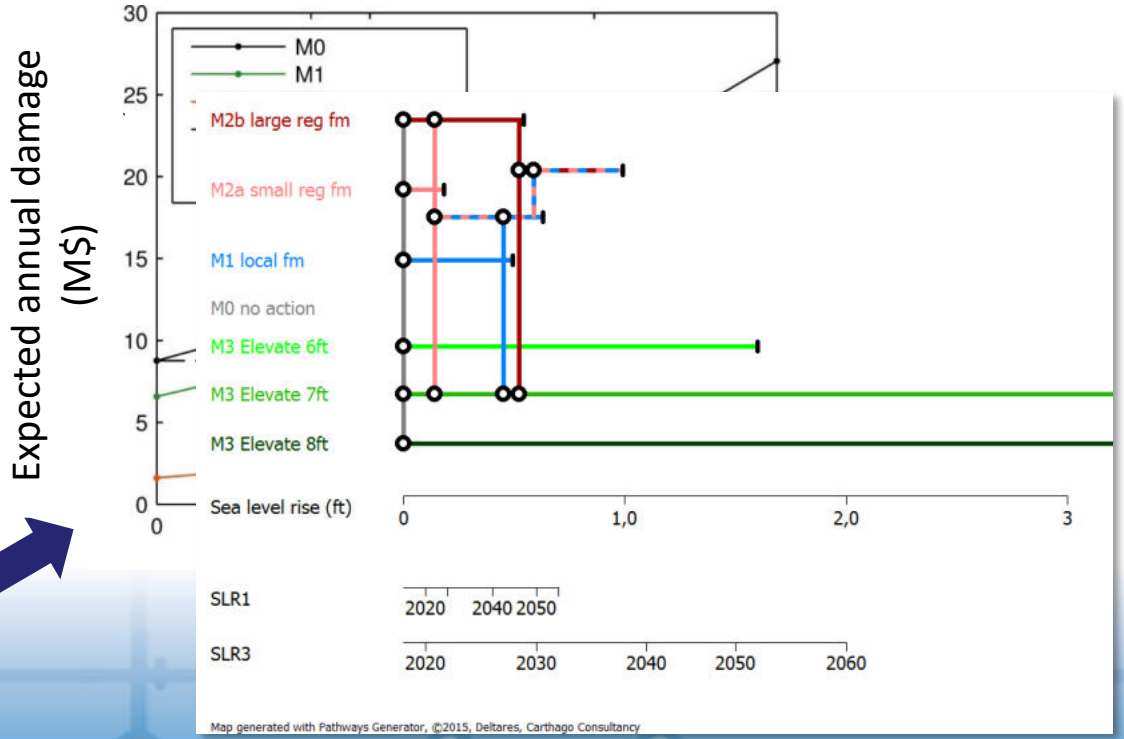
Hydrologic Drivers:
- Rainfall (4x);
- Storm Surge (1/10)
- Sea Level Rise (3x)

Hydrodynamic Model XPSWMM

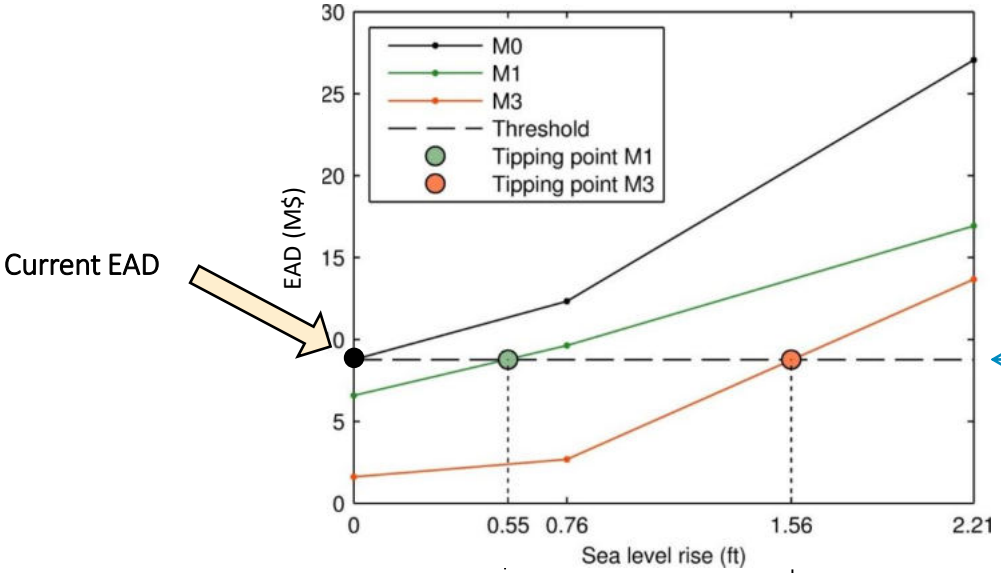
Delft-FIAT



Adaptation Options



Adaptation tipping points



Current EAD

Objective:
Expected annual damage (EAD) should not exceed current levels

Threshold = current EAD

SLR1 → 2065 (0.76 ft)

2045

SLR3 → 2065 (2.21 ft)

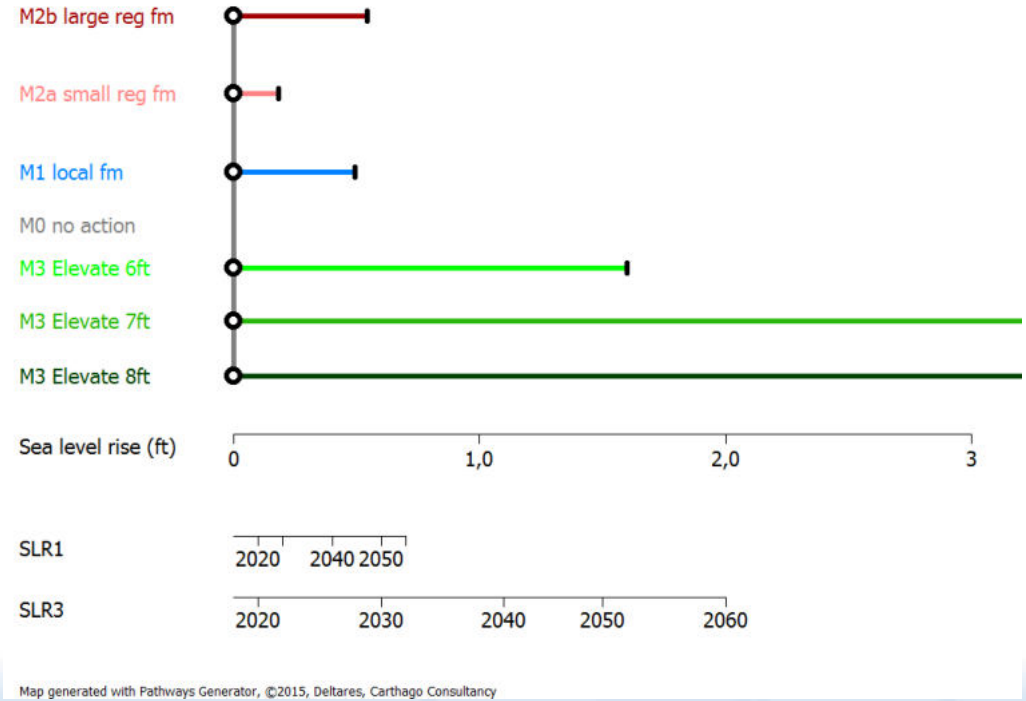
2025

2050

Adaptive pathways

Structural measures

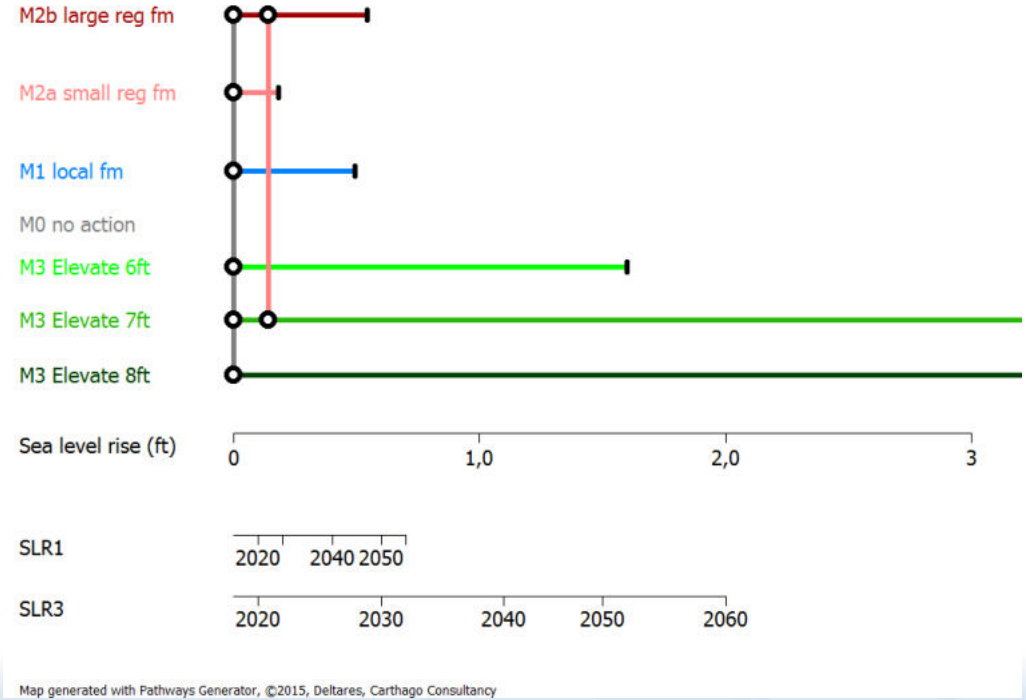
Land use measures



Adaptive pathways

Structural measures

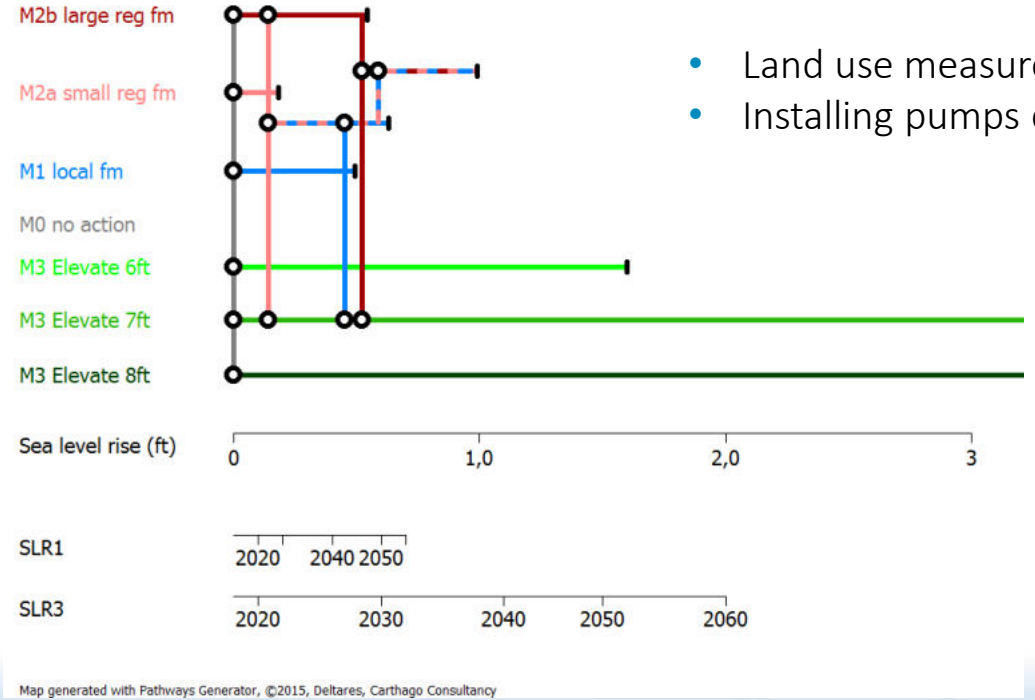
Land use measures



Adaptive pathways

Structural measures

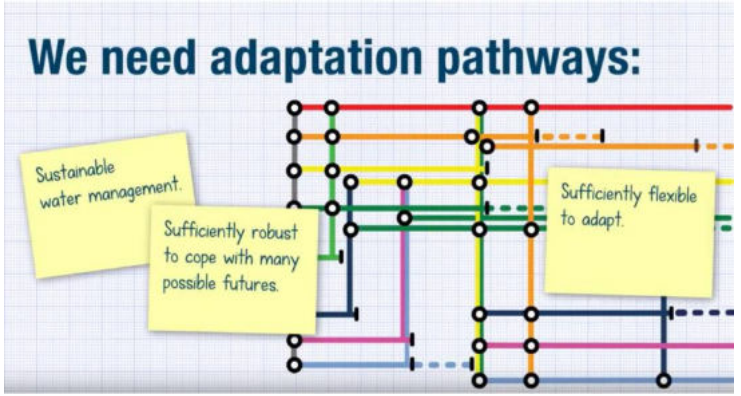
Land use measures



- Land use measures are needed in the end
- Installing pumps can buy some time.

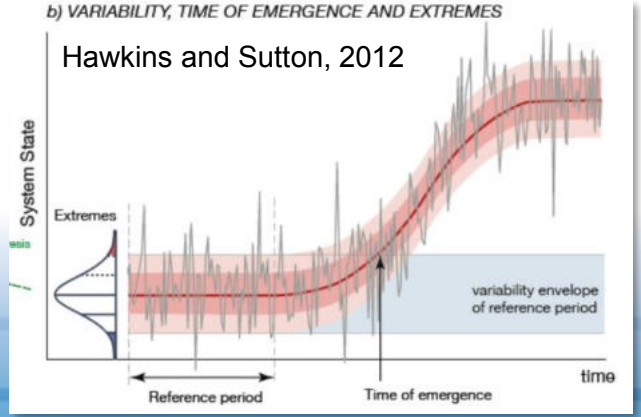
DAPP | a summary

- Decision making under uncertainty
- Adds adaptiveness (flexibility, robustness) and time
- Pathways open decision space, identify path-dependencies and overcome policy paralysis
- Tipping points identify when to act
- Monitoring keeps us on track
- Assessment modes: model-based, expert, participatory pathways



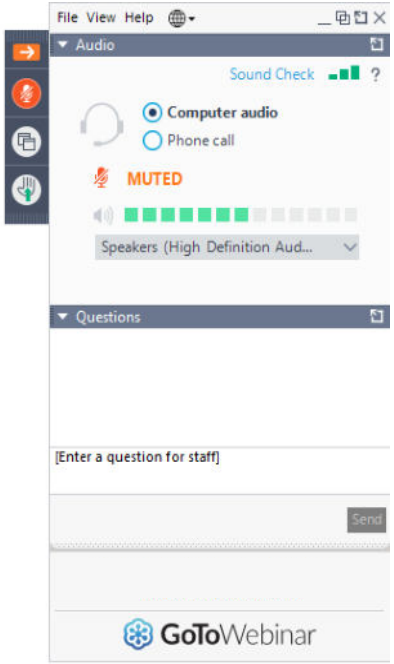
Recent and ongoing developments

- Generic adaptation pathways to sea level rise: https://doi.org/10.1088/2515-7620/ab1871
- Economic evaluation for pathways that considers transfer cost: https://doi.org/10.1007/s10584-019-02409-6
- Detecting timely, reliable and convincing signals of change: https://doi.org/10.1016/j.gloenvcha.2018.08.003
- Compound flooding in Louisiana
- Adaptation to uncertain high-end sea level rise



Haasnoot et al. 2019

DAPP | Questions?



#daretoask

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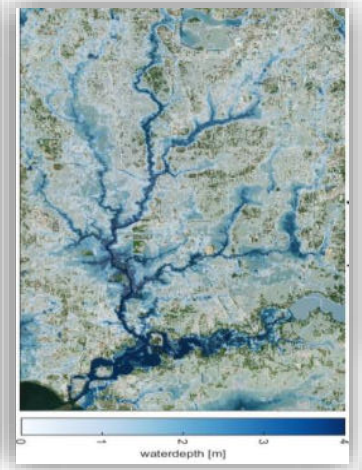
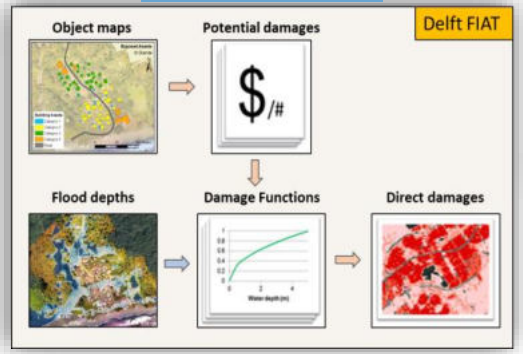
Tools supporting DAPP

Serious Gaming

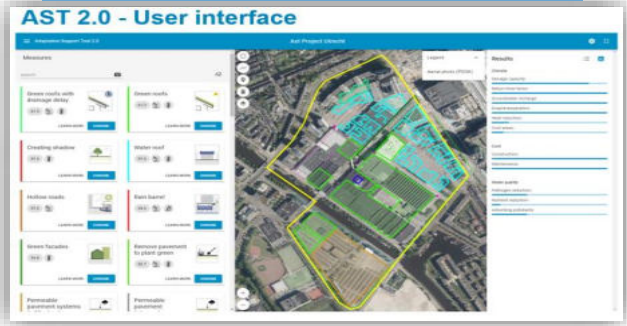
SFINCS



Delft-FIAT



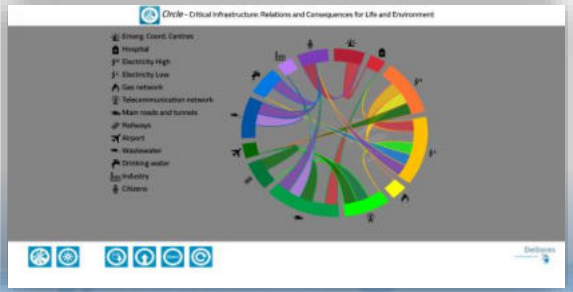
Adaptation Support Tool



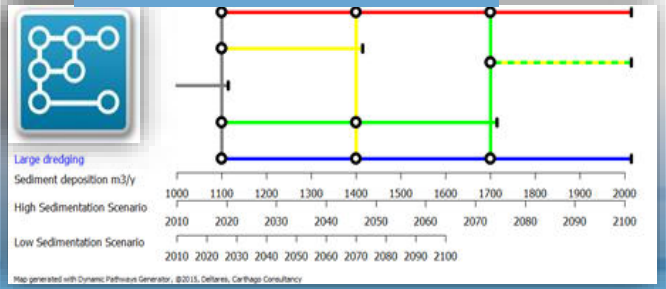
Delft-FIAT Accelerator

1. Input water depth map from anywhere in the world
2. Automatically looks up global exposure data for the area
3. Automatically looks up appropriate damage functions
4. Returns damage map, risk map, and report

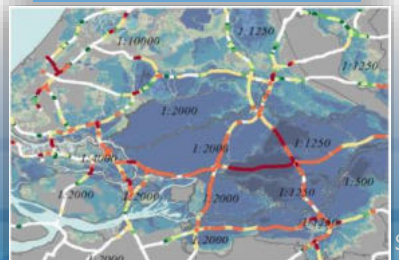
CIRCLE



Pathway generator



Criticality tool



Modeling for the DAPP process

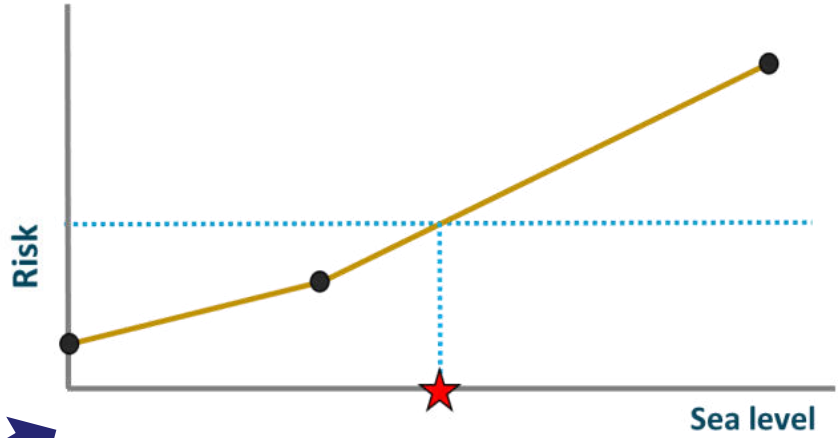
Dynamic Adaptive Policy Pathways (DAPP)

Drivers

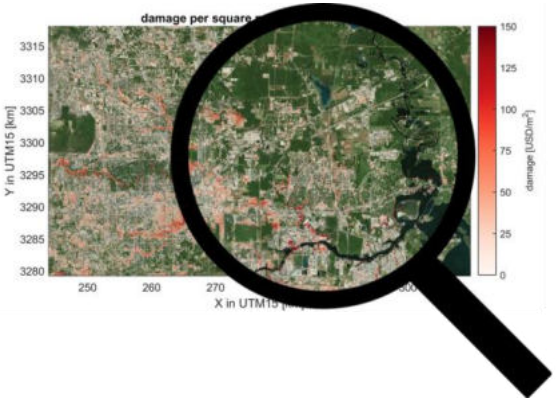
Adaptation Options

Hazard Model

Damage and risk model

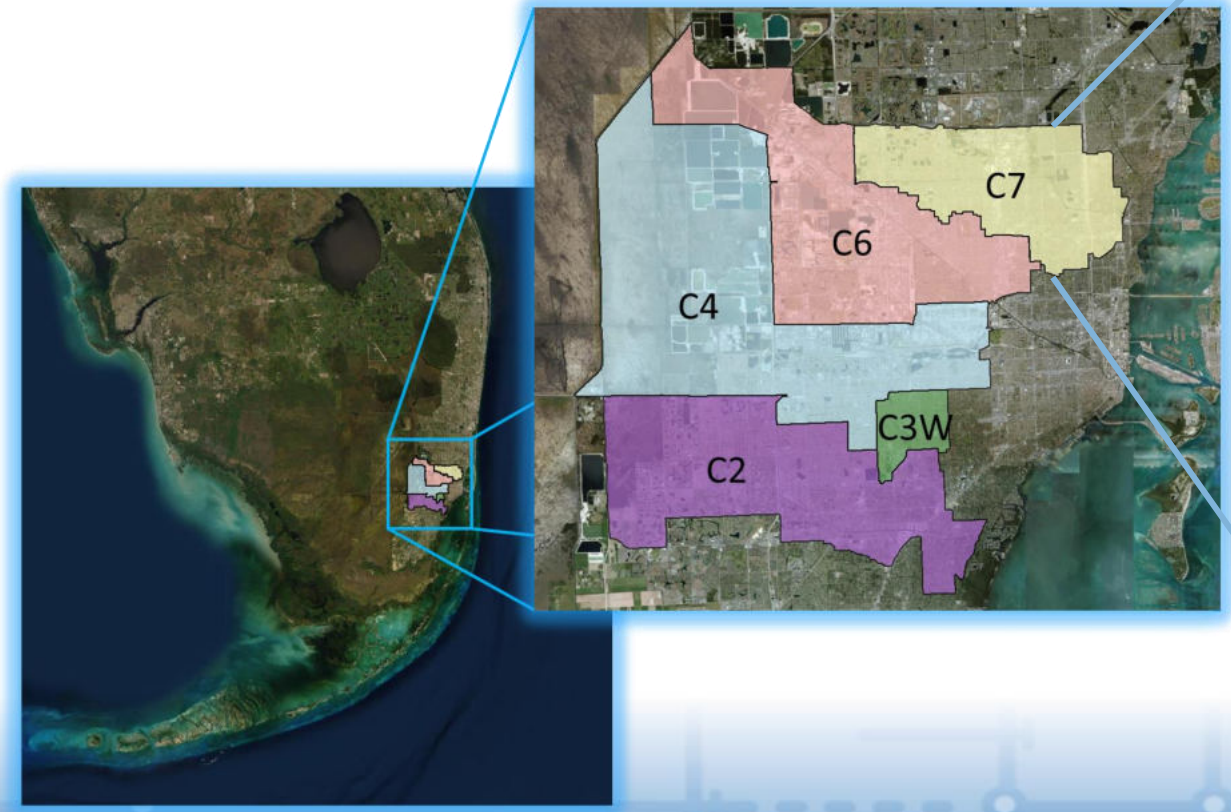


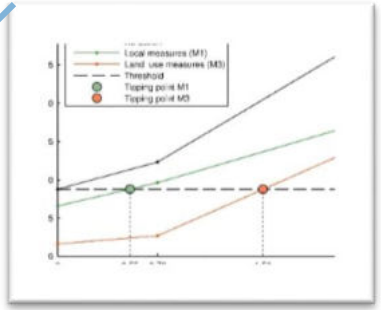
Why a DAPP quick-scan tool

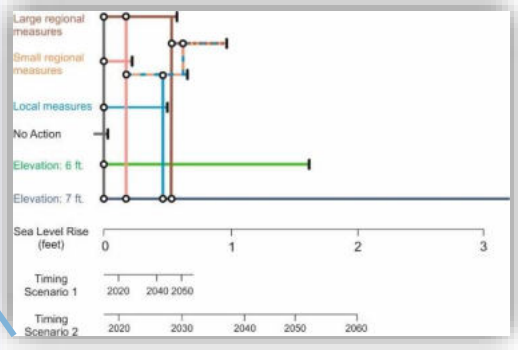


- Quick overview
  - risk --> most at-risk areas
  - system response to climate change
  - risk reduction and shelf-lives of measures
  - influence of risk tolerance on the shelf-life of measures
- Engaging stakeholders in workshops
- Educational tool to understand DAPP process

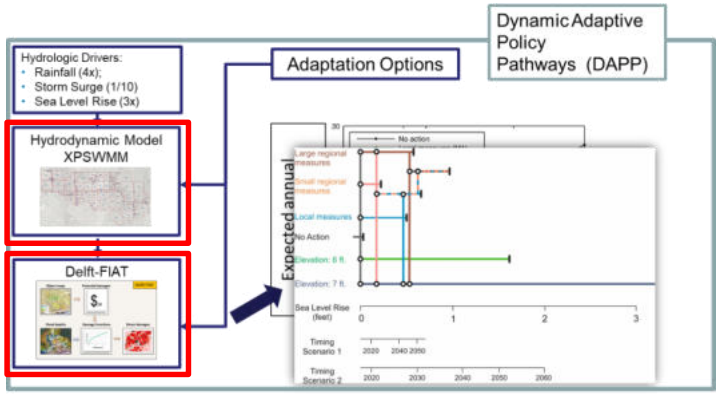
Quick scan tool for Miami







Recipe for a quick-scan model



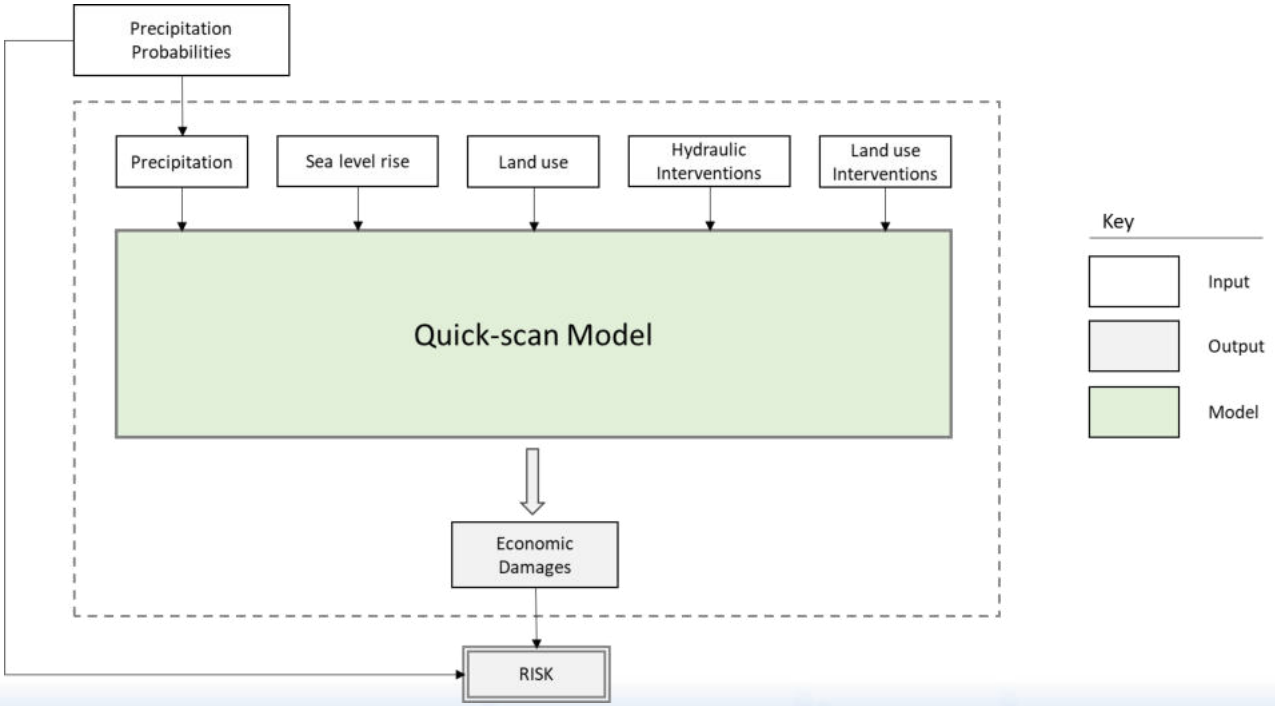
Ingredients:

- Simple hydraulic model
- Fast and automated damage model

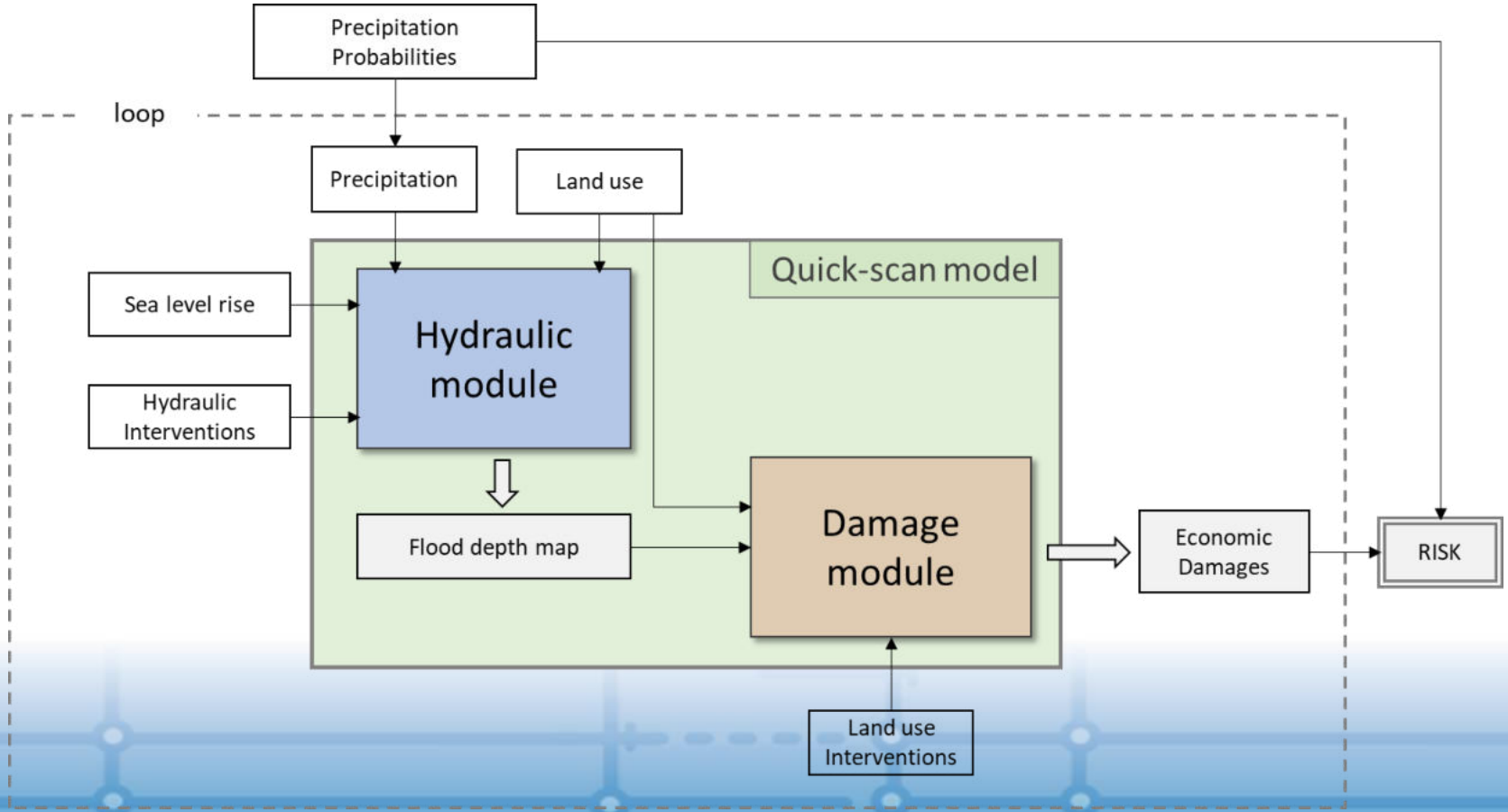
Steps:

- Calibrate the combined hydraulic-damage model
- Implement hydraulic and land-use measures in the model

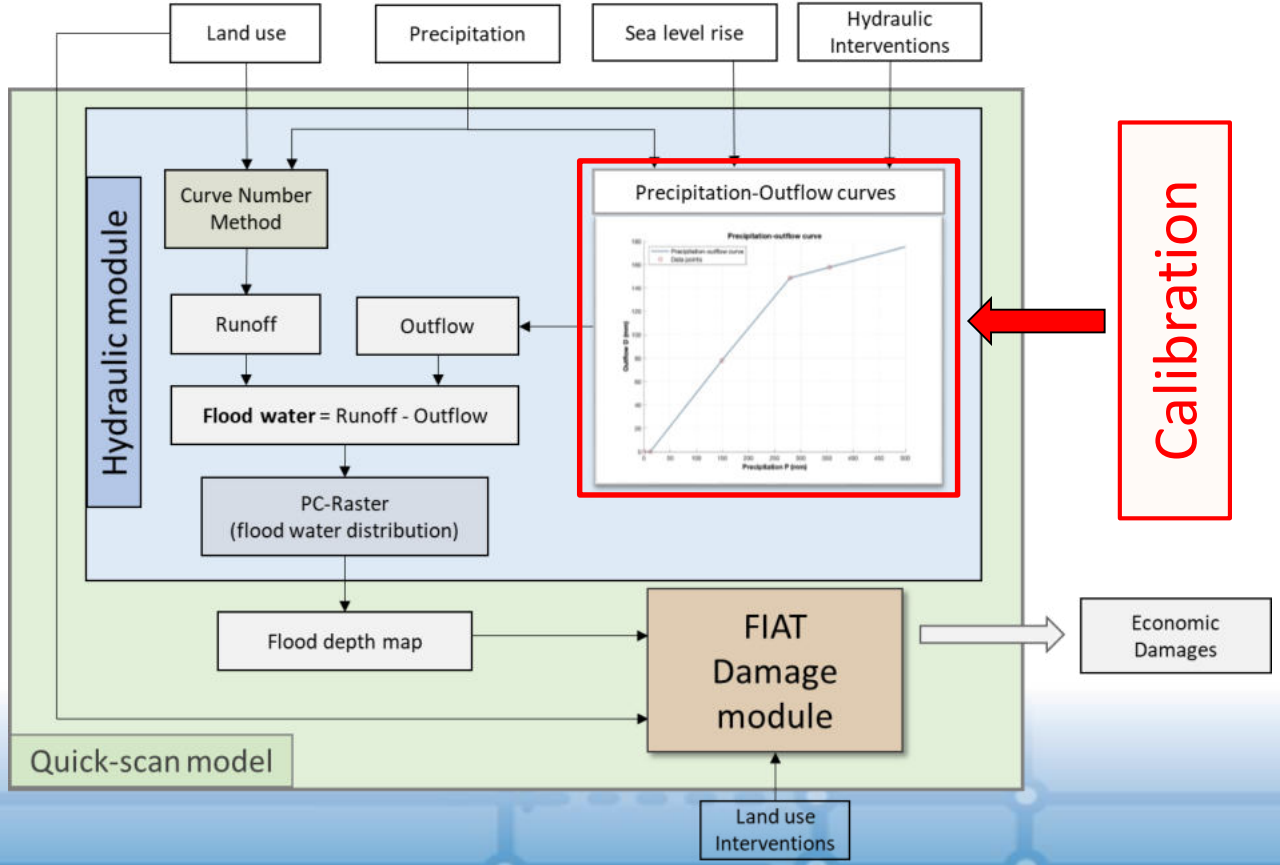
Quick scan tool - overview



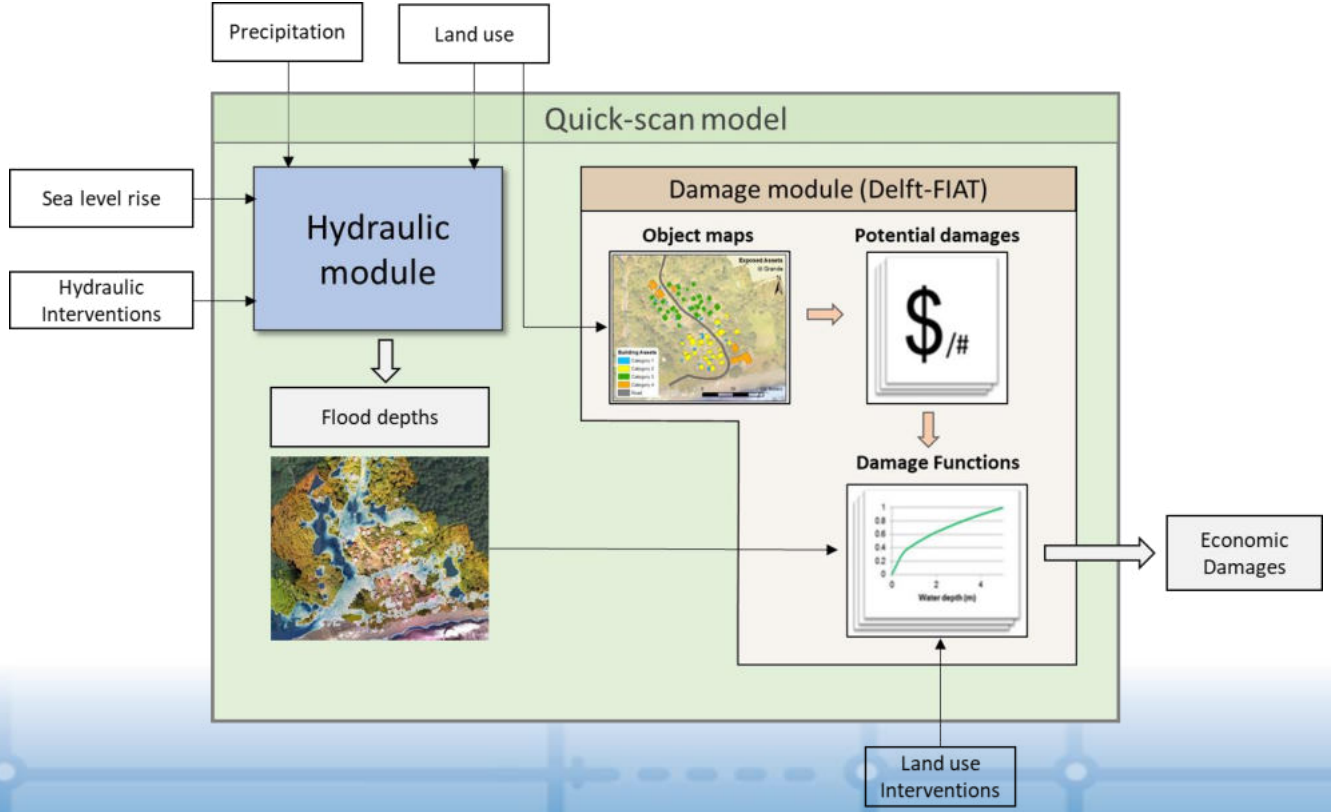
Quick-scan tool model structure



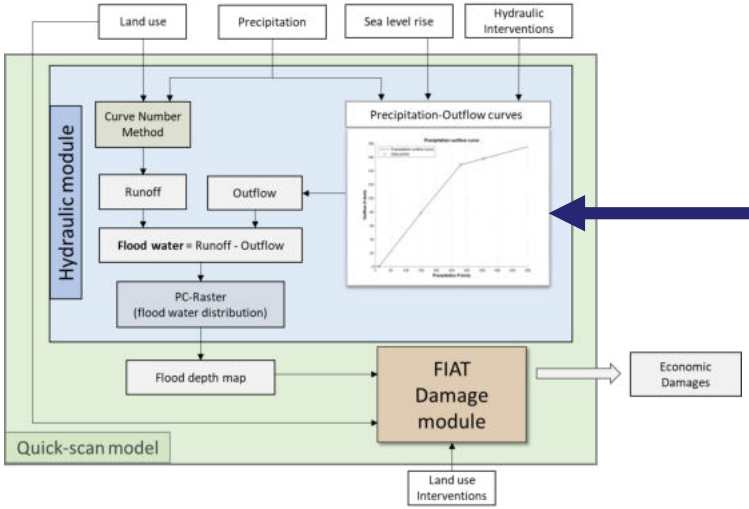
Under the hood: hydraulic module

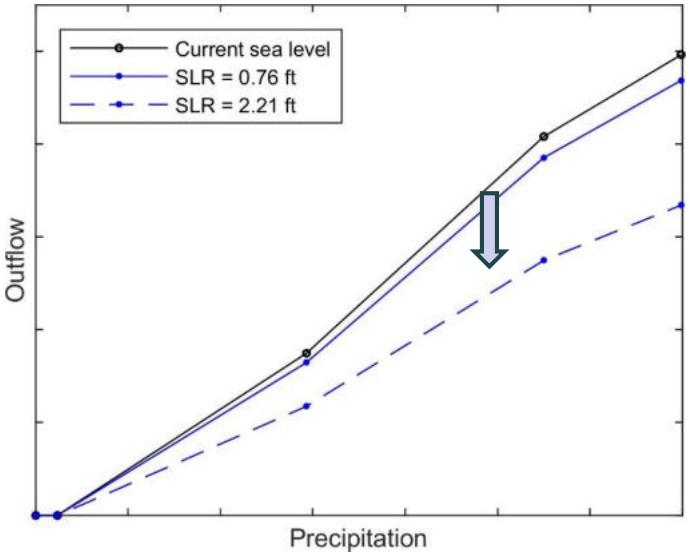


Under the hood: damage module



Sea level rise





Measures (same as C-7 study)

M0 – No action

Hydraulic measures

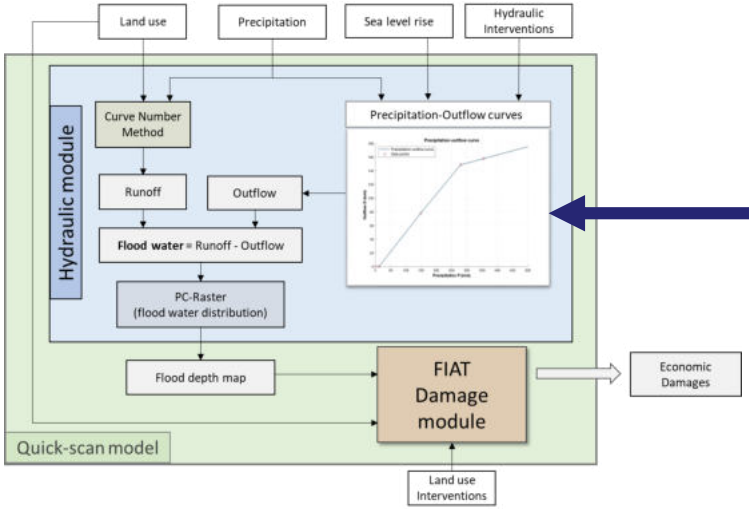
M1 – Local flood mitigation: flood walls, exfiltration trenches, flap gates, and local pumps

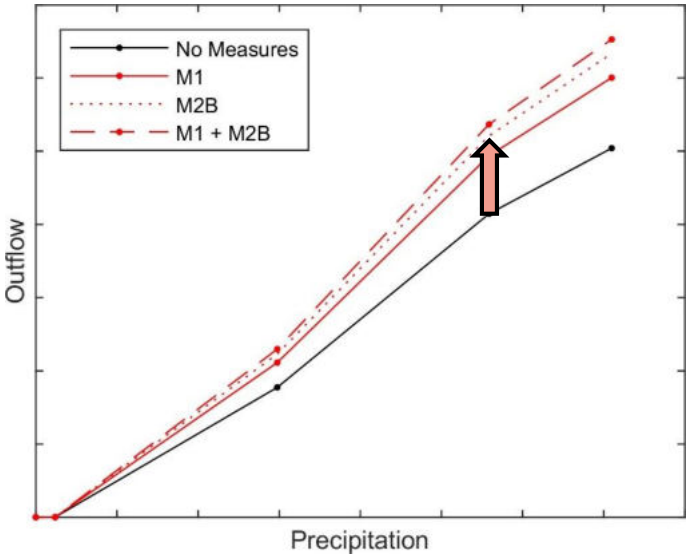
M2 – Regional flood mitigation: forward pumps at S-27 coastal structure (small & large pumps)

Land-use measure

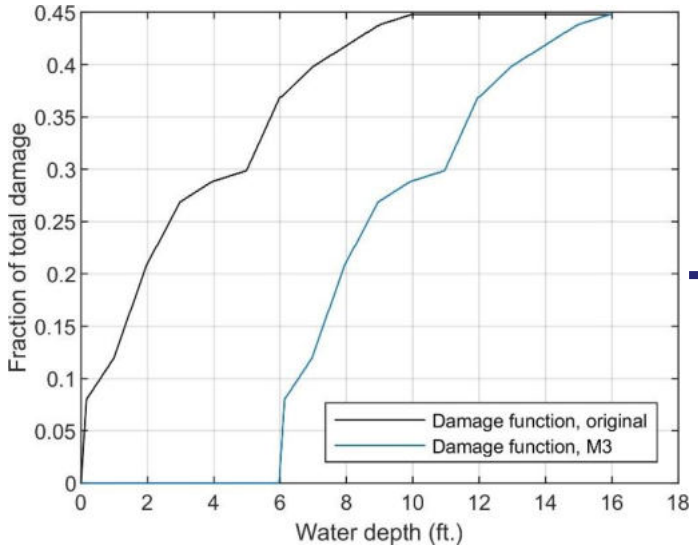
M3 - Land-use mitigation: raise roads and buildings to 6 feet elevation

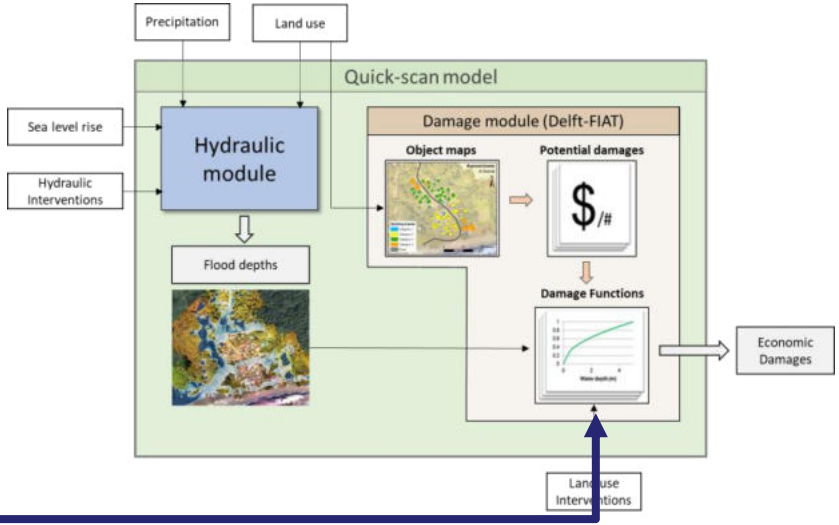
Hydraulic measures (M1 & M2)



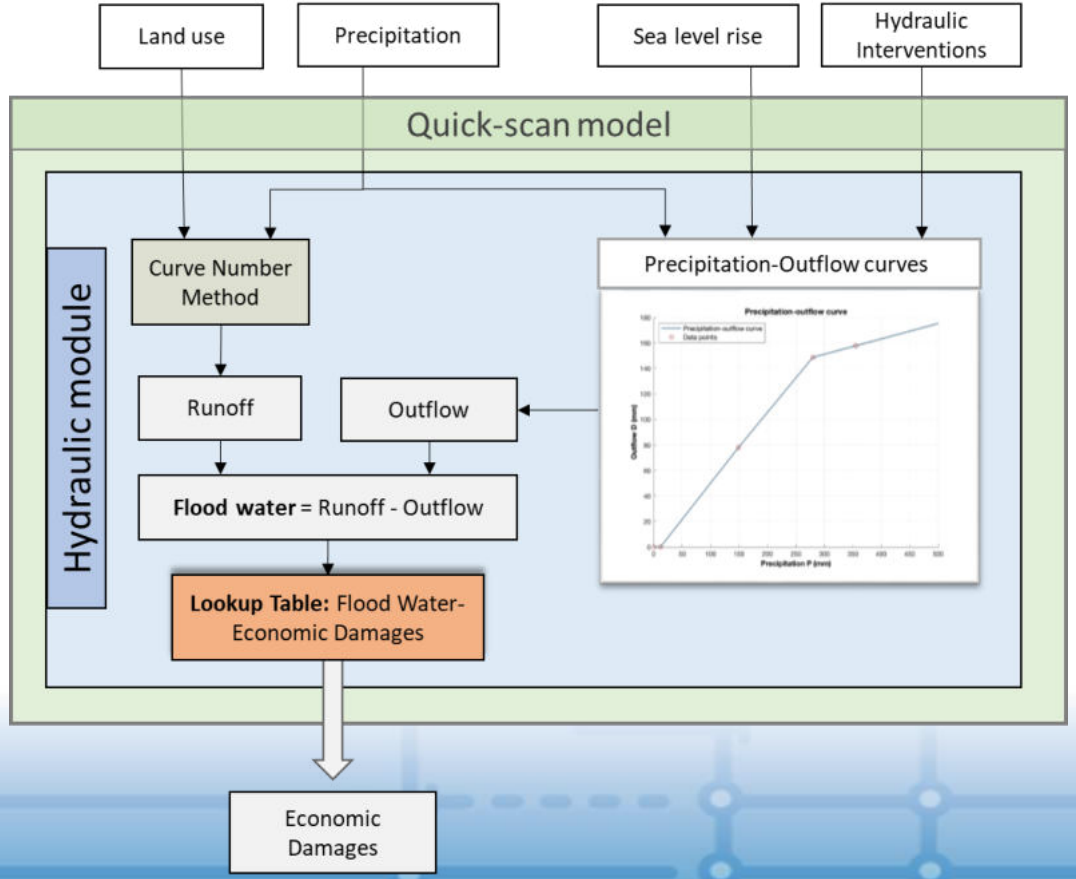


Raising roads and houses (M3)





Speeding it up: pre-processing

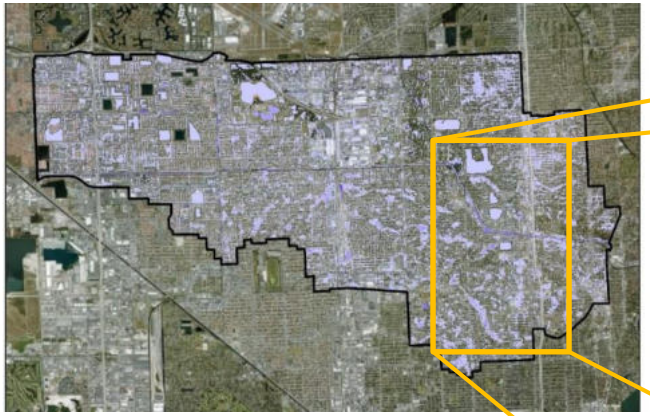


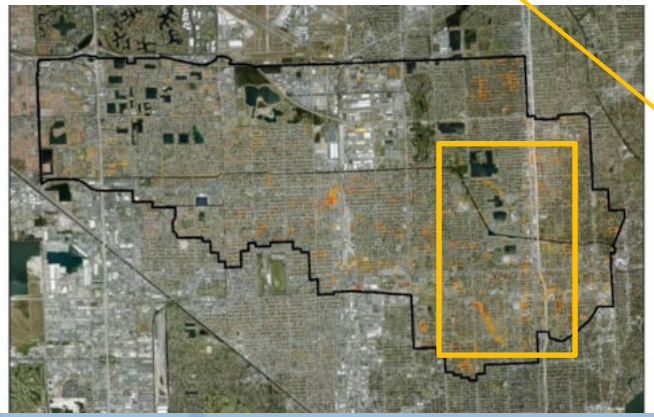
Run time

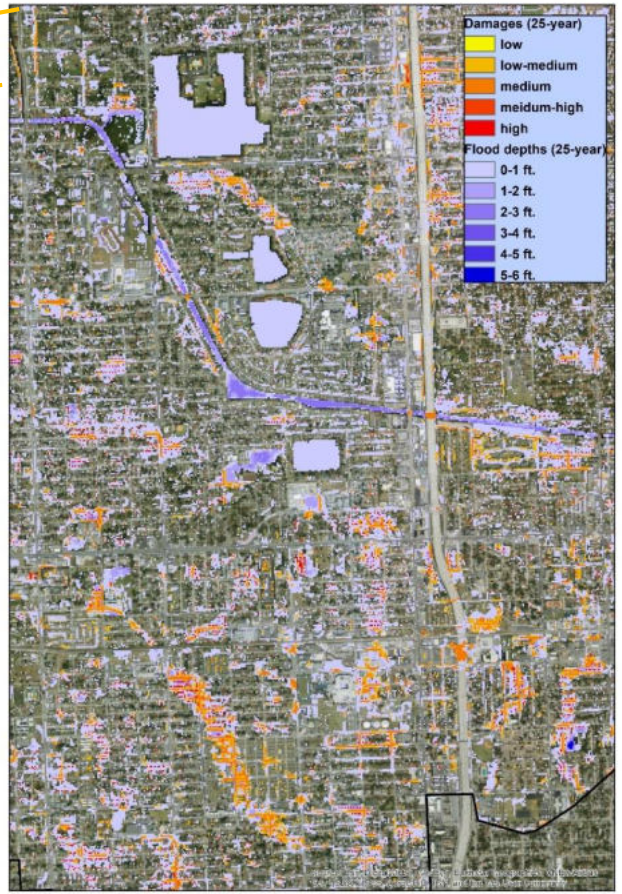
Single run	⇒	2 seconds
Risk analysis	⇒	30 seconds

Taking it for a test drive

Flood depth and damages



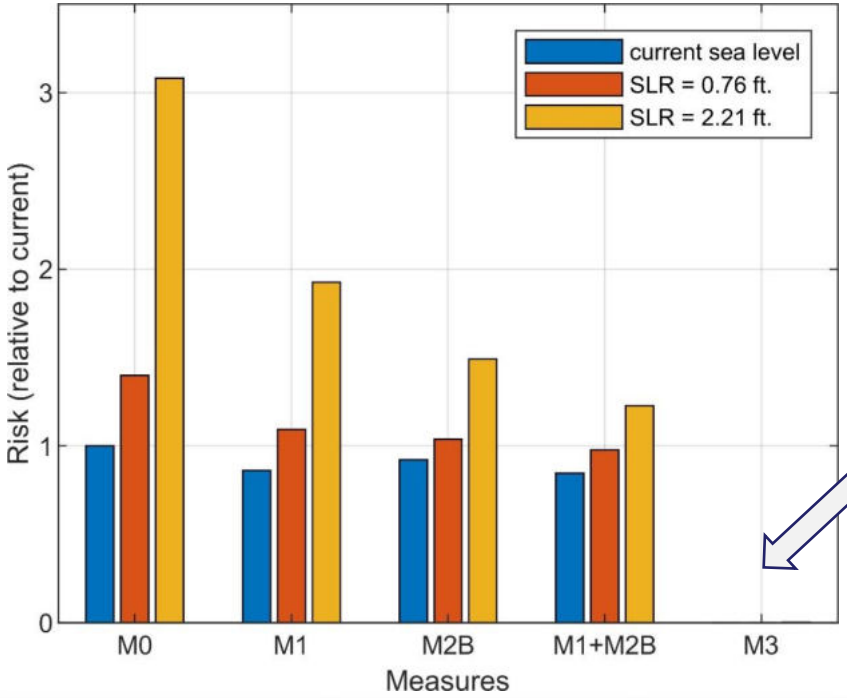




Risk

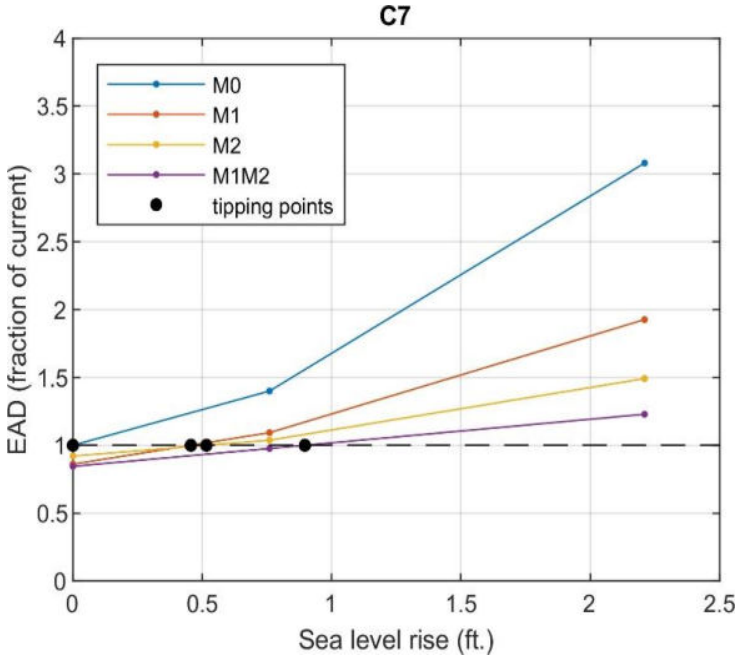
- Three sea levels
  - CSL = 0 SLR
  - SLR1 = 0.76 ft. SLR
  - SLR3 = 2.21 ft. SLR
- Five measures/combinations
  - M0 (no measures)
  - M1 (local flood mitigation measures)
  - M2 (regional pump)
  - M1 + M2 (combination local measures + regional pump)
  - M3 (elevating structures and roads)

Risk analysis, C-7



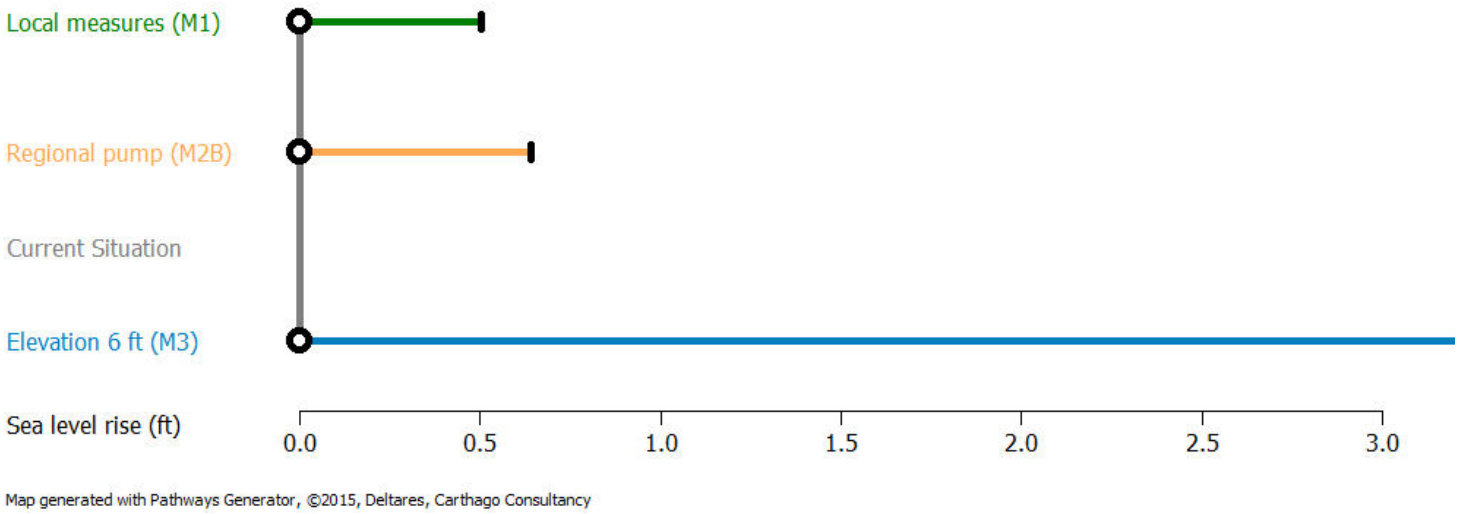
Risk reduced to zero

Tipping points



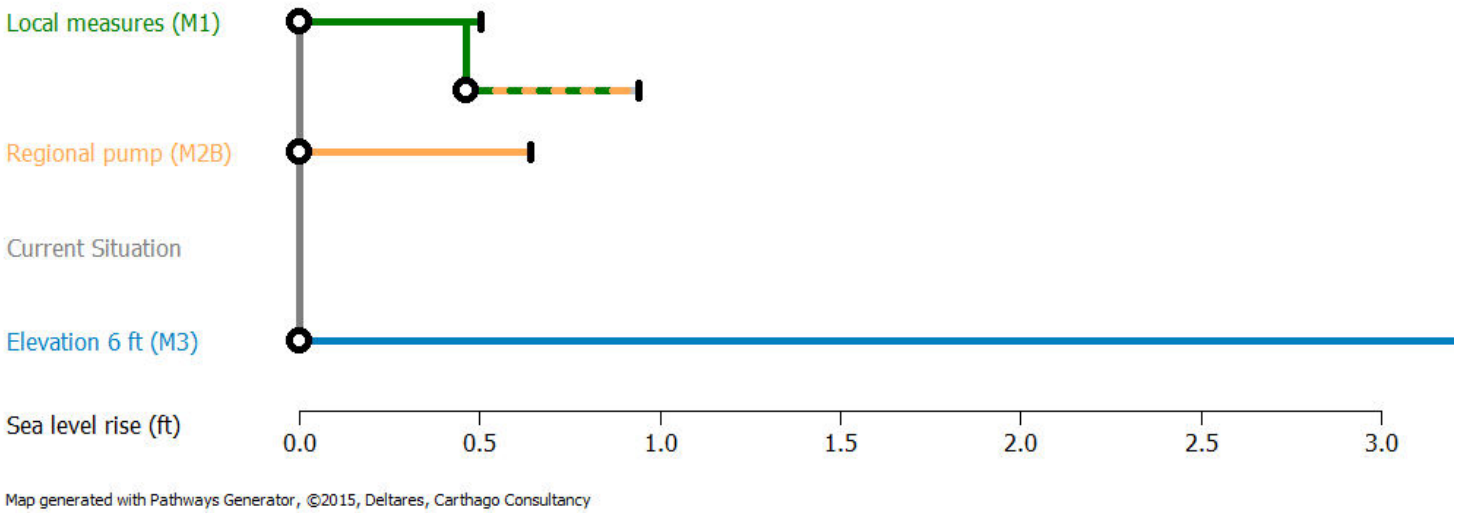
	previous C-7 study			quick-scan model		
	Current Risk	5% increase	10% increase	Current risk	5% increase	10% increase
M0	0.00	0.09	0.19	0.00	0.10	0.19
M1	0.55	0.66	0.77	0.46	0.62	0.77
M2B	0.50	0.79	0.95	0.52	0.80	0.96

Pathways map



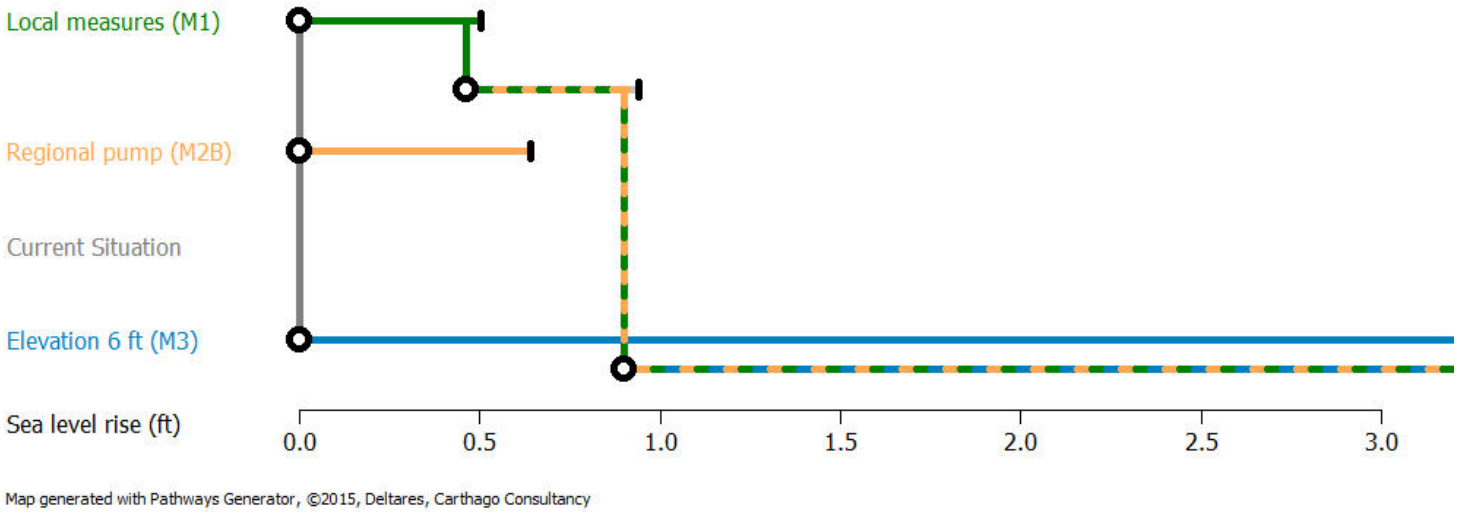
Map generated with Pathways Generator, ©2015, Deltares, Carthago Consultancy

Pathways map



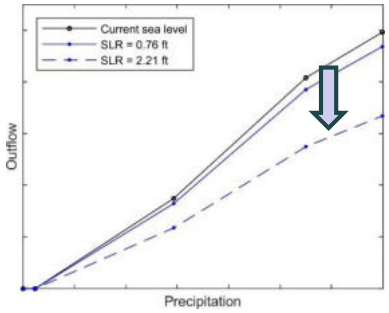
Map generated with Pathways Generator, ©2015, Deltares, Carthago Consultancy

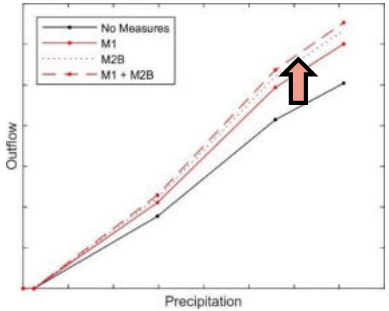
Pathways map

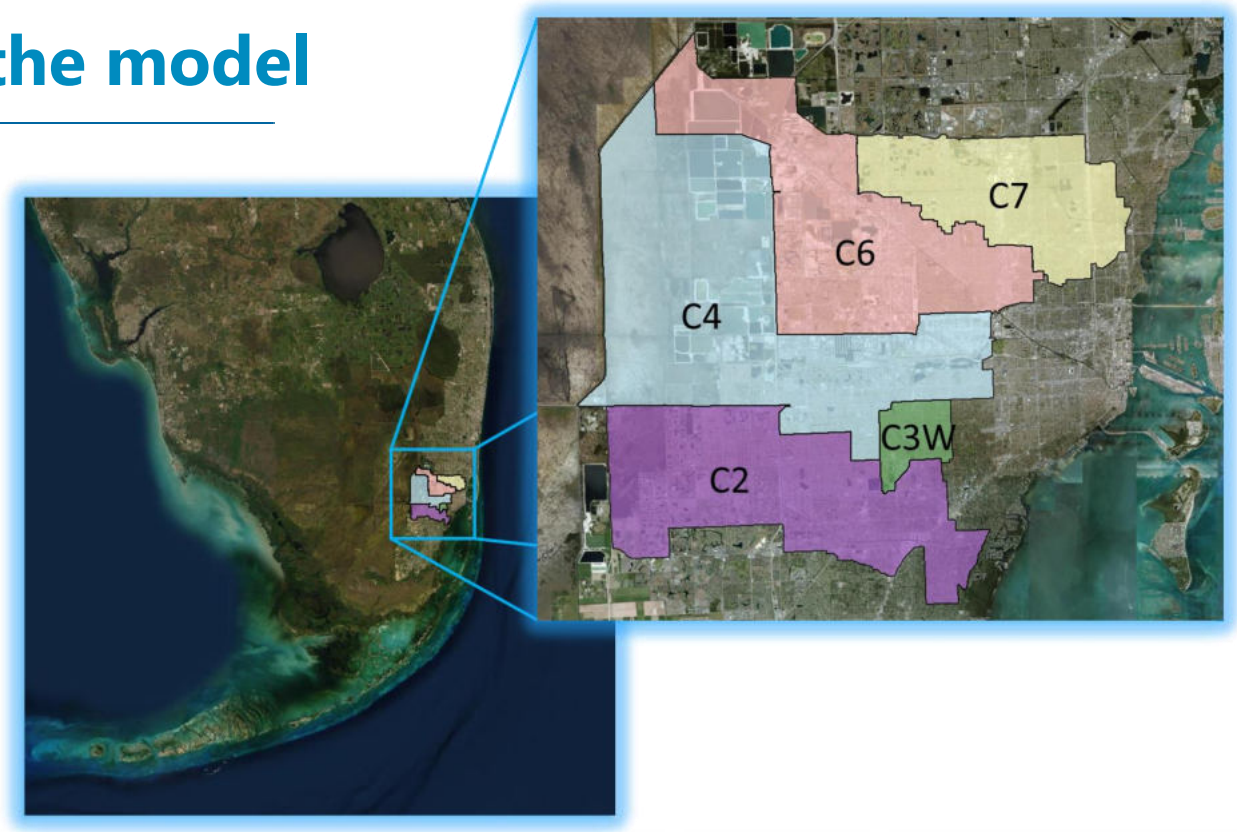


Map generated with Pathways Generator, ©2015, Deltares, Carthago Consultancy

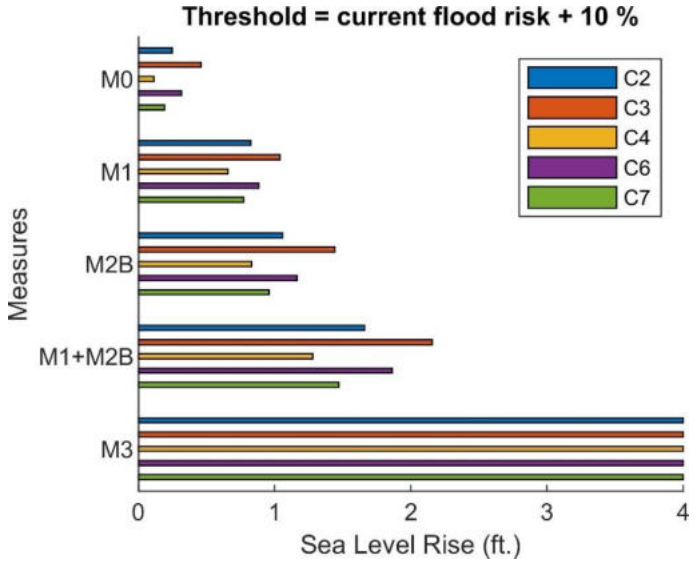
Expanding the model

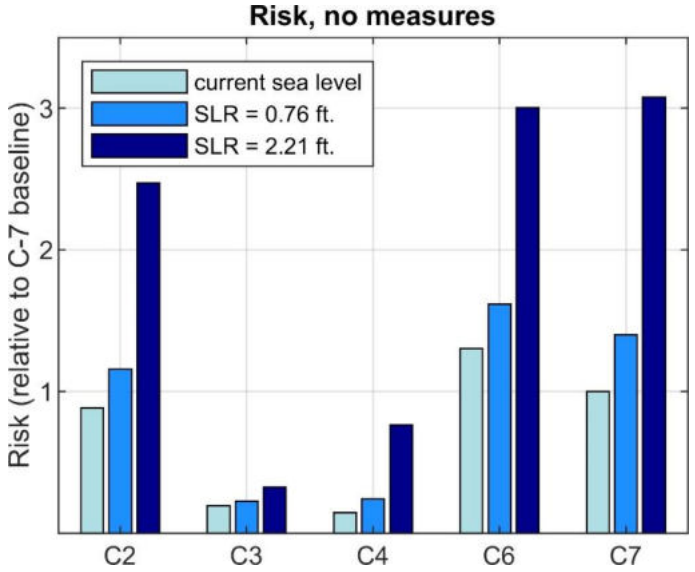






Multi-basin results

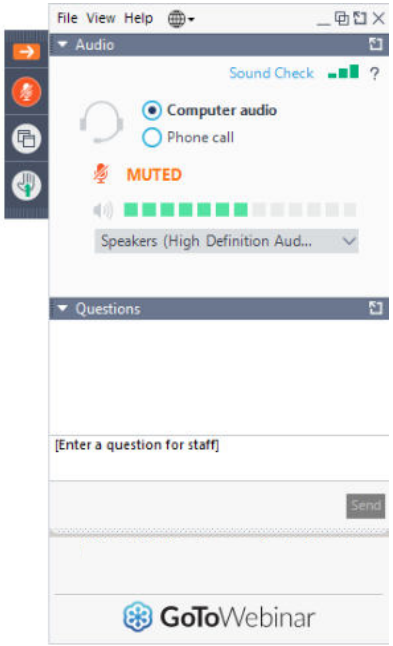




Engaging stakeholders

- Can play with the effectiveness of measures
- Include new measures with expert opinion about relative effectiveness
- Choose different sea level rises
- Change precipitation frequency
- Take future development into account

Discussion



#daretoask

Thank you for your attention

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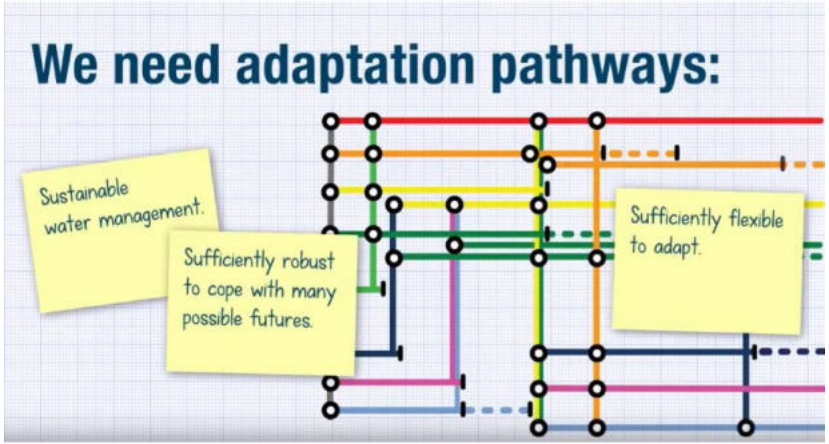

More information:

- https://www.deltares.nl/en/adaptive-pathways/
- https://publicwiki.deltares.nl/display/DFIAT/Delft-FIAT+Home
- https://www.deltares.nl/en/software-solutions/
- Recordings of the webinar.

We hope to see you at the Climate summit!