

# RAMBOLL IN BRIEF

- Independent engineering, management and design consultancy
- Founded 1945 in Denmark
- 12,800 experts
- Close to 300 offices in 35 countries
- Particularly strong presence in the Nordics, the UK, North America, Middle East and Asia-Pacific
- Owned by Ramboll Foundation



# COPENHAGEN CLOUDBURST PLANS

# COPENHAGEN CASE DRIVERS AND PROCESS



- Climate Plan, 2009



- Extreme cloudburst 15 August 2010



- Climate adaptation plan, 2011



# BEFORE: Extensive Flooding

02 July 2011: > 150mm  
RAIN fell in 2 HOURS.



**GASVÆRKSVEJ  
Copenhagen**

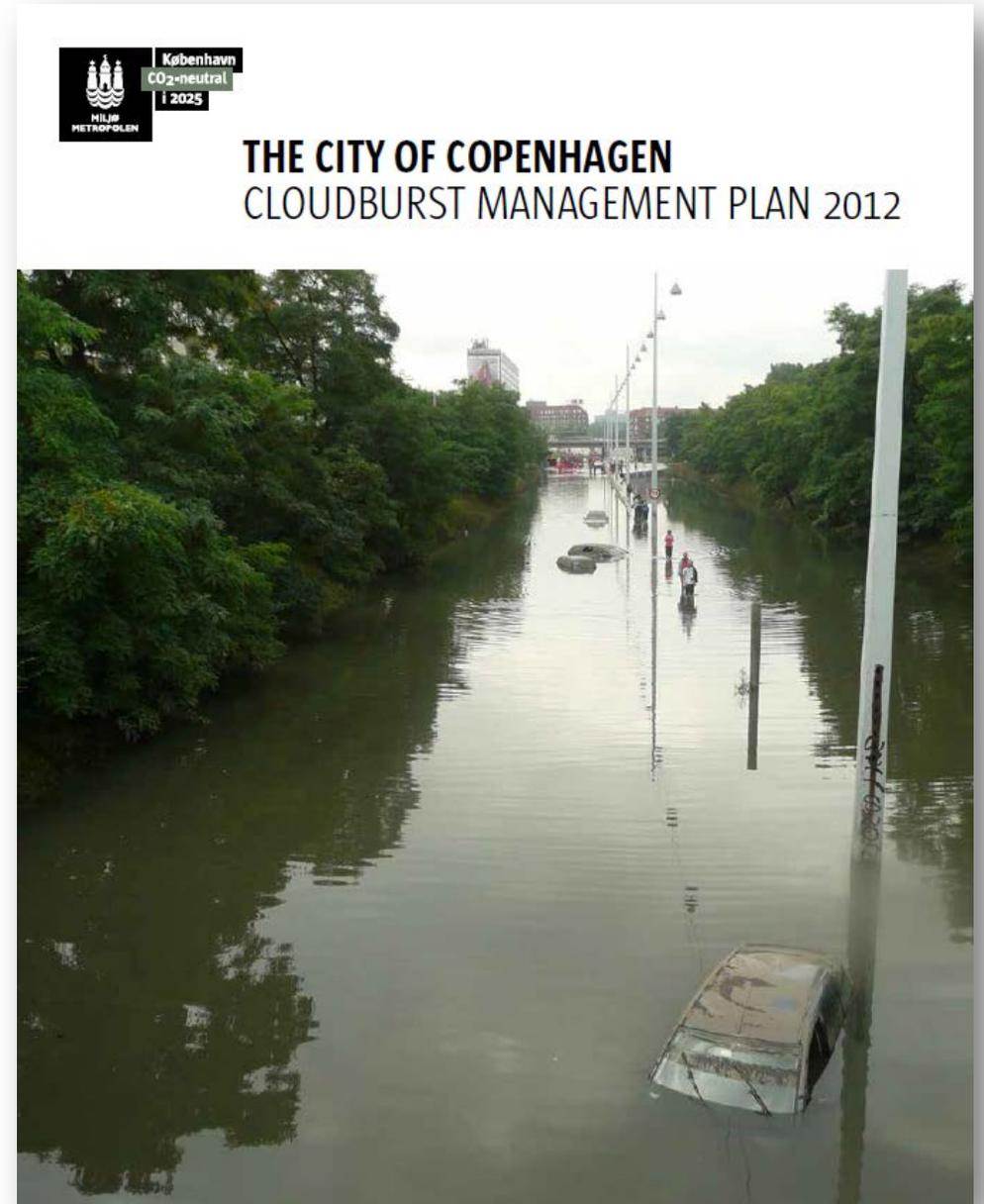
**Game  
Changer**

July, 2011 - Copenhagen was hit by a destructive flood leaving 50,000 homes without heat for a week, resulting in over 90,000 insurance claims, and causing upwards of \$1 billion in property damage, transport delays, and production halts.

**RAMBOLL**

# COPENHAGEN CASE DRIVERS AND PROCESS

- Climate plan KK, 2009
- Extreme cloudburst 15 August 2010
- Climate adaptation plan, 2011
- Extreme cloudbursts 2 July and 15 August 2011
- Cloudburst Management Plan 2012
- Specific projects 2014 ->





Existing Parking transforms into Plaza

### **Change of Thinking**

The cost of doing nothing creates losses of \$60 million a year (City of Copenhagen). Let's create robust solutions that add value and mitigate Cloudbursts.

Parks are proven to increase property value 10-15% (Trust for Public Land).

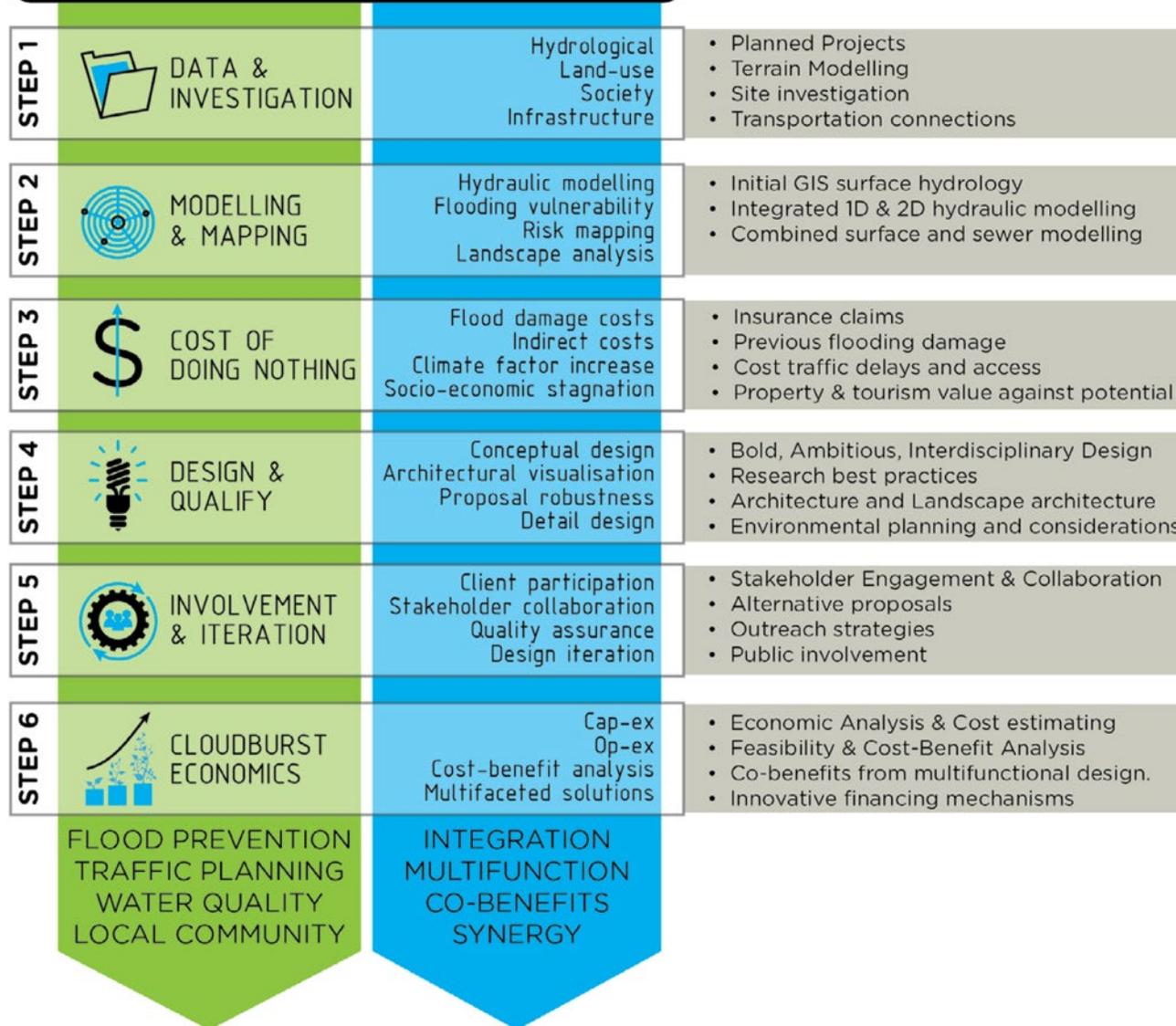


# COPENHAGEN CLOUDBURST MANAGEMENT PLAN

Long Term Goal: Max. 4 inches  
of water on the ground for a  
100 year rain event

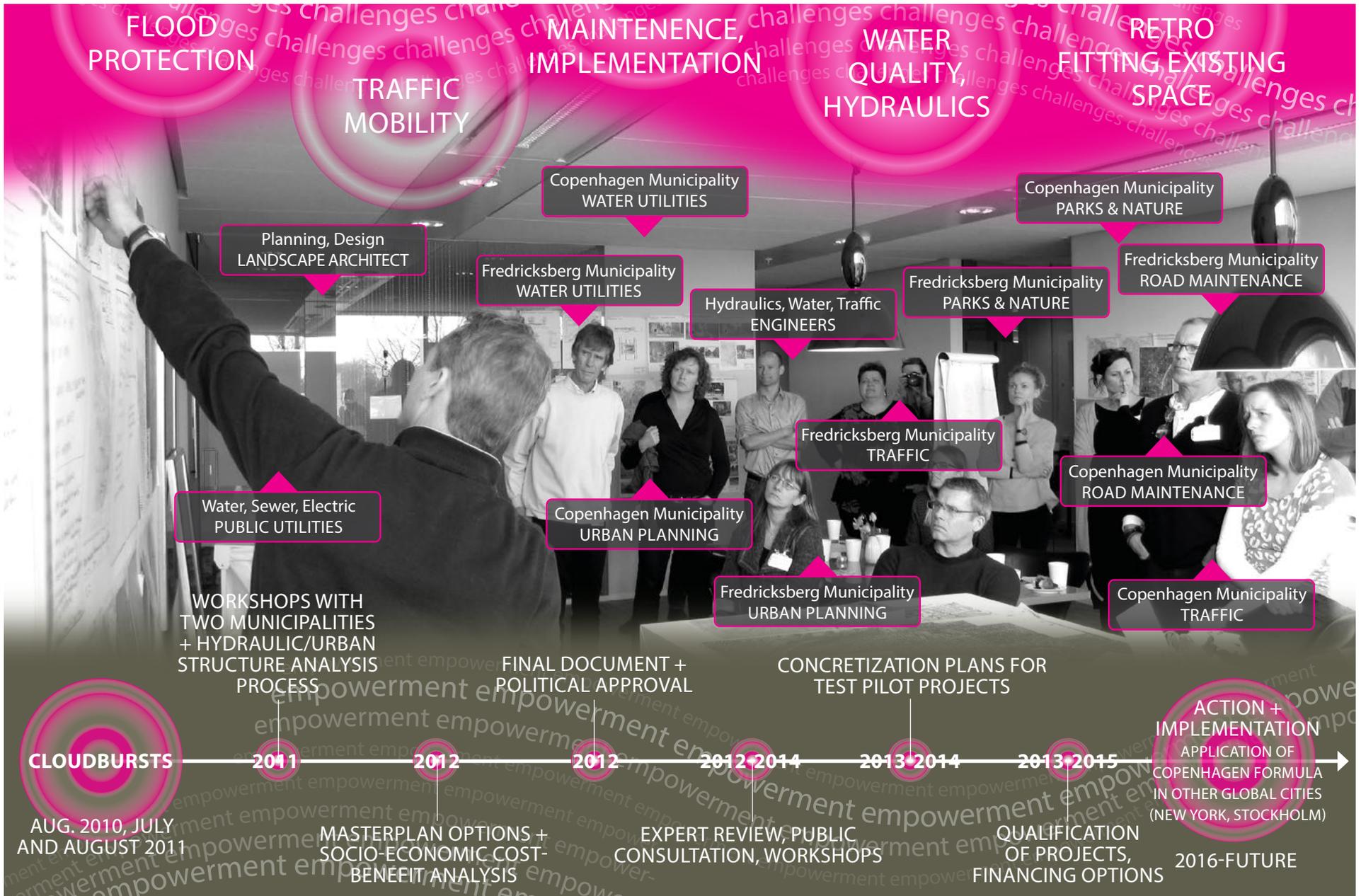
- Copenhagen Cloudburst Formula -

# BLUE GREEN SOLUTIONS



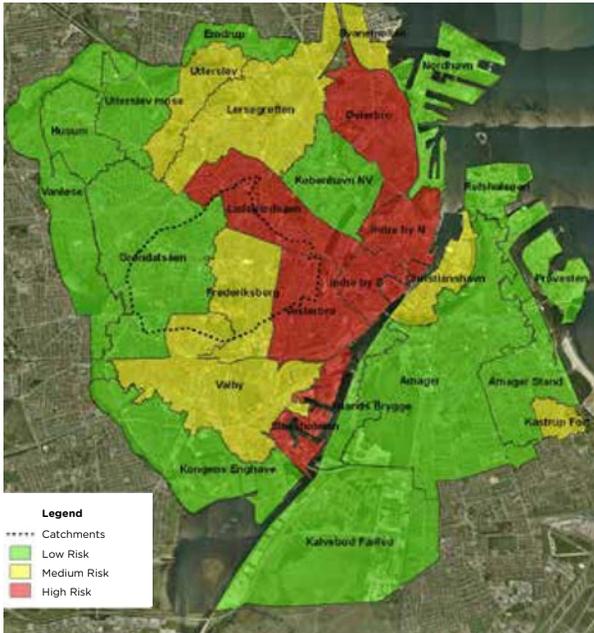
**Copenhagen  
Cloudburst  
Formula**

Blue-Green surface solutions with reduced piping infrastructure - is proven to be more investment friendly than piped solutions and creates diverse direct and indirect benefits for socio-economic conditions.



**Public-Private  
Collaboration**

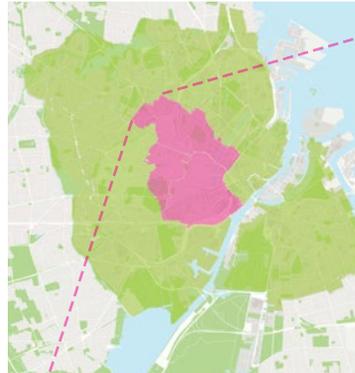
The Copenhagen Formula adapts to interdisciplinary approaches - away from siloist, isolated thinking. A common vision aligned engineers, hydraulic experts, GIS, information technologists, architects and planners, biologists, economists, communication specialists, and landscape architects with the local municipality.



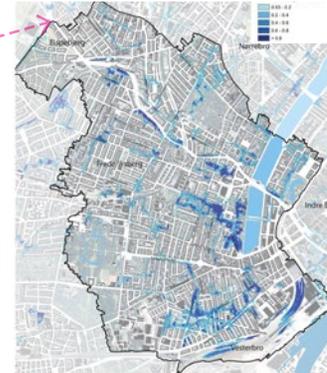
Red Catchments are highest at risk to flooding and sea surges



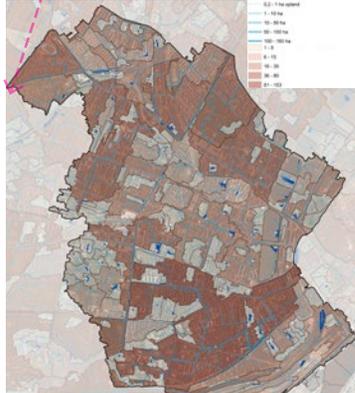
Waterway Courses through Copenhagen



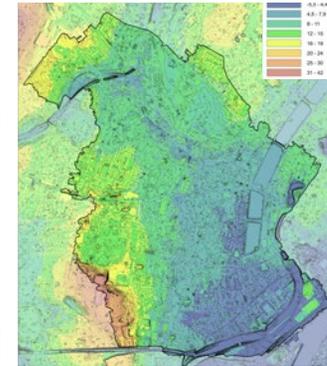
Highest Risk Catchment as Pilot Project



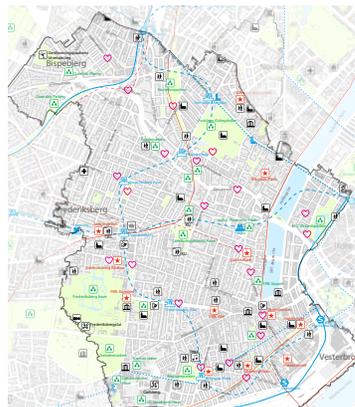
Flood Risk Mapping



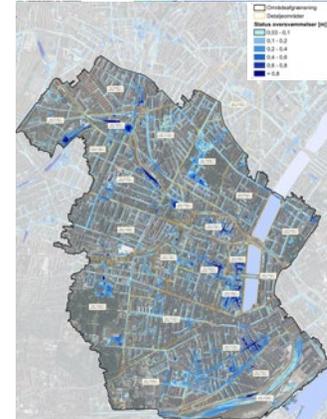
Watershed Catchments, Sub-Catchments



Digital Terrain Model - Slope



Social Corridors and Mobility Network



Sub-Catchments and Risk Attributed to Flooding Potential



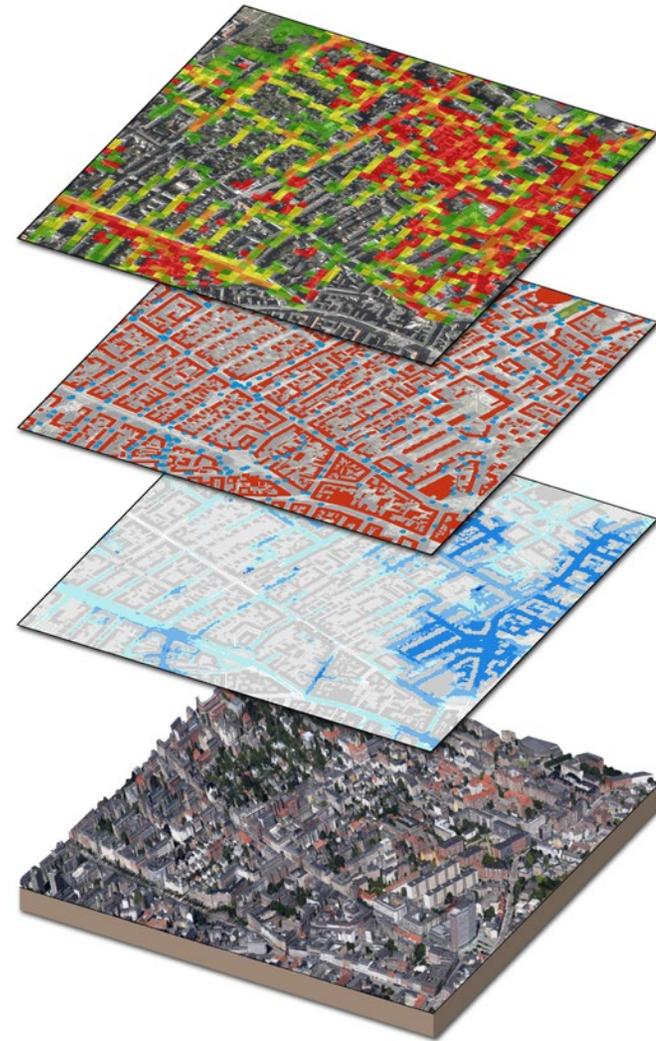
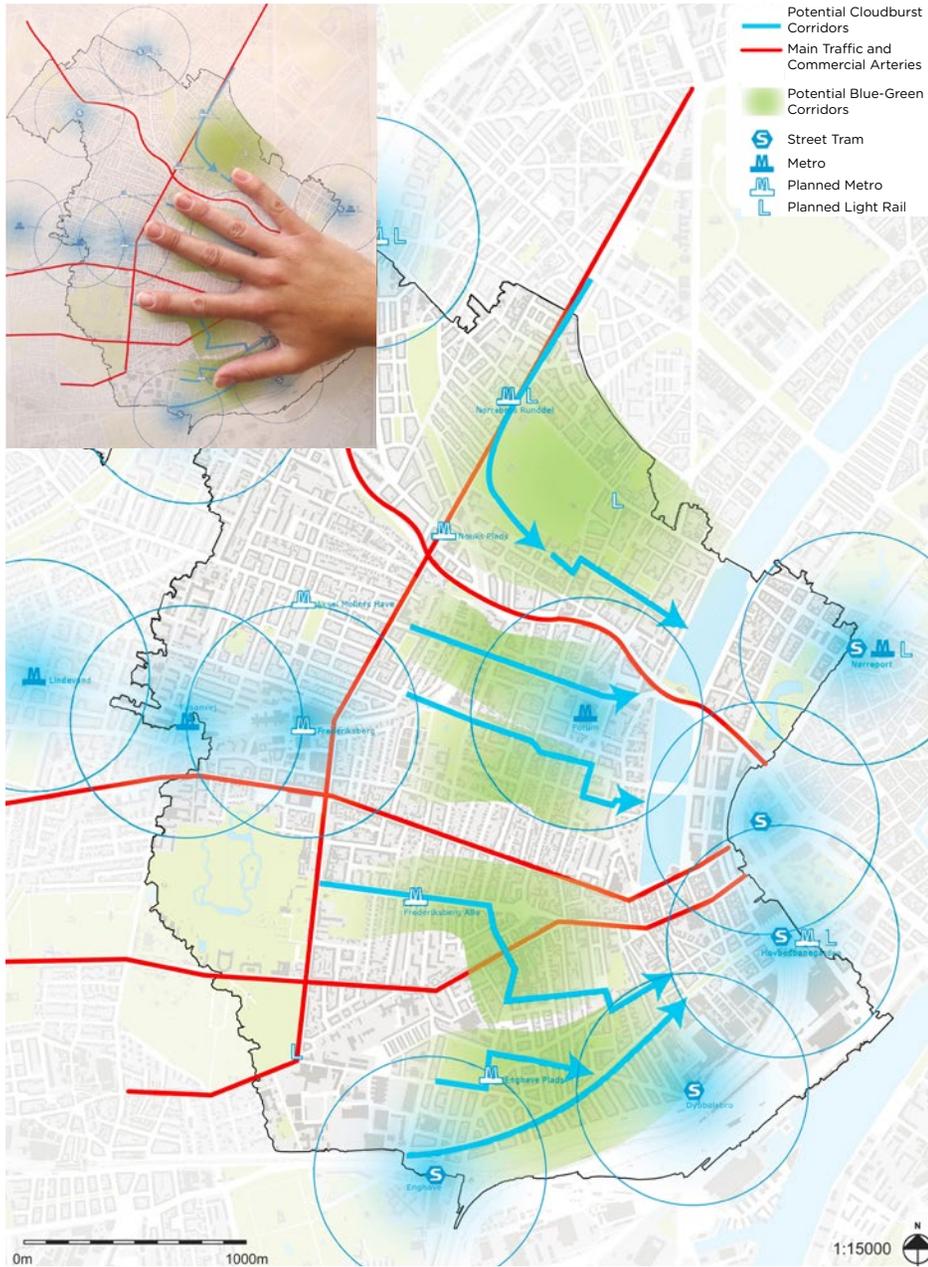
Risk-Analysis in proximity to Sankt Joergens Lake



Planning must be Collaborative

## Analysis-Based Solutions

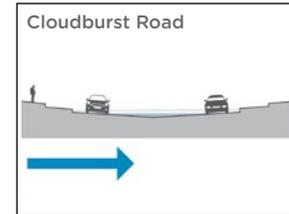
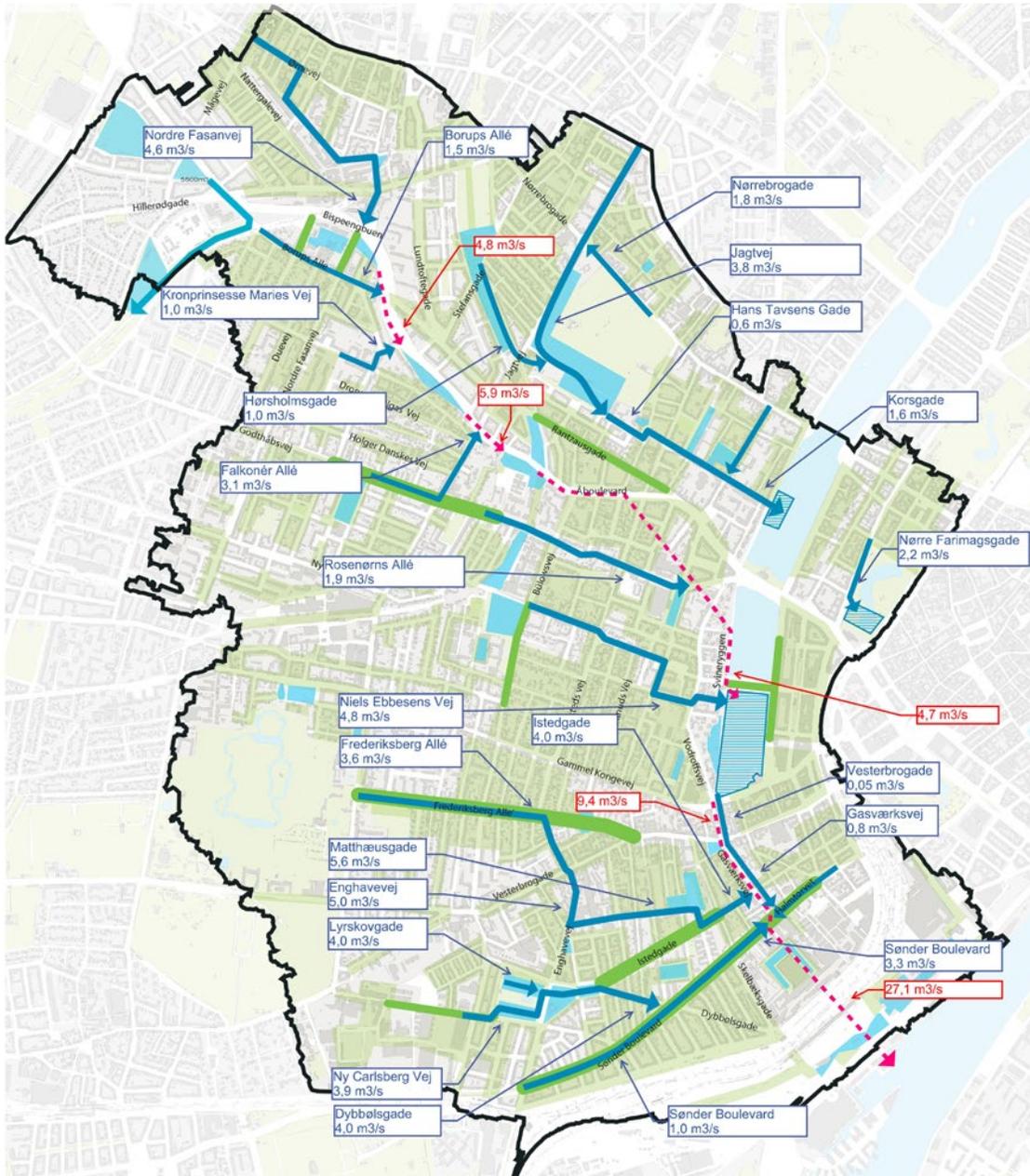
The Lådegåds-Åen catchment was selected as a prototypical test area due to its high risk to flooding and sea surges. Comprehensive site analysis led to establishing the Copenhagen Cloudburst Formula, a Cloudburst Toolkit, and a community engagement platform.



Detailed Analysis shows the complexity involved in determining areas most at risk to flooding and potential catalyst sites that can serve as test project areas

## Common Vision

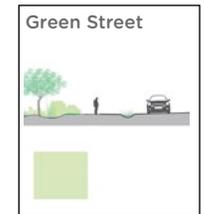
Within the Lådegårds-Åen catchment, a system of Cloudburst boulevards follow the ‘fingers’ of the existing river network, identifying opportunities for investment along green corridors where surface solutions ensure mitigation is visible, interactive. Payback = a vibrant, liveable city.



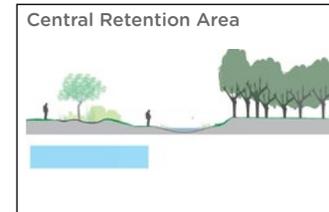
Cloudburst roads are used to channel and direct cloudburst water. These streets can be formed with a unique V-shaped profile and raised kerbs to ensure water will flow in the middle of the road, away from the buildings - contrary to standard engineering practice. Channels and swales can be established along road edges so that water runs in urban rivers or green strips. Cloudburst roads may also be combined with Cloudburst piping below the surface to create tool synergies.



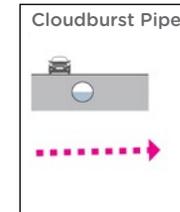
Detention streets are streets that are typically located slightly upstream of vulnerable low-points. In these streets there should be a detention volume established to handle stormwater before reaching the more vulnerable points downstream.



Green streets are proposed as upstream connections to all Cloudburst roads. The green streets should be established with a combination of small-scale channels and stormwater planters or permeable paving. Stormwater should be collected, delayed and then channeled towards the Cloudburst roads.



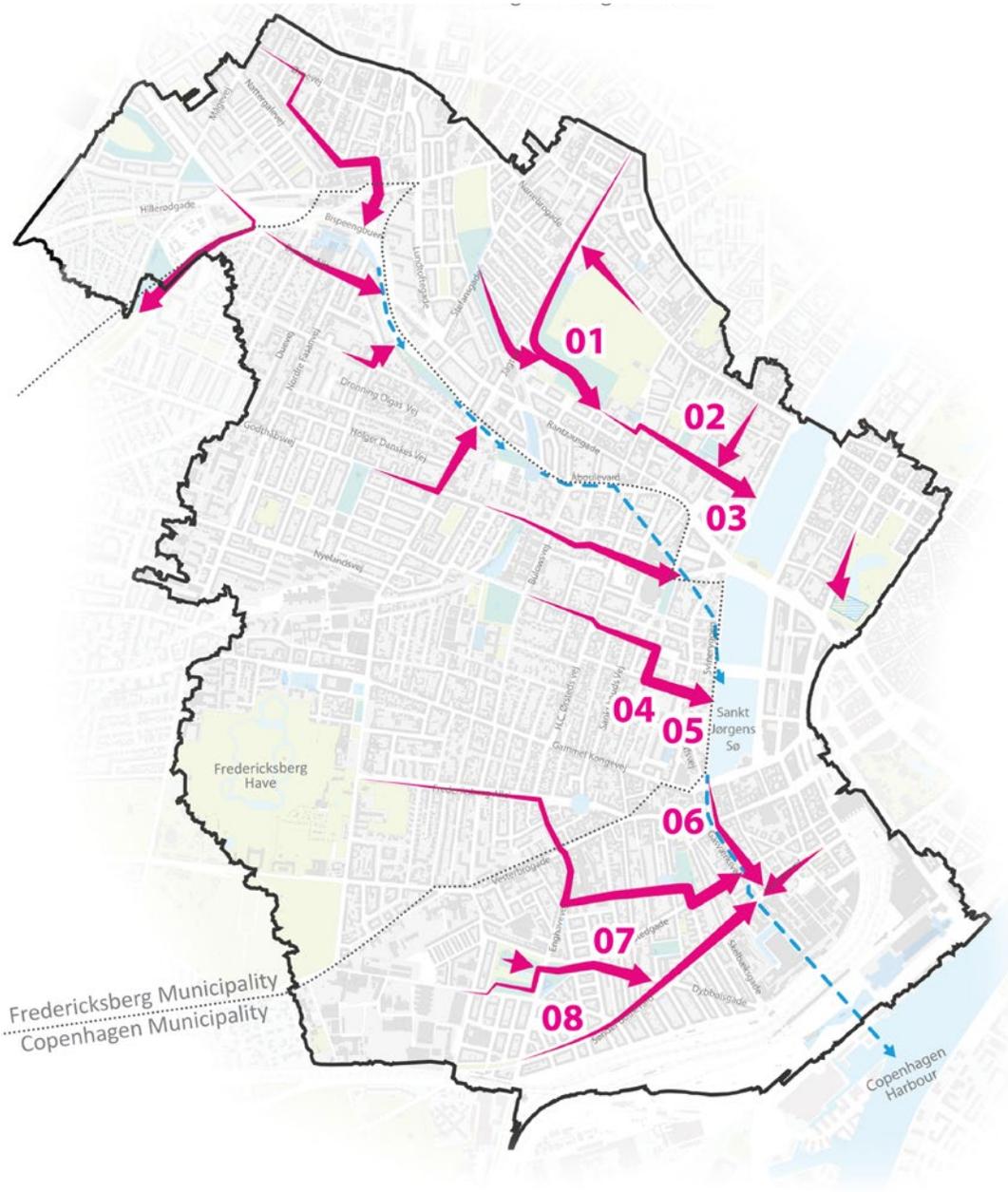
Central retention areas are proposed in the squares and parks where it is possible to delay stormwater, so that Cloudburst roads can be established in smaller dimensions. The central retention elements can be, for example, open depressions in the parkland or lowered seating areas. Alternatively, they can be established as underground storage such as soak-away crates or rain gardens. Central retention elements will typically be placed in connection with adjacent Cloudburst roads.



A Cloudburst pipe handles rainwater in the same way as Cloudburst roads. This is placed just below street level to ensure connection to other surface solutions. This solution is used if there is no useable space for aboveground solutions.

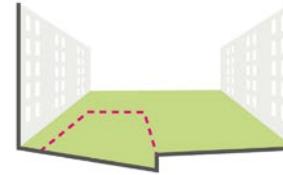
## Evaluating Development Options

While two options were created, Masterplan Option 1 results in higher quality open spaces, lower investment costs, and more flexible flood mitigation solutions. Blue-Green tools (shown above) combine with Cloudburst piping and the existing city infrastructure network.

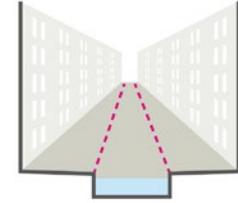


## CLOUSBURST TOOLBOX

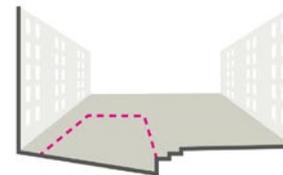
**01** Park  
Hans Tavsens



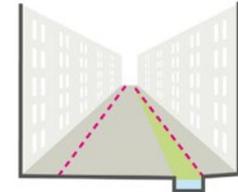
**05** Urban Canal  
Vodrofsvej



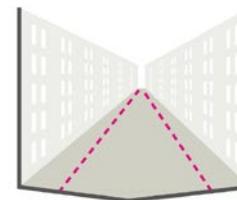
**02** Plaza  
Blågård's Plads



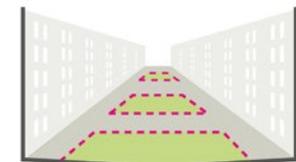
**06** Urban Creek  
Svend Trøsts Vej Sønderboulevard



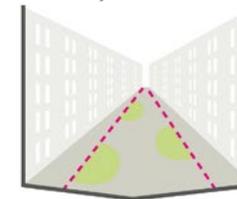
**03** Street  
Korsgade



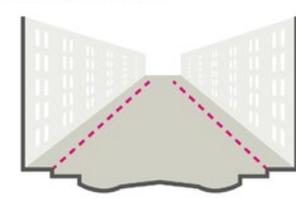
**07** Retention Boulevard  
Istegade Sønderboulevard



**04** Green Street  
Gasværksvej

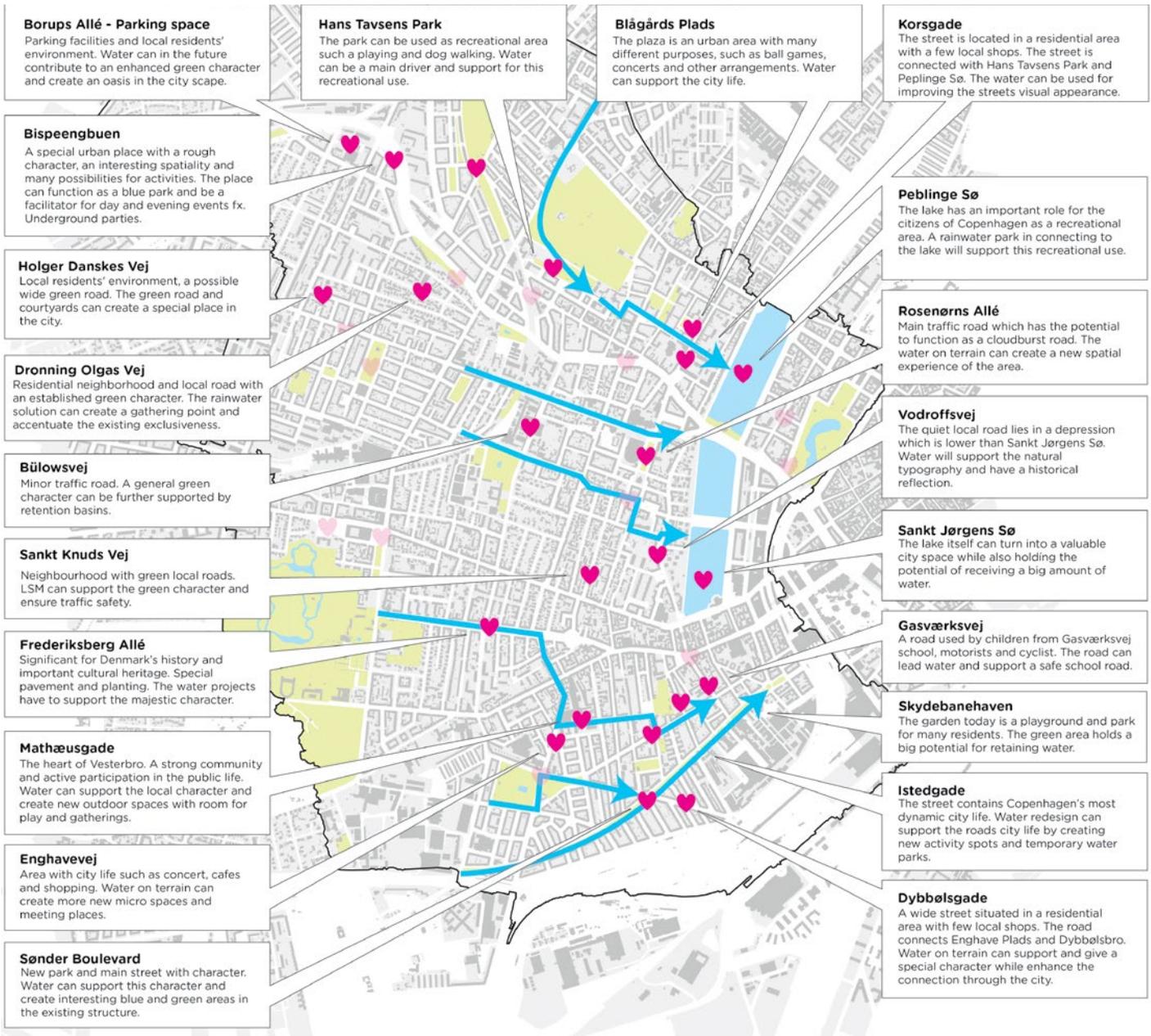


**08** Boulevard  
Sønderboulevard



## Cloudburst Toolkit

Based on the Pilot Project results, eight Urban Intervention Tools were developed to mitigate streets, parks, and plazas. The Cloudburst Toolkit combines hydraulic engineering (Grey Solutions) with Blue-Green Solutions to establish a model for universally-applicable Cloudburst mitigation tools.



**01 Park**  
Hans Tavsens



**02 Plaza**  
Blågårds Plads



**03 Street**  
Korsgade

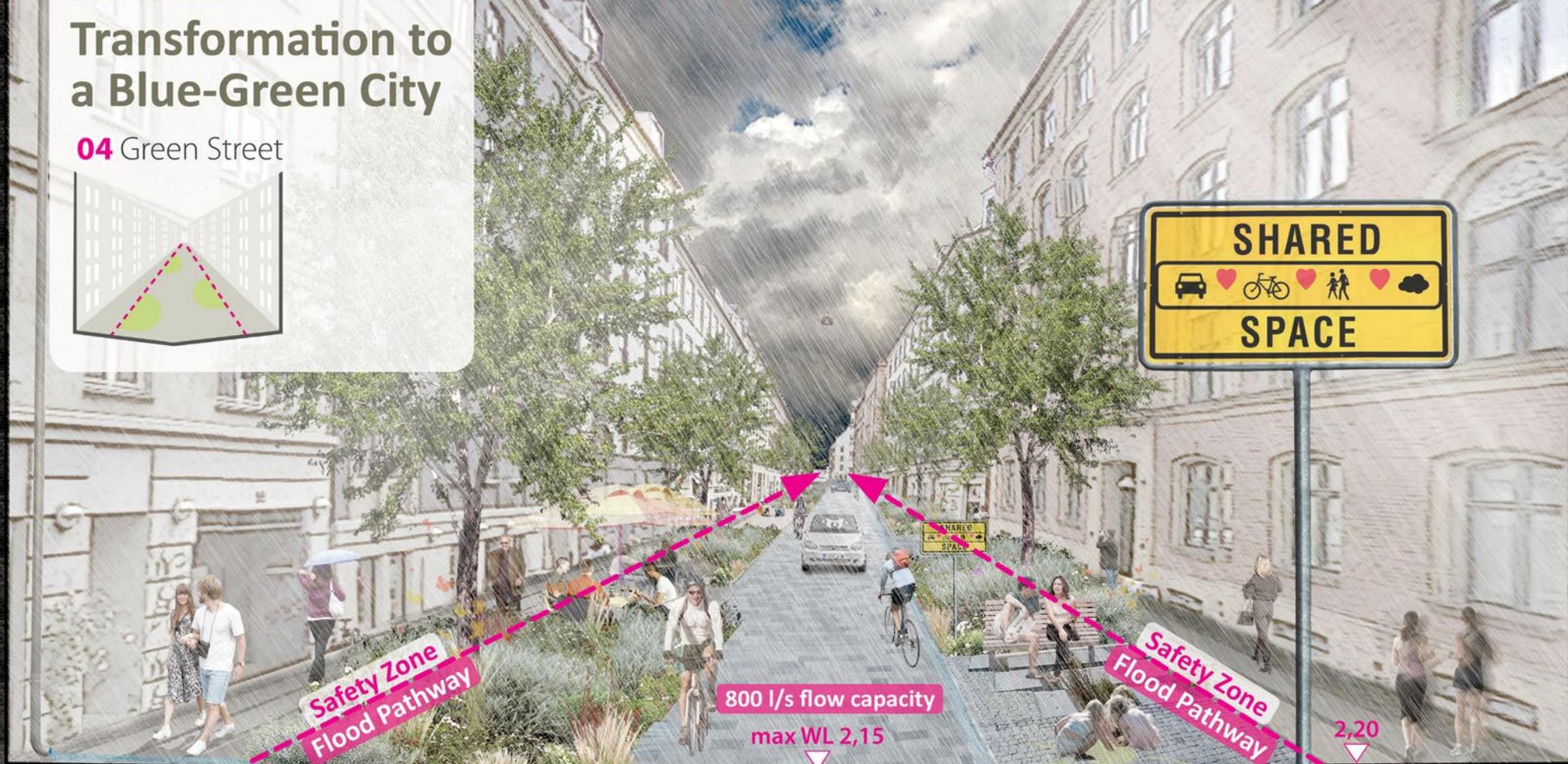
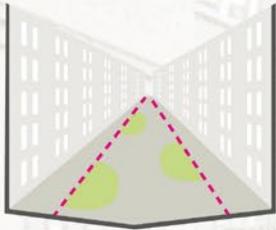


**Selective Intervention**

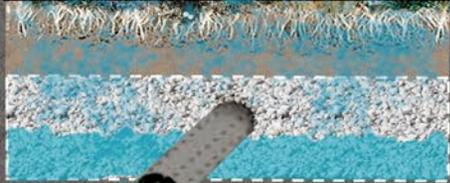
Hot Spots (sites suitable for test implementation of the “Cloudburst Toolkit”) were identified by the Landscape Architect. Each tool is shown to demonstrate its applicability within the Pilot Project as well as universal applicability as a typology-based solution.

# Transformation to a Blue-Green City

## 04 Green Street



EVERYDAY RAIN  
**30% DISCONNECTION**  
 from existing combined  
**SEWER** system.



2,5 m

3,5 m

(16 m)

4,0 m

3,5 m

2,20

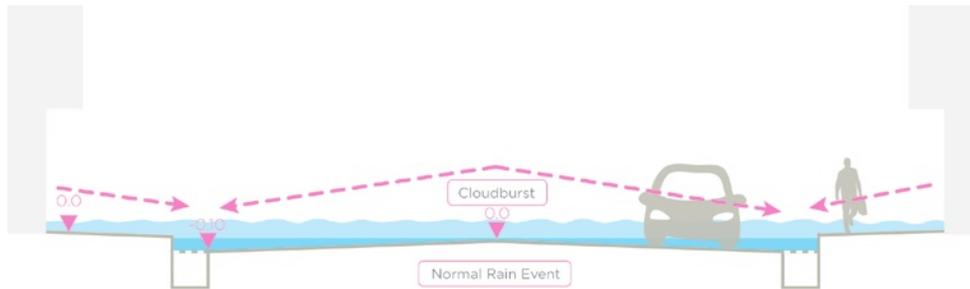
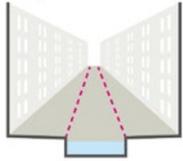


walk	planter   urban activation	cycle - 2 way   drive - 1 way	urban activation   planters	walk
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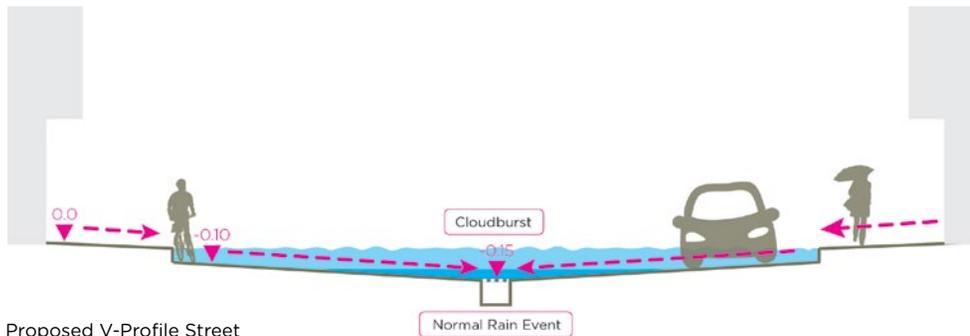
**Tool: Green Streets**

Green streets utilise lowered street profiles to create a Safety Zone and a Flood Pathway Corridor. Shared public spaces integrate pedestrians, cyclists, motorists, and alternative transportation along a common public realm. Solutions are visible public education tools.

**05 Urban Canal**  
Vodrofsvej



Conventional: Existing Crowned Street



Proposed V-Profile Street

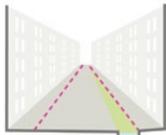


**Tool: Urbn Canal**  
**'V-Profile'**

A V-Shaped road profile challenges conventional traffic engineering, retrofitting Cloudburst Streets by flipping street layouts. The radical change allows street widths to be reduced while increasing retention capacity to handle daily and extreme rain events.

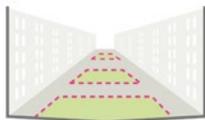
**06 Urban Creek**

Gasværksvej Sønderboulevard



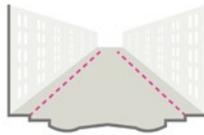
**07 Retention Boulevard**

Istegade Sønderboulevard



**08 Boulevard**

Sønderboulevard



**Driving Investment**

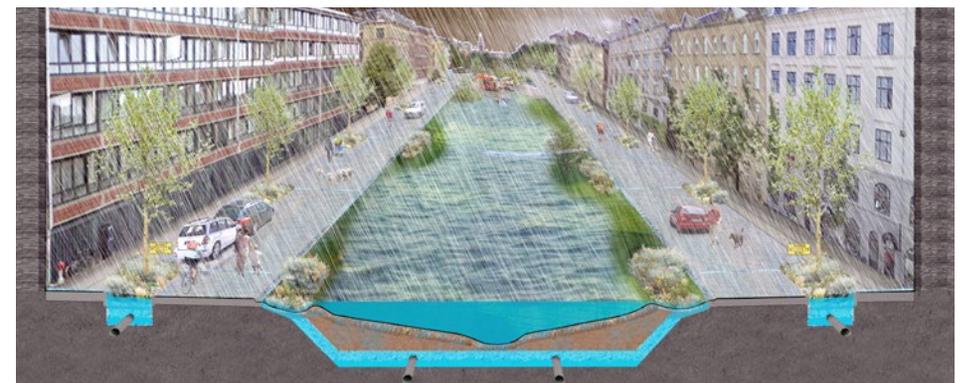
Blue-Green infrastructure helped to lower capital, operational, and maintenance spaces by as much as 75% (American Rivers 2012) while Danish Consultants calculated that \$200 million investment cost could be saved by combining Blue-Green with minimized conventional piping.



Rain Event Handled within Multi-Functional Tools including Urban Creek, Retention Boulevard, and Boulevard

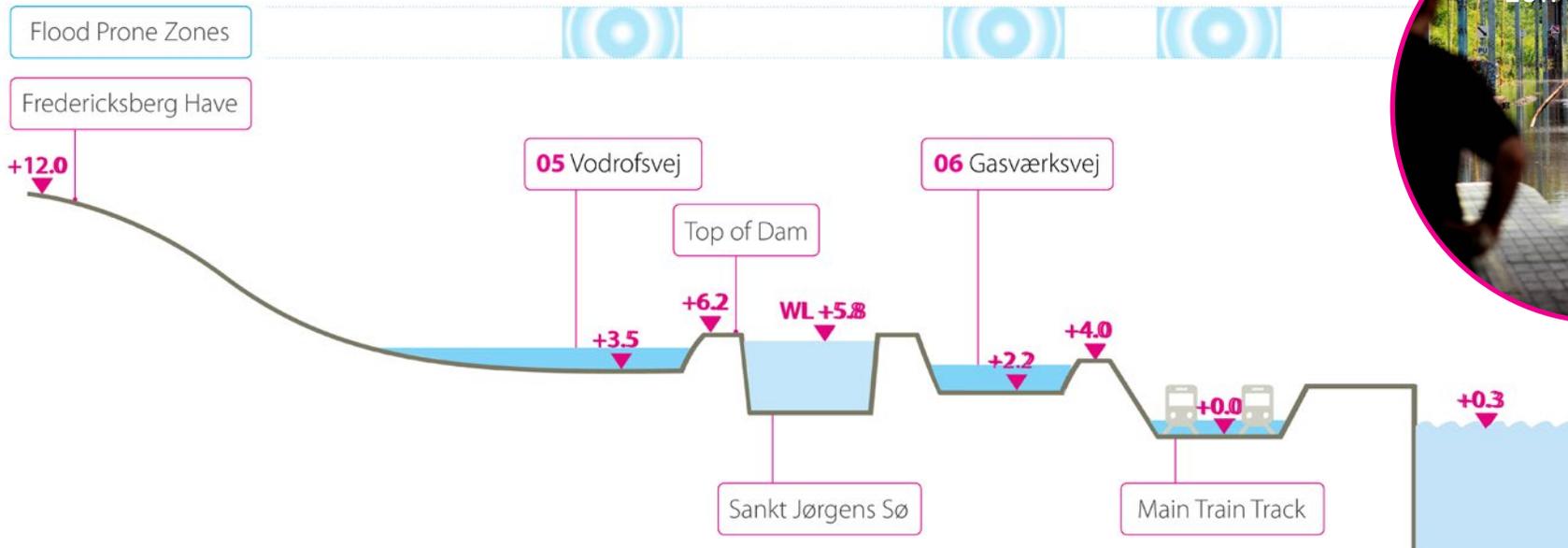


Dry, Normal

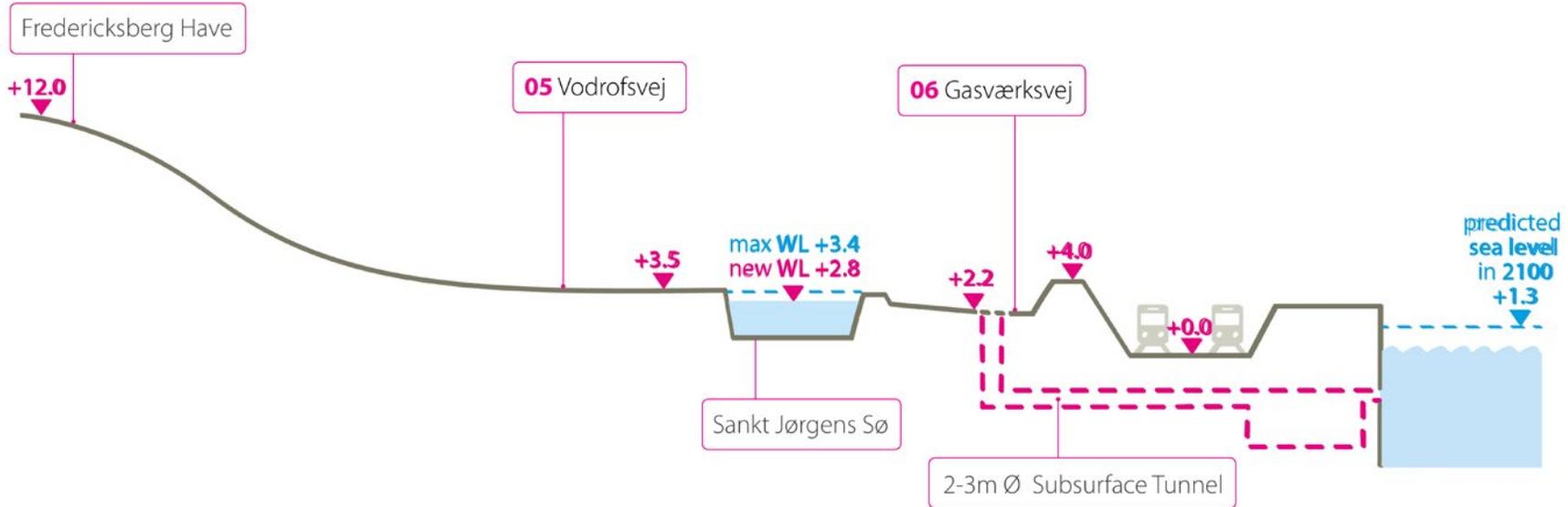


Cloudburst

# BEFORE: Barriers



# AFTER: Connections



**Testing  
Cloudburst  
Theory**

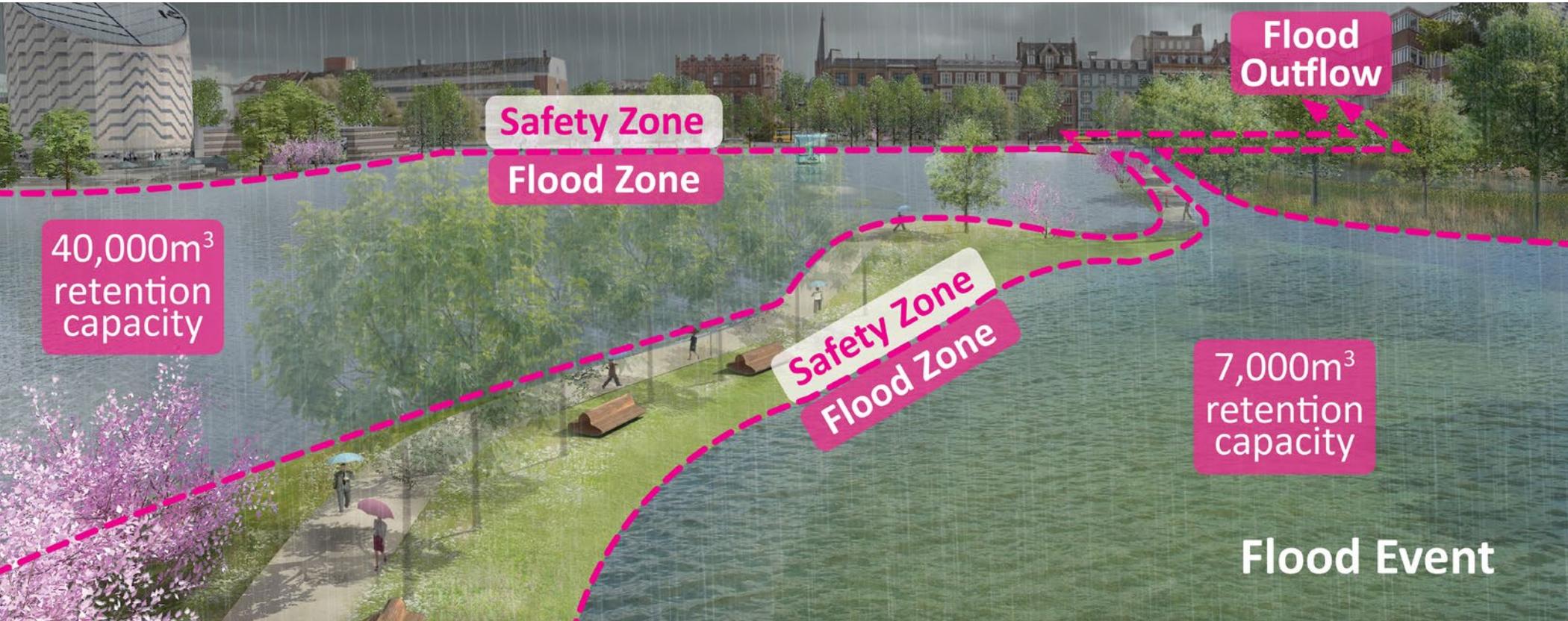
Sankt Joergens Lake is currently higher than surrounding green spaces. Removing the physical barrier to the waterfront and creating a bypass tunnel, combining Blue-Green techniques with 'Grey' piping, creates a new people place while mitigating Cloudburst flooding.

# SANKT JØRGENS SØ Dry

Existing Lake Edge

Existing Lake Edge

**Applying the Copenhagen Formula**  
Multi-functional edges with accessible waterfronts, creating habitat zones paired with beach and recreational program while retaining and improving existing urban structure. Even during rare Cloudbursts, the lake provides flood storage and protects surrounding areas from flooding.





Flooded Streets



**A New 'Old' Destination**  
 The lake becomes a multi-functional park space with recreation, fitness, and heritage amenities that capitalize space use, simultaneously mitigate Cloudbursts and normal rain events, and beckons residents and guests to engage with the active waterfront edge.

**3.3x more active**

Residents in green neighborhoods are three times more likely to be physically active when compared to non-green neighborhoods (Forestry Commission).

**↑10% real estate value increase**

Green areas increase adjacent real estate value between 10-15%, or 1% for every 1 hectare of space within walkable proximity (Trust for Public Land, 2009).

**\$200 MILLION SAVED**

Cloudburst solution to combine Blue-Green solutions with a reduced pipe size both saves money and creates a multi-functional solution, establishing benefit synergies.

# CONTACT

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