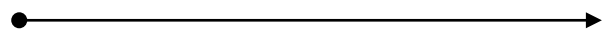


Adapting to Uncertainty:  
Re-thinking Critical  
Infrastructural Systems

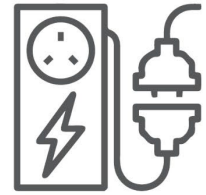
Ranee Leung  
May 22, 2019

## Critical Infrastructure

- Basic systems and services



Transportation



Energy



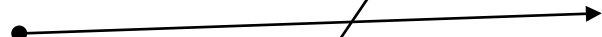
Water



Chemicals



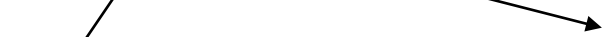
Communication



Defence



Emergency Services



Finance



Food



Government



Health



Shelter



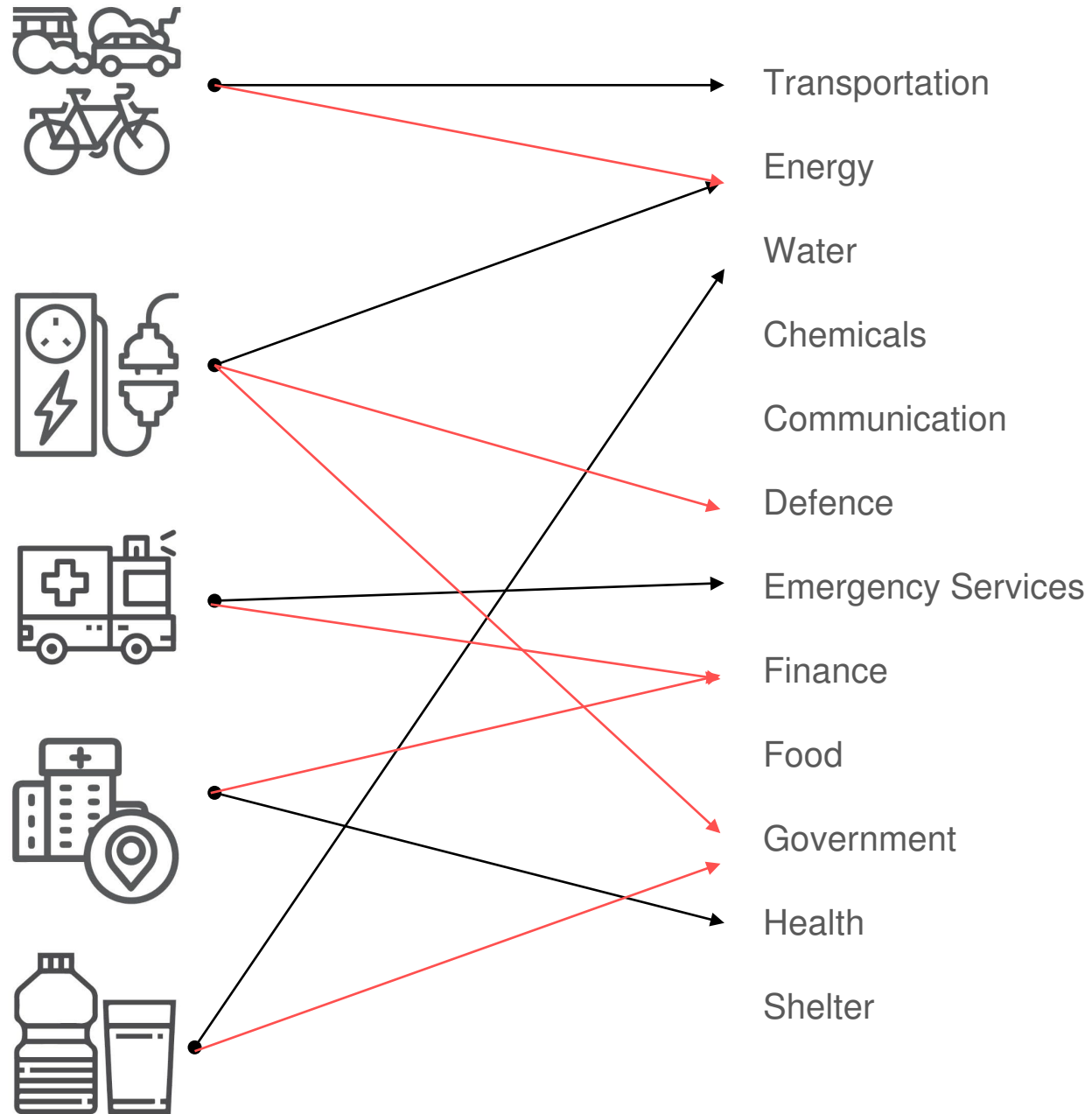
# Critical Infrastructure & Systems

What if one of these systems failed due to a power failure or a flood?



## Interdependencies in Critical Infrastructure

- Long-lasting disruptions

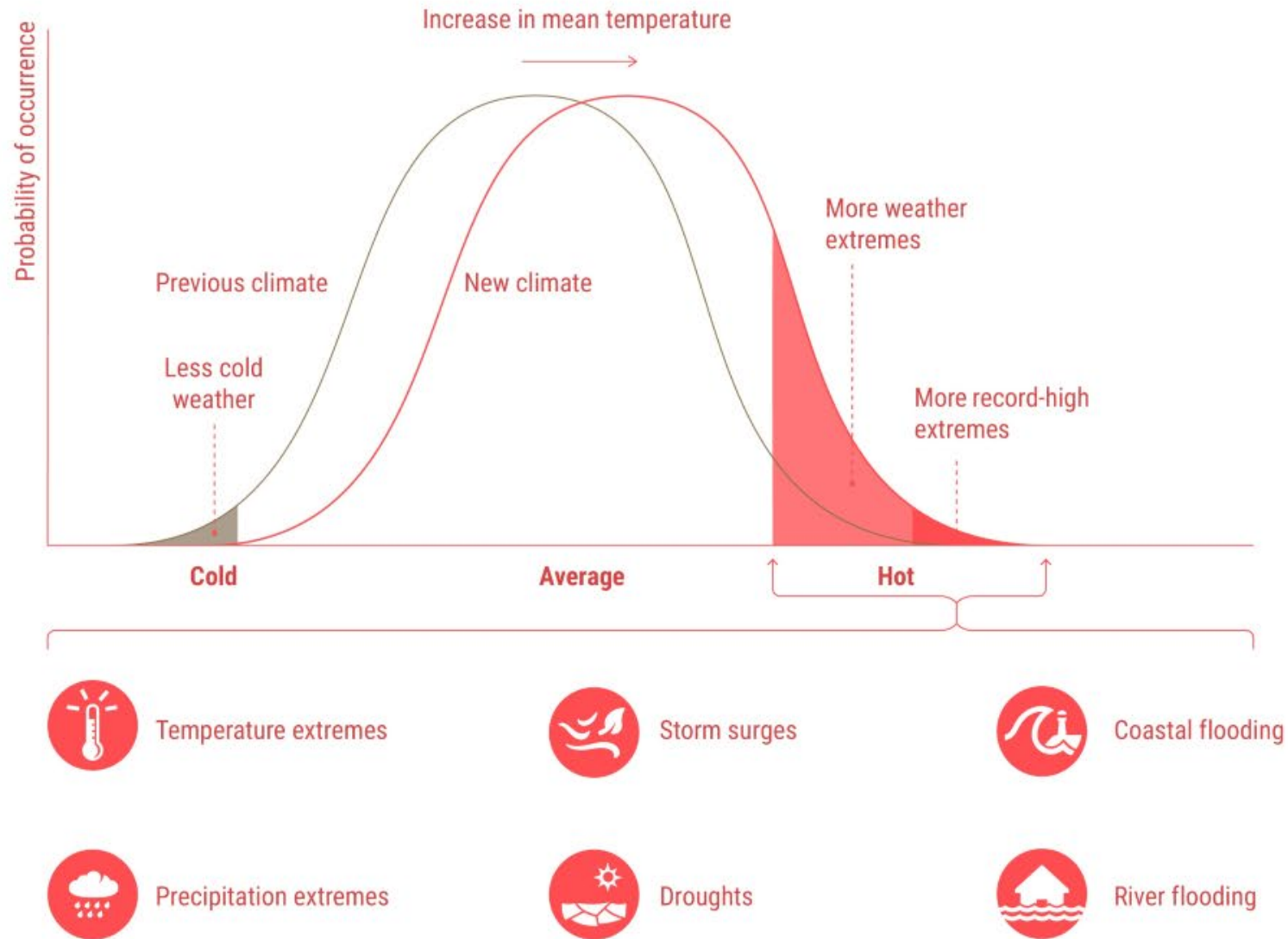


## Critical Infrastructure & Systems

These 'extreme events' are becoming *more intense* and more *frequent*.

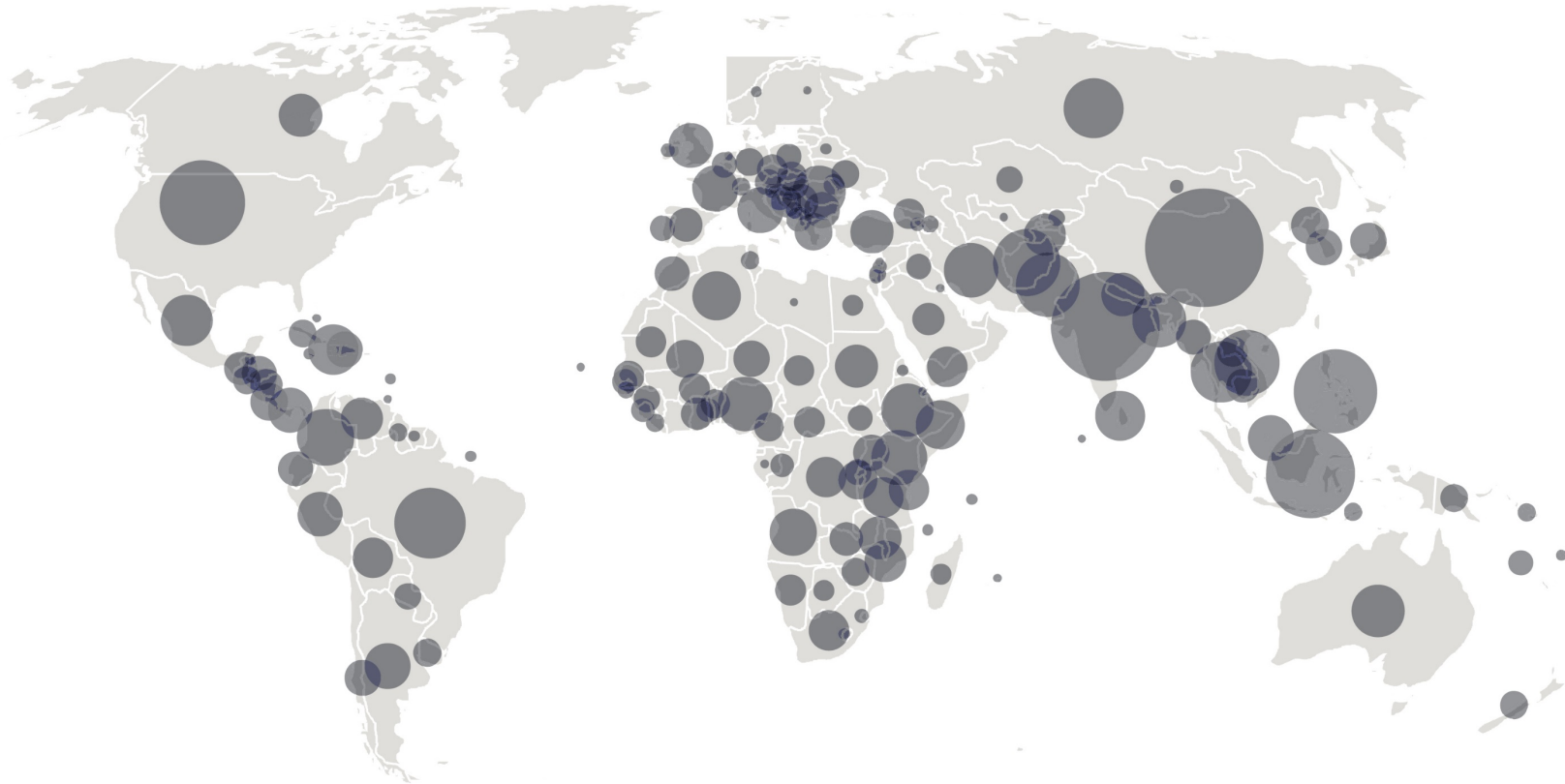


# Climate Extremes



## Uncertainties

Climate uncertainties  
alongside political  
and economic  
uncertainties



Flooding events and number of occurrences from 1996-2015 around the world  
(Source: CRED)

## Existing Critical Infrastructure

- Not possible to protect all critical infrastructure systems and services
- Areas most physically vulnerable

**CRITICAL INFRASTRUCTURE**



*Energy*



*Waste*



*Communication*



*Emergency Services*



*Finance/  
Government*



*Food*



*Water*



*Transportation*



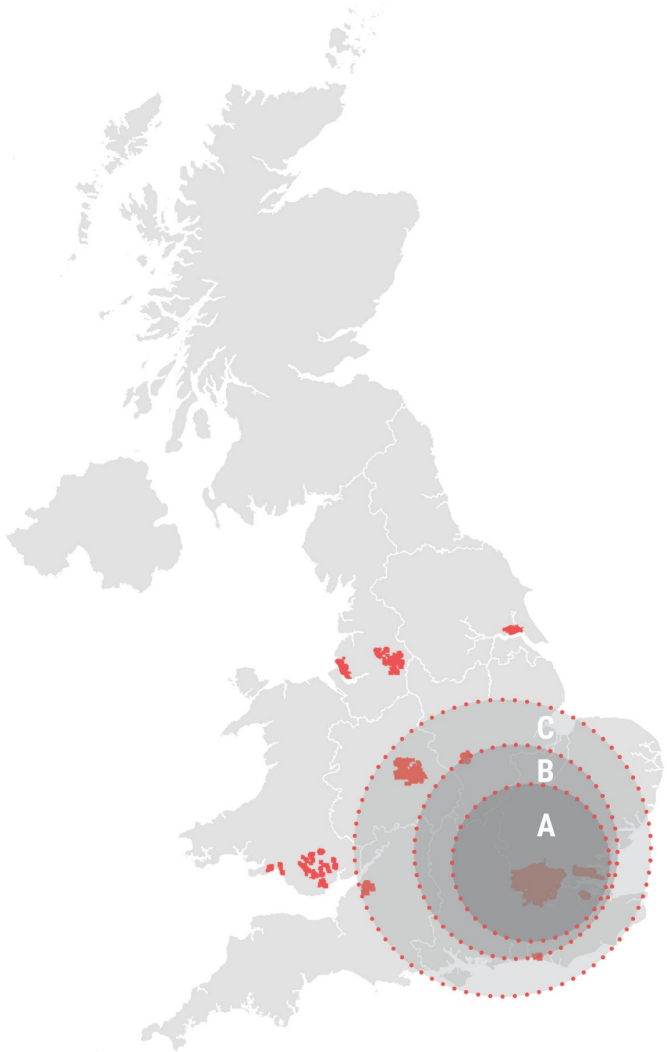
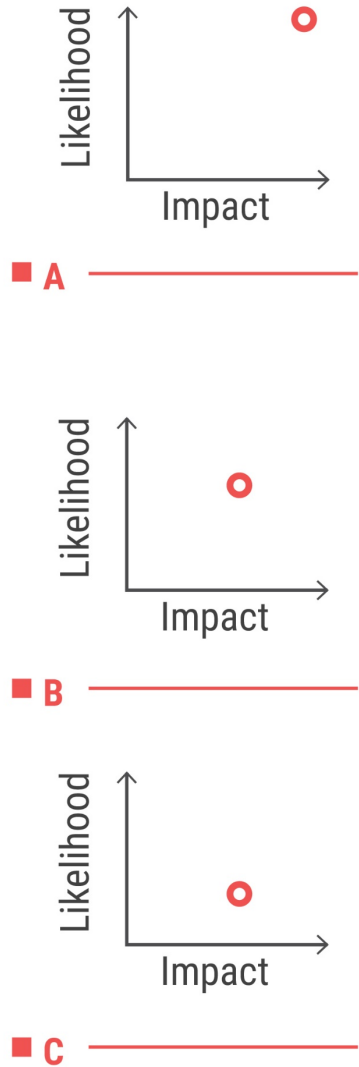
*Healthcare*



*Shelter*

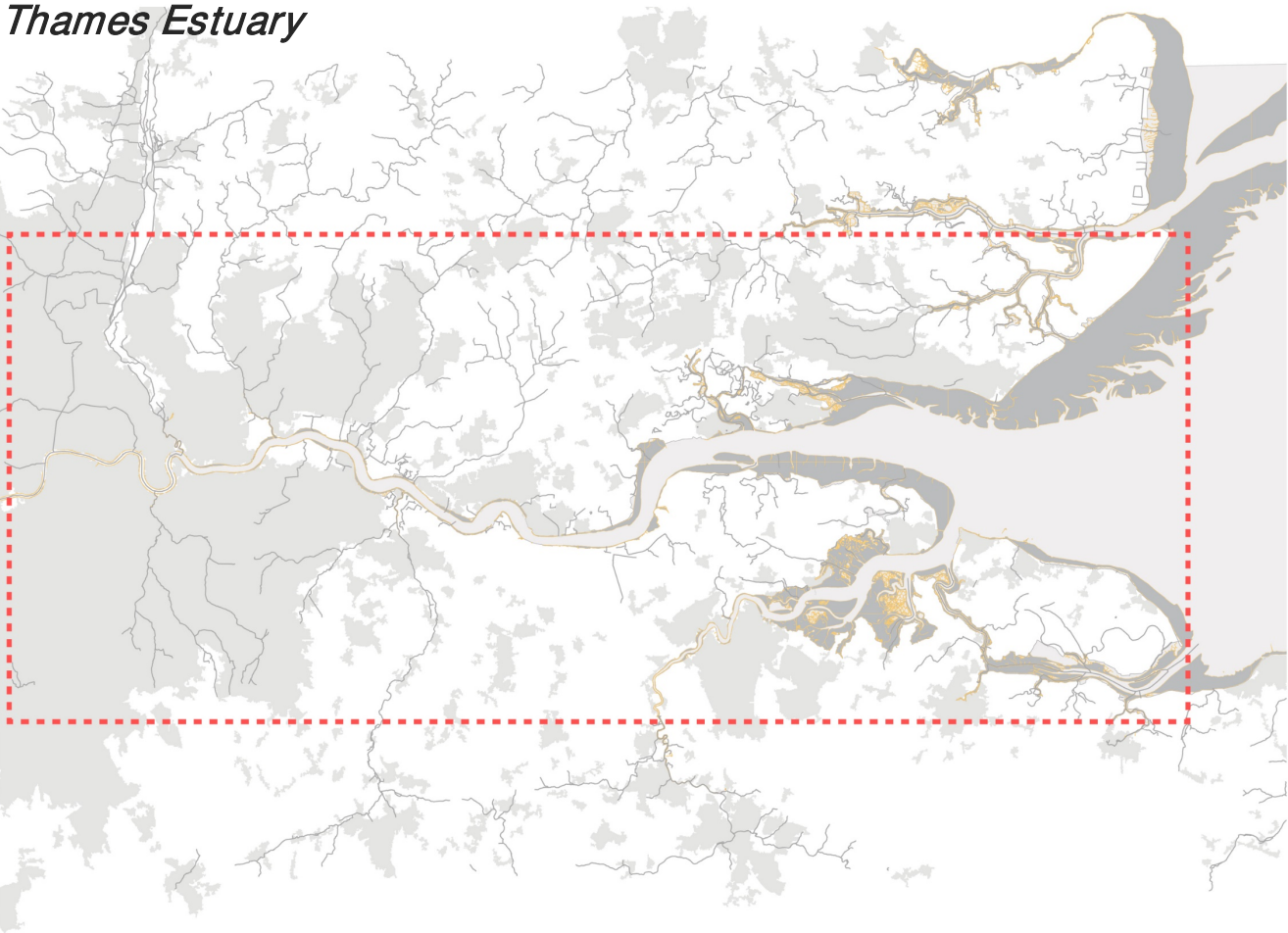


# Flood Risk Thames Estuary



Map of UK Flood Risk Matrix impact to critical infrastructure

# Flood Risk Thames Estuary



- ↑ Growing risk
- ↑ High Urbanized
- ↑ Political & Economic Zones

How well do you think critical infrastructure systems can respond to sudden shocks and recover from them?



## Compounding Issues

- Resilient critical infrastructure and systems



Ensuring service continuity



No agency responsible for system failure

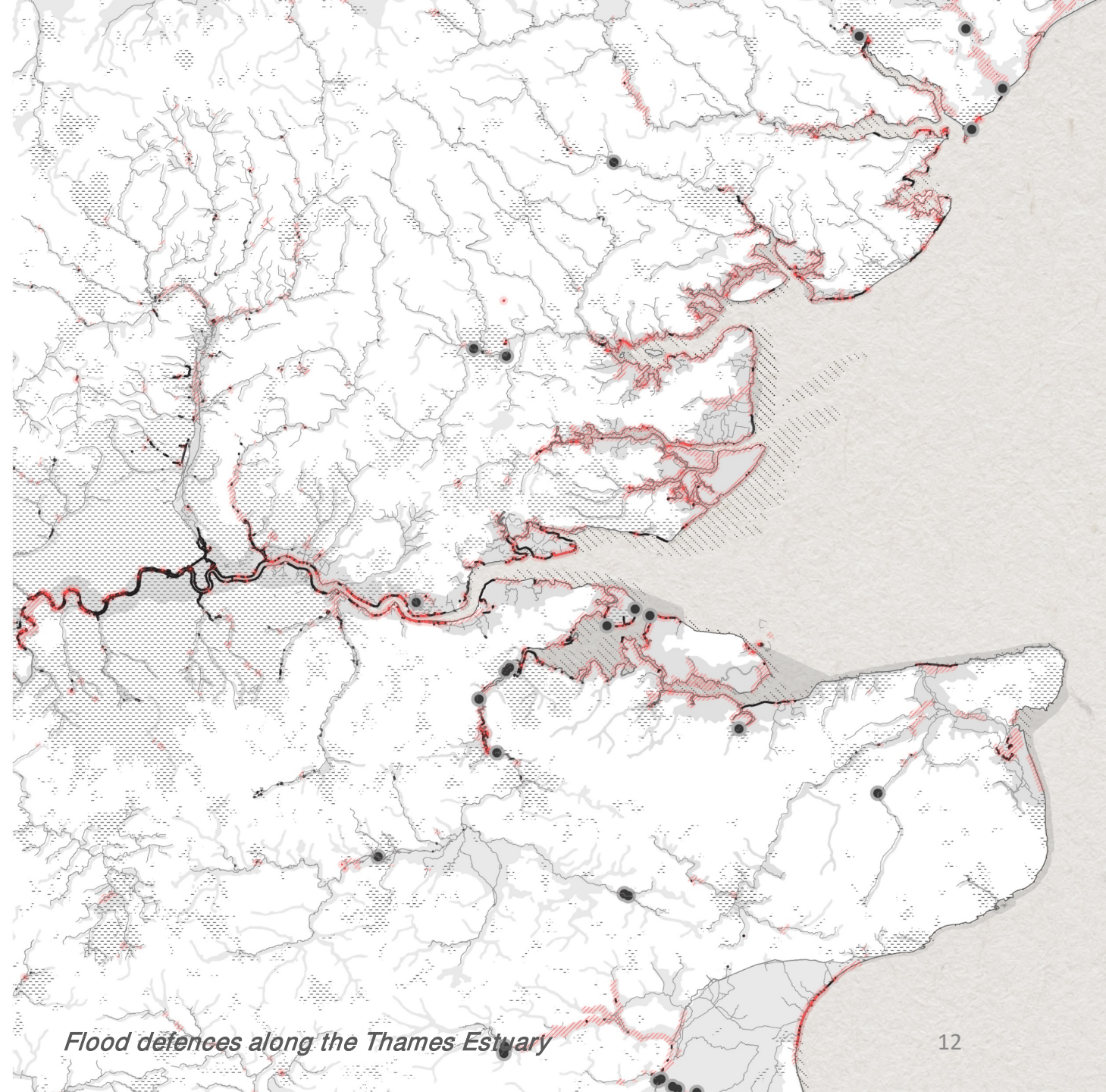


Assets exposed expected to double by 2080



Aging flood defenses to be replaced by 2030-2060

- Urbanized Area
- Dunes
- High ground
- Wall
- Demountable defences
- Flood gate



## Research Question

**How to develop dynamic and adaptable strategies for vulnerable critical systems to address deep uncertainty and flood risk for the Thames Estuary Region?**



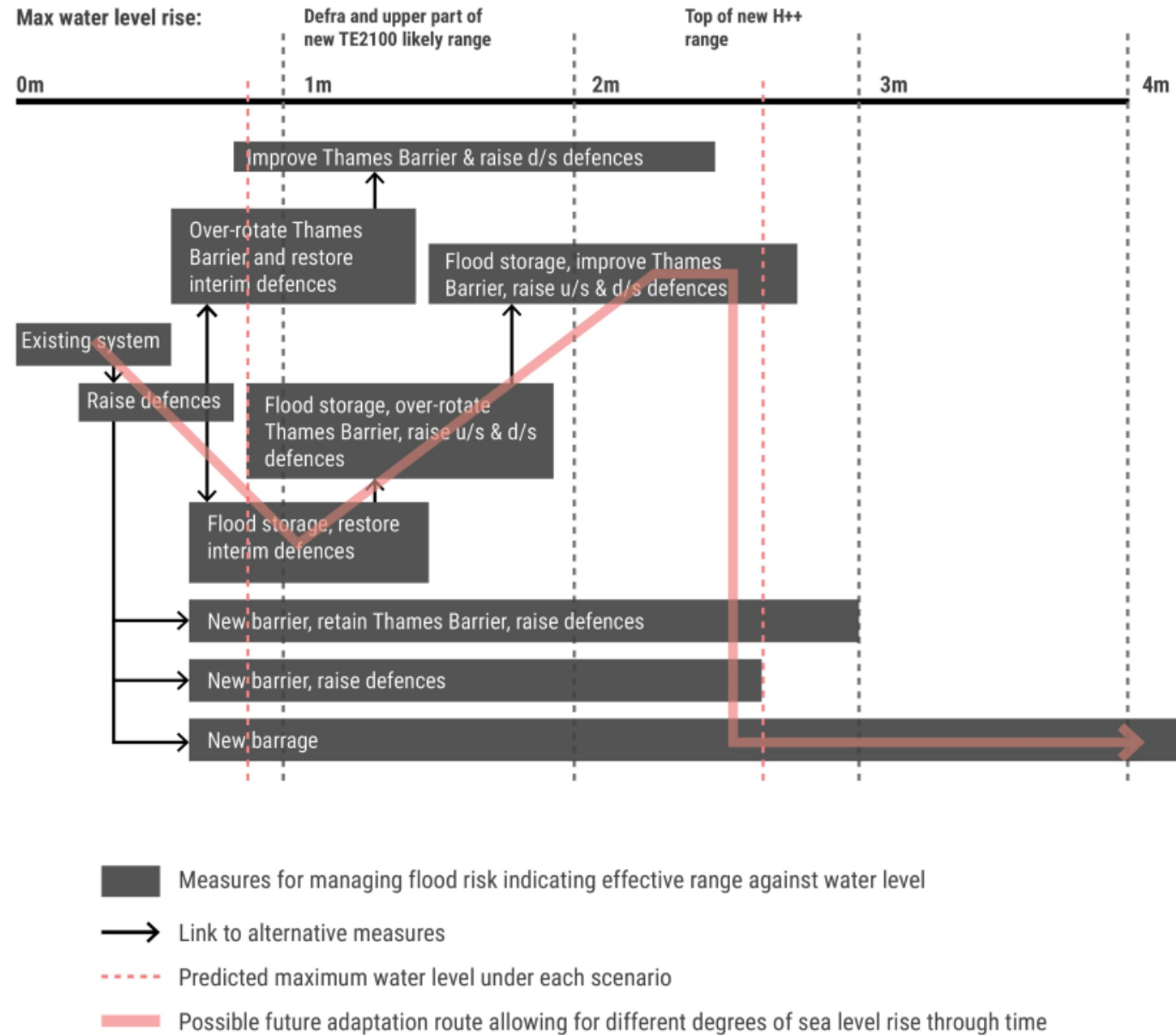
# Risk Management Cycle



# Thames Estuary 2100 Plan

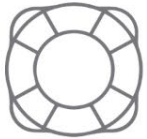
## Critique:

- Mitigation and reinforcing traditional approaches to flood defences
- Environmental degradation



## Residual Risks & Contingency Plan

What if there was a system failure or breach in defences? Is there a backup plan?

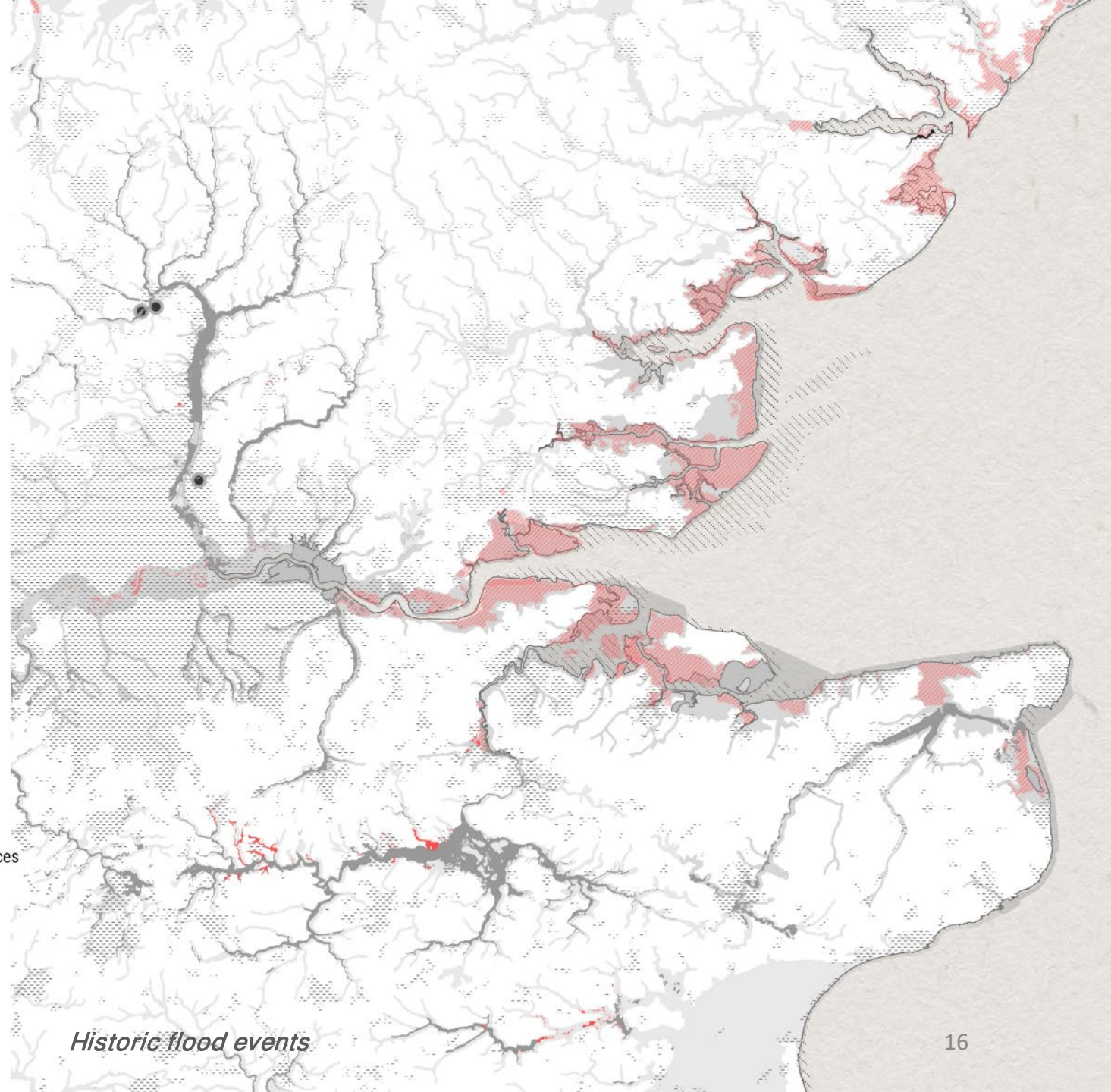


No spatial contingency plan



Less than 10% of the population are aware of the risks

- Urbanized Area
- Over topping of defences
- Flood zones
- Operational failure/breach in defences
- Local drainage/surface water
- Channel capacity exceeded
- Obstruction/blockage- debris
- Mechanical failure







**How do we create a spatial contingency plan? And can we use this as an opportunity to integrate early response and recovery into planning?**

## Contingency Planning

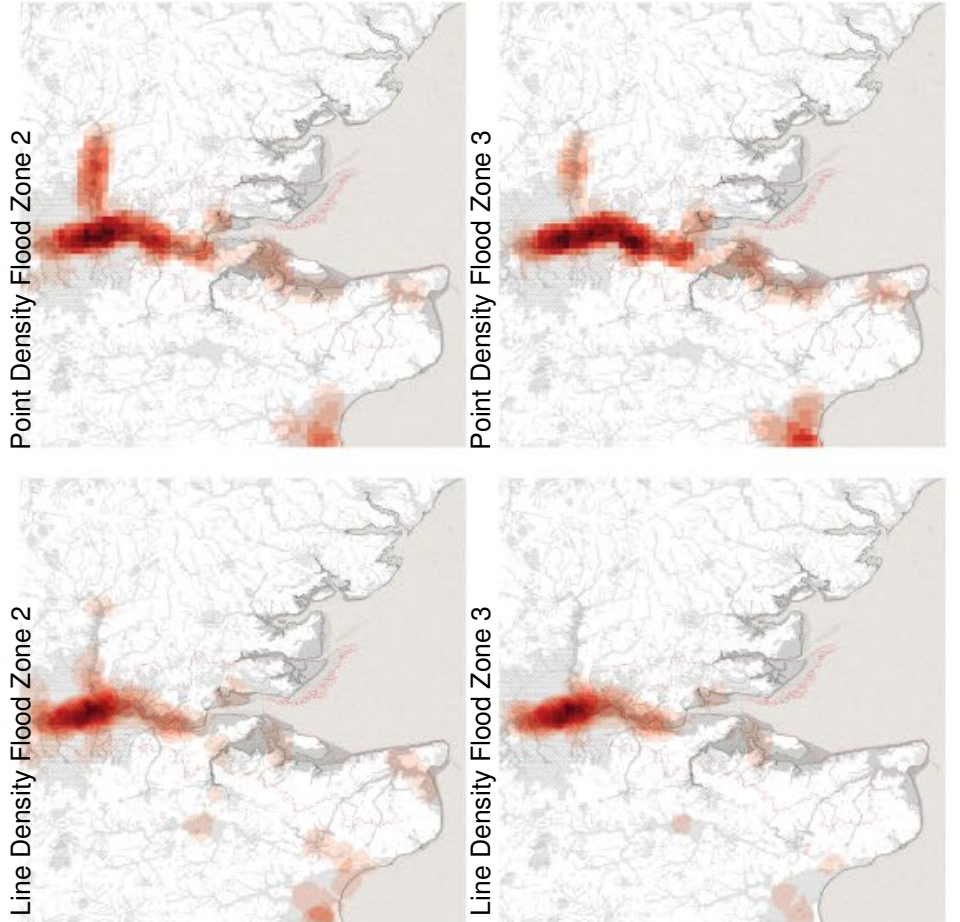
```
graph LR; A[Track available essential services in an emergency] --> B[Analyze impact of hazards events]; B --> C[Develop adequate arrangements for affected populations];
```

Track available essential services in an emergency

Analyze impact of hazards events

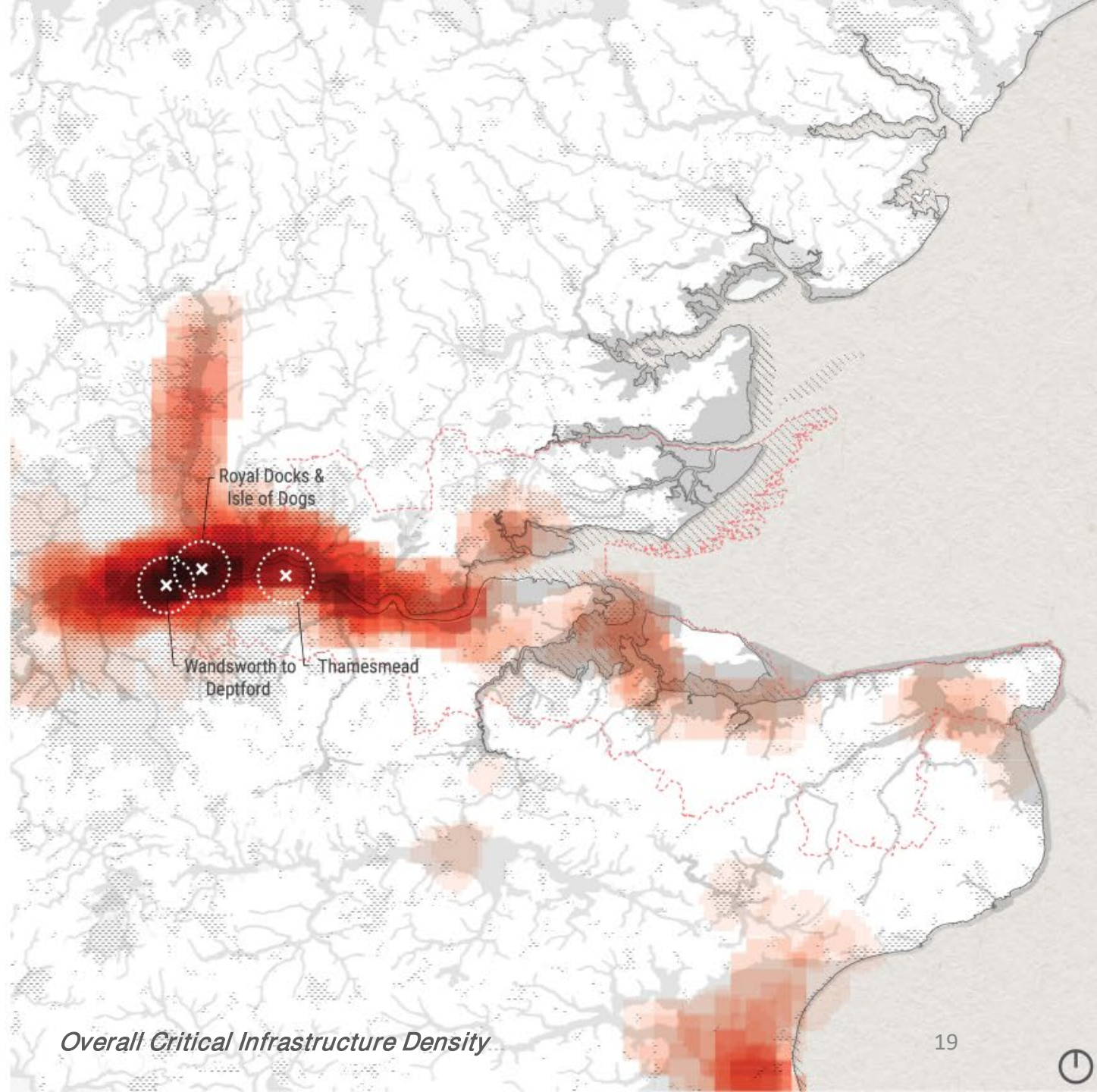
Develop adequate arrangements for affected populations

# Defining Vulnerable Policy Units Through Flood Exposure



## Chosen Vulnerable Policy Units

1. Wandsworth to Deptford
2. Royal Docks
3. Isle of Dogs



## Chosen Vulnerable Neighbourhoods



**Wandsworth to  
Deptford**

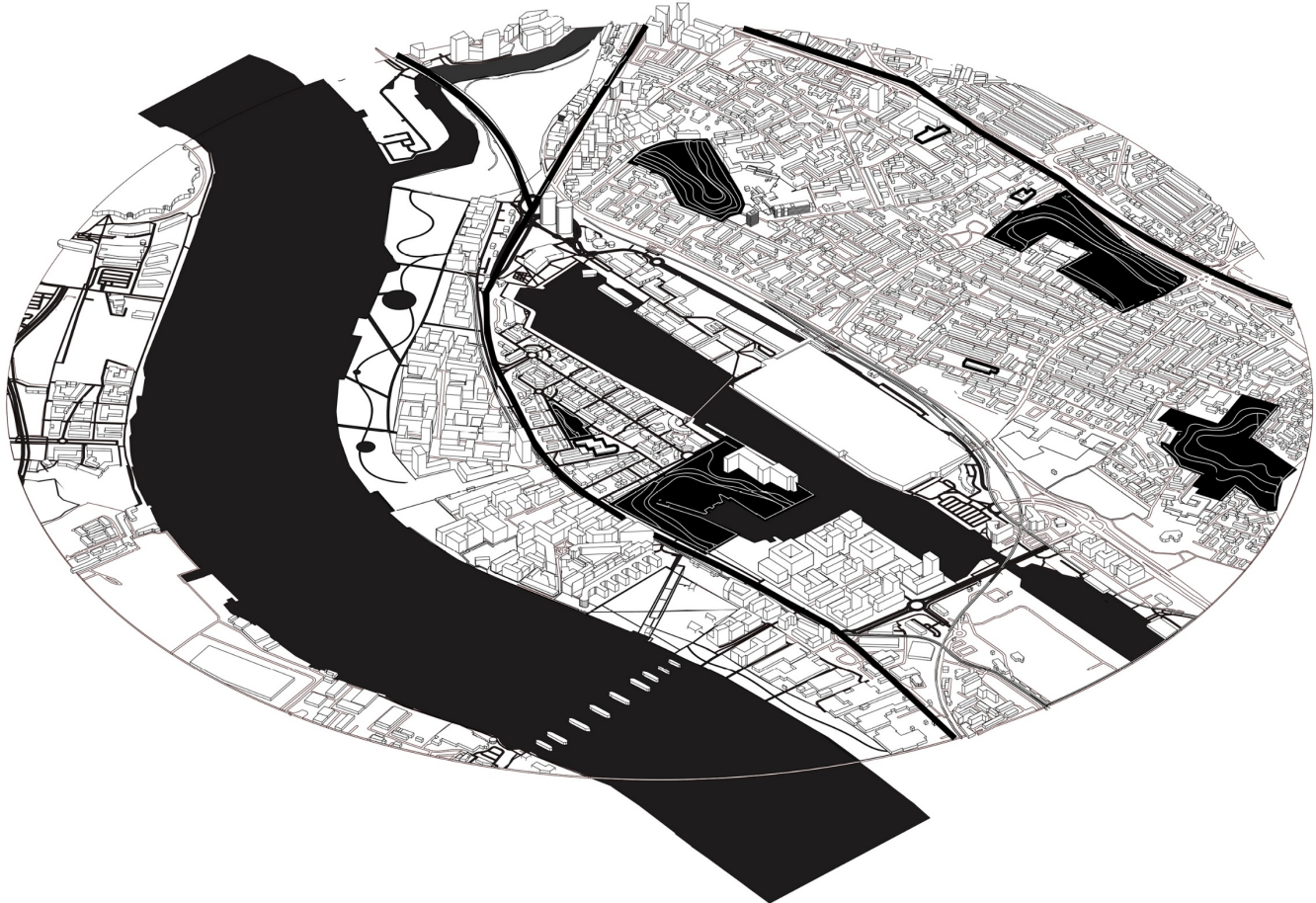


**Isle of  
Dogs**



**Royal  
Docks**

**Aspect 1: Emergency Backbone Services**



# Contingency Planning

**CRITICAL INFRASTRUCTURE**



*Energy*



*Waste*



*Communication*



*Emergency Services*



*Finance/  
Government*



*Food*



*Water*



*Transportation*



*Healthcare*



*Shelter*

# Aspect 1: Emergency Backbone Services

**CRITICAL INFRASTRUCTURE**



**Energy**



**Waste**



**Communication**



**Emergency Services**



**Finance/  
Government**



**Food**



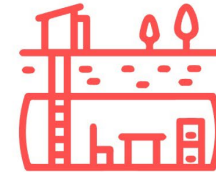
**Water**



**Transportation**  
Emergency Backbone  
in delivering response  
& services



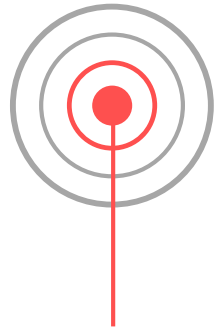
**Healthcare**



**Shelter**  
Schools, Medical  
Facilities  
& Temporary (Open  
Spaces)

# Evaluating the Existing System: Overview

**TRAVEL TIME**



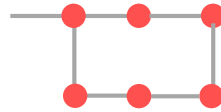
**Shelter**

**Serviceability**  
*Travel Time*

**PROVISION OF RELIEF**



**Schools**   **Medical  
Facilities**



**Shelter  
Network**

**Accessibility**  
*Provision of Relief*

**ACCESS TO LIFESAVING  
SERVICES**

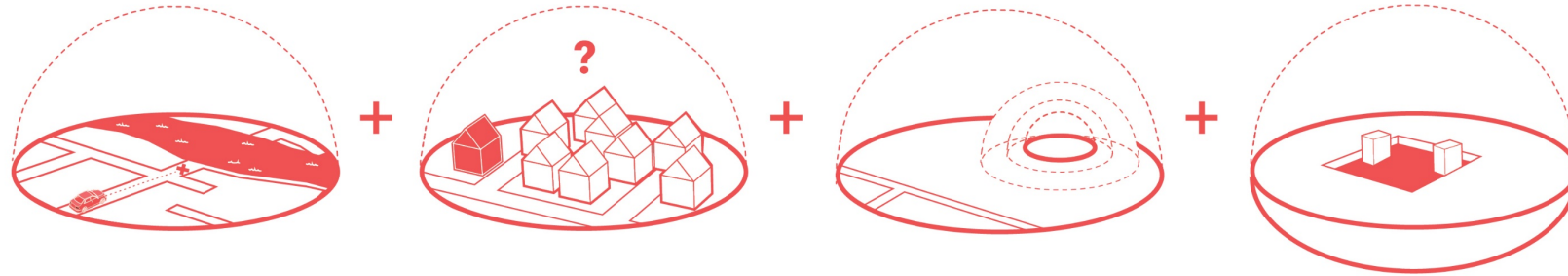


**Park Network  
& Park  
Capacity**

**Accessibility**  
*Access to Lifesaving  
Services*<sub>24</sub>



## Overview of Findings



Insufficient accessible and alternative emergency road networks

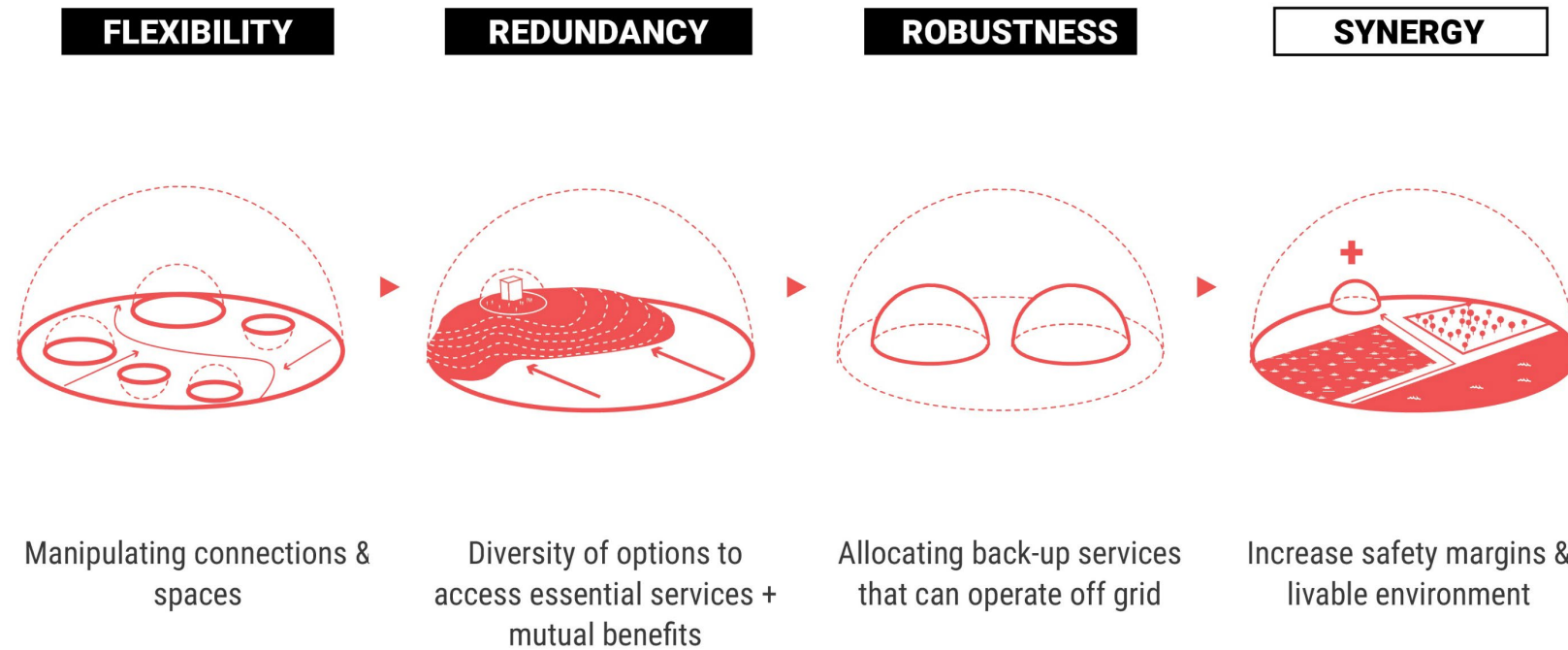
Inadequate numbers and areas of safe refuge

Lack of accessibility to nearby shelters

Trapped volume of water

## Design Aims

- Encourage faster response and recovery



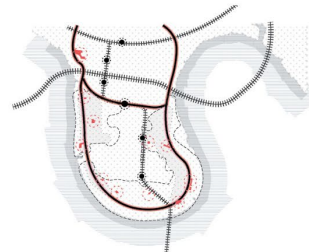
# Vulnerable Neighbourhoods



Isle of Dogs

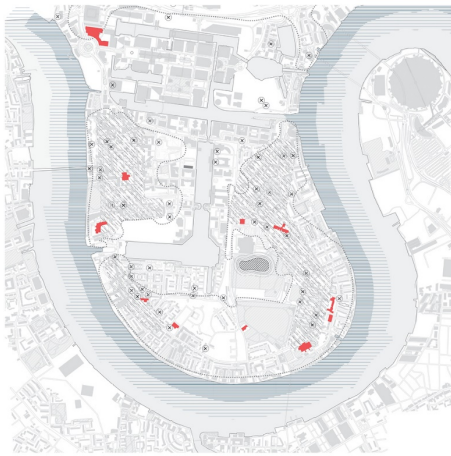


**Flood depth: 3m**  
**Danger:** Limited in/out access

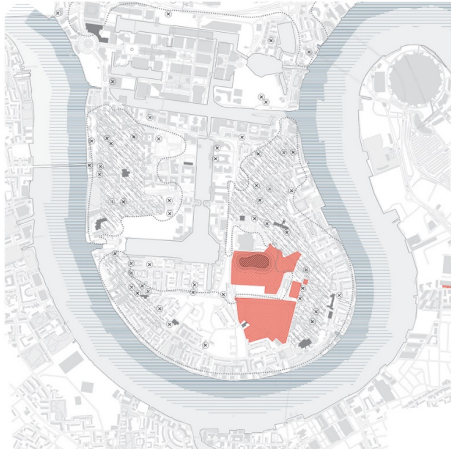


**Shelter & Open Space**  
**Relationship: 1** Large Open Space with smaller scattered.  
**CI lacks connection** to parks

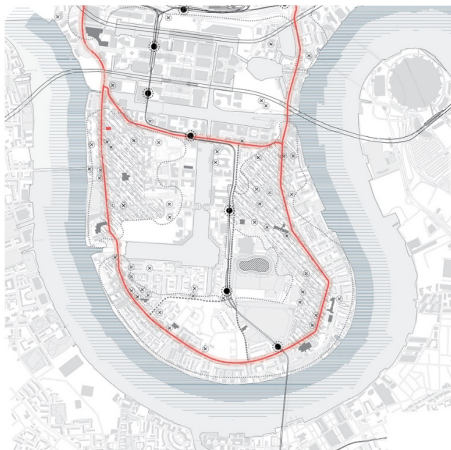
# Making the Plan



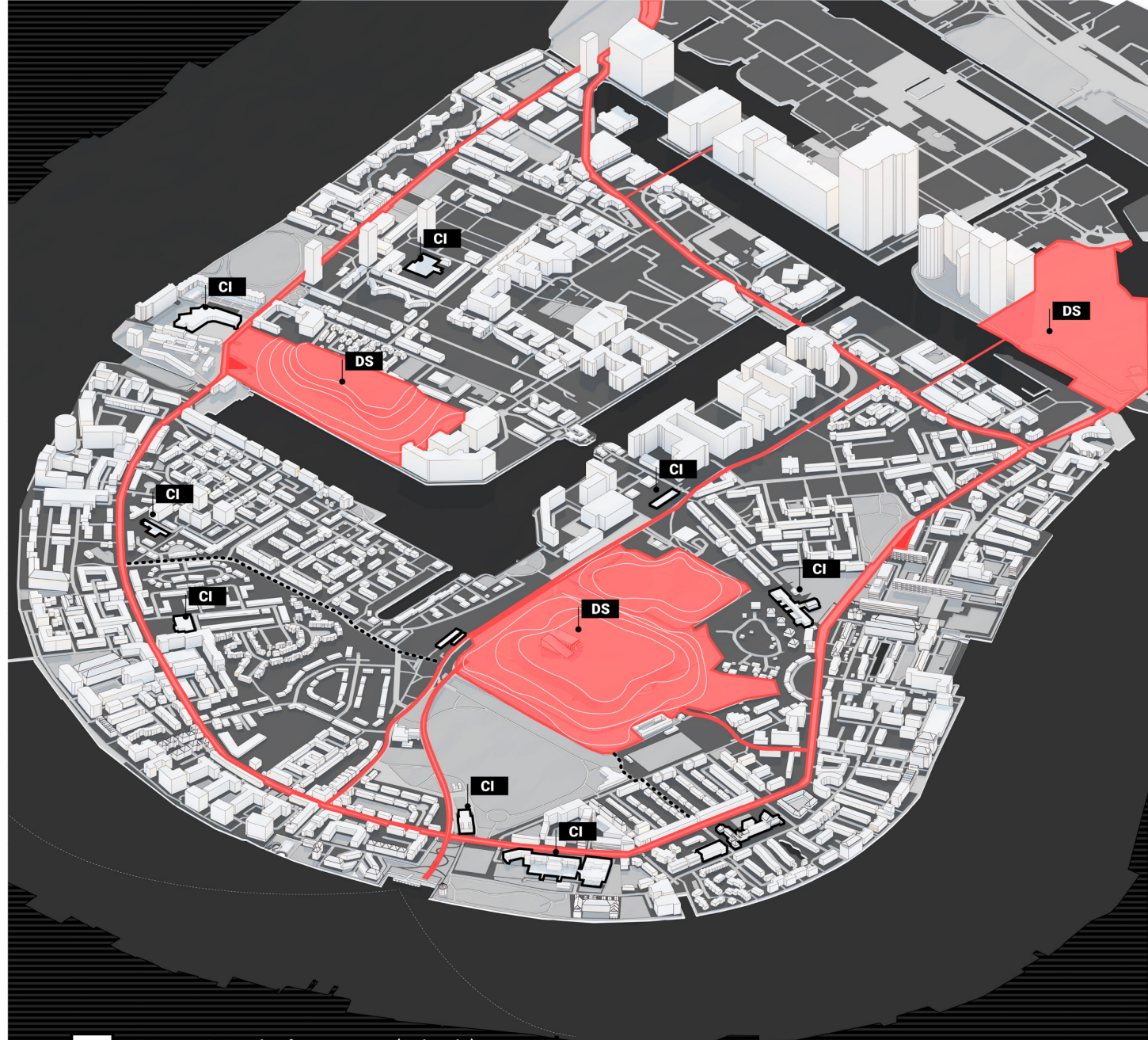
Designated Shelters



Safety Zones (Open Spaces)

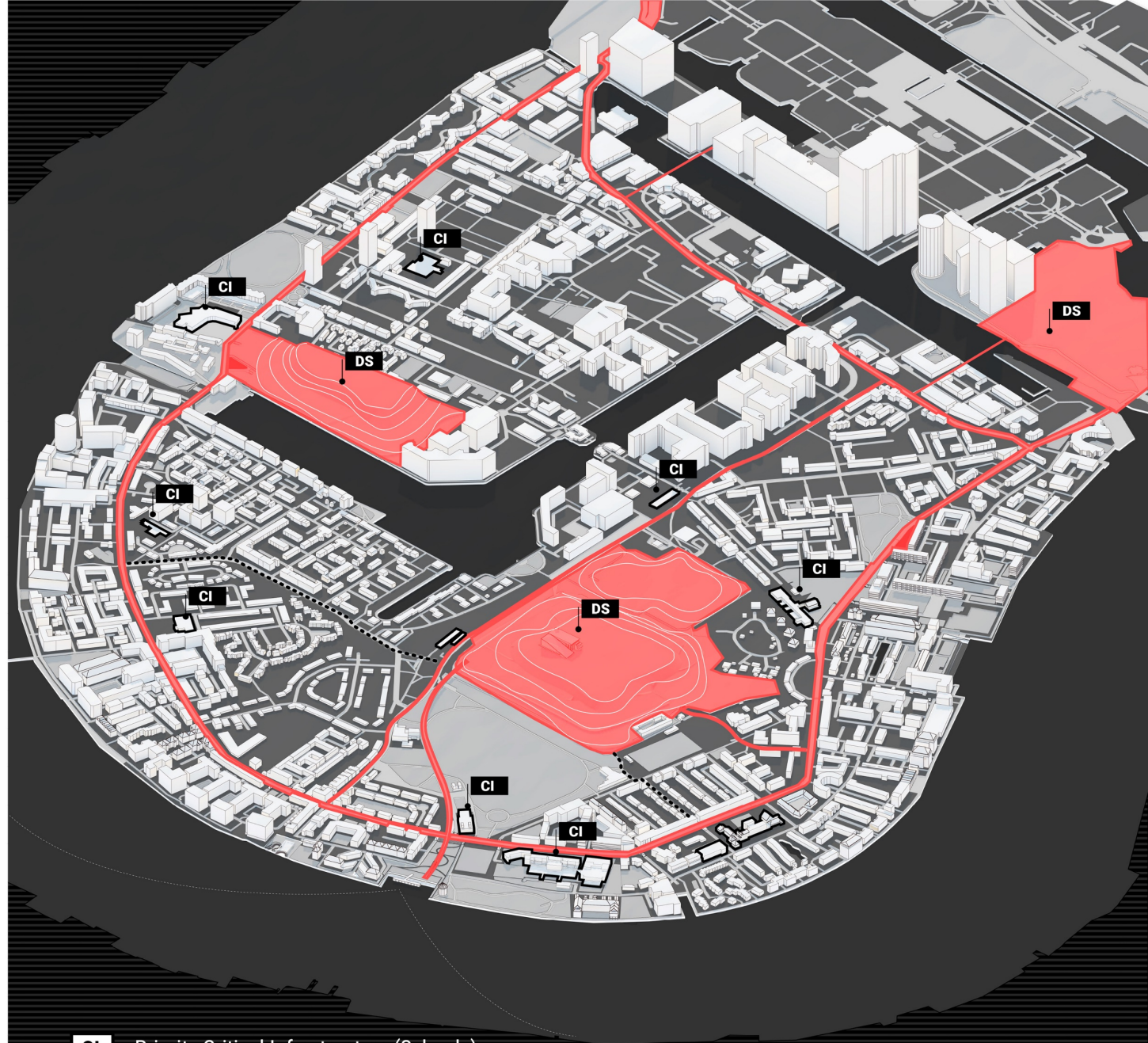
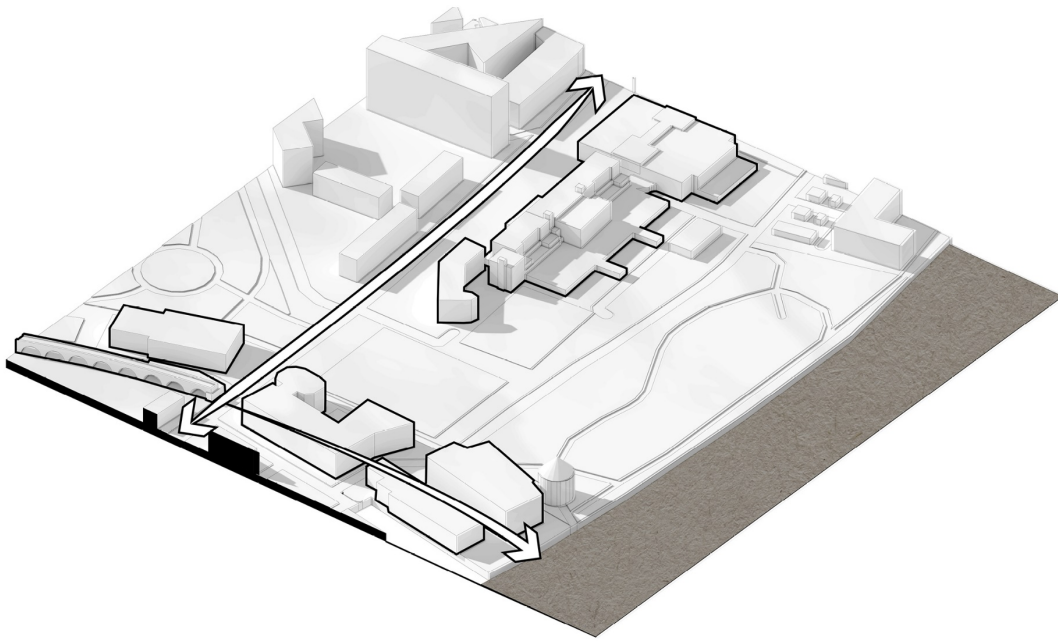


Elevated Road Network



- CI** Priority Critical Infrastructure (Schools)
- DS** Designated Safe Grounds - Permanent Public Access

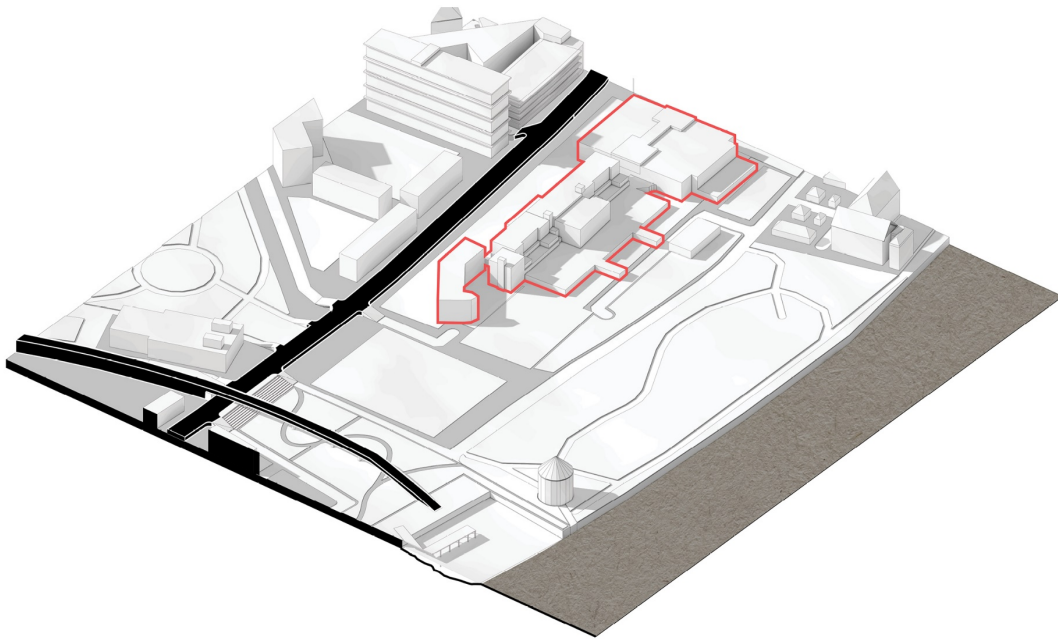
# Proposed Changes to Critical Infrastructure



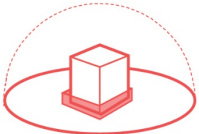
**CI** Priority Critical Infrastructure (Schools)

**DS** Designated Safe Grounds - Permanent Public Access

# Proposed Changes to Critical Infrastructure

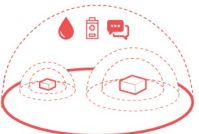


.....● **Option 01: Reinforcement**



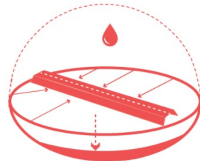
Dry-proofing or wet proofing

.....● **Option 02: Redundancy**

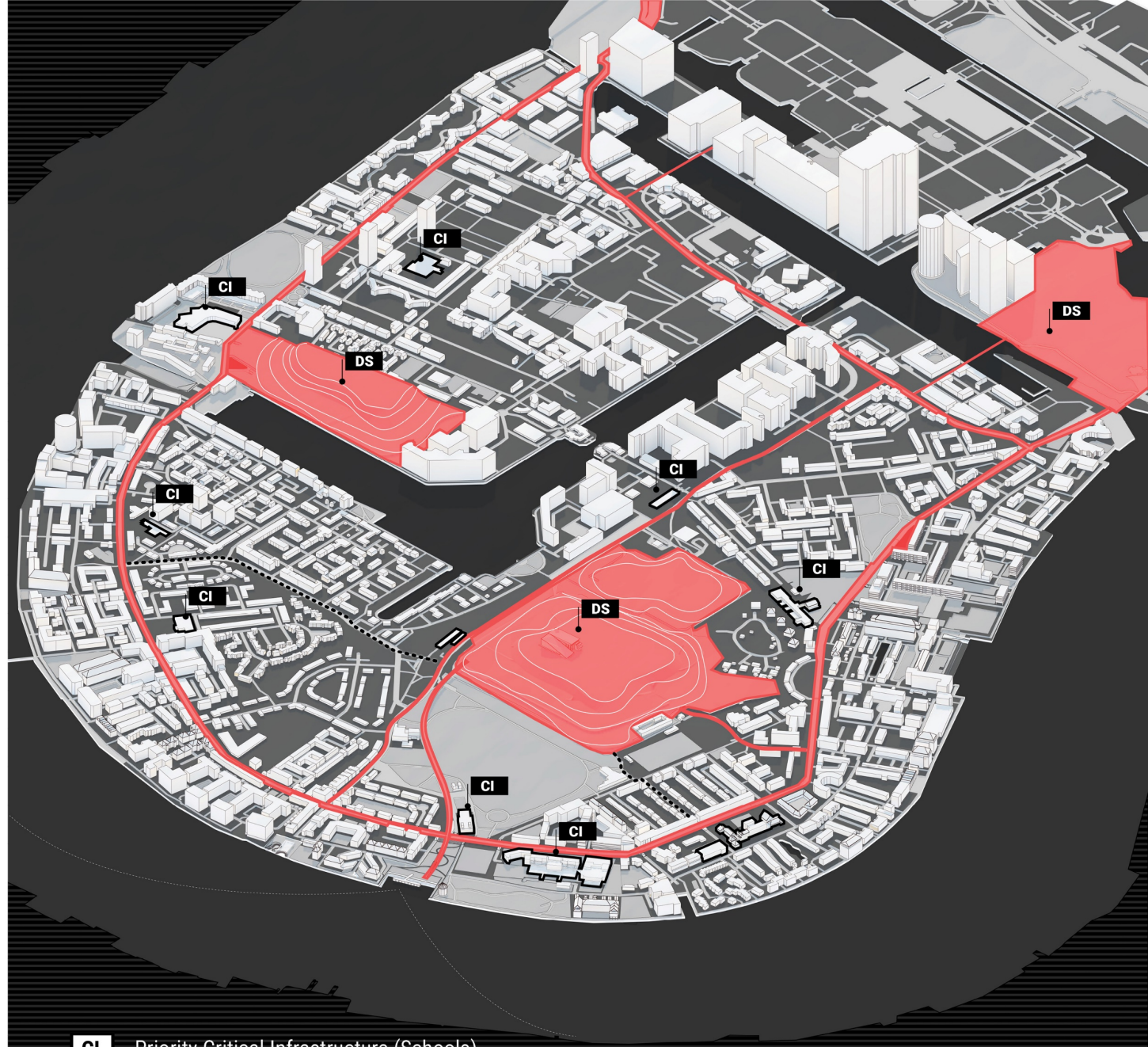


Adding spare capacity + back-up systems

.....● **Option 03: Retrofitting roads**



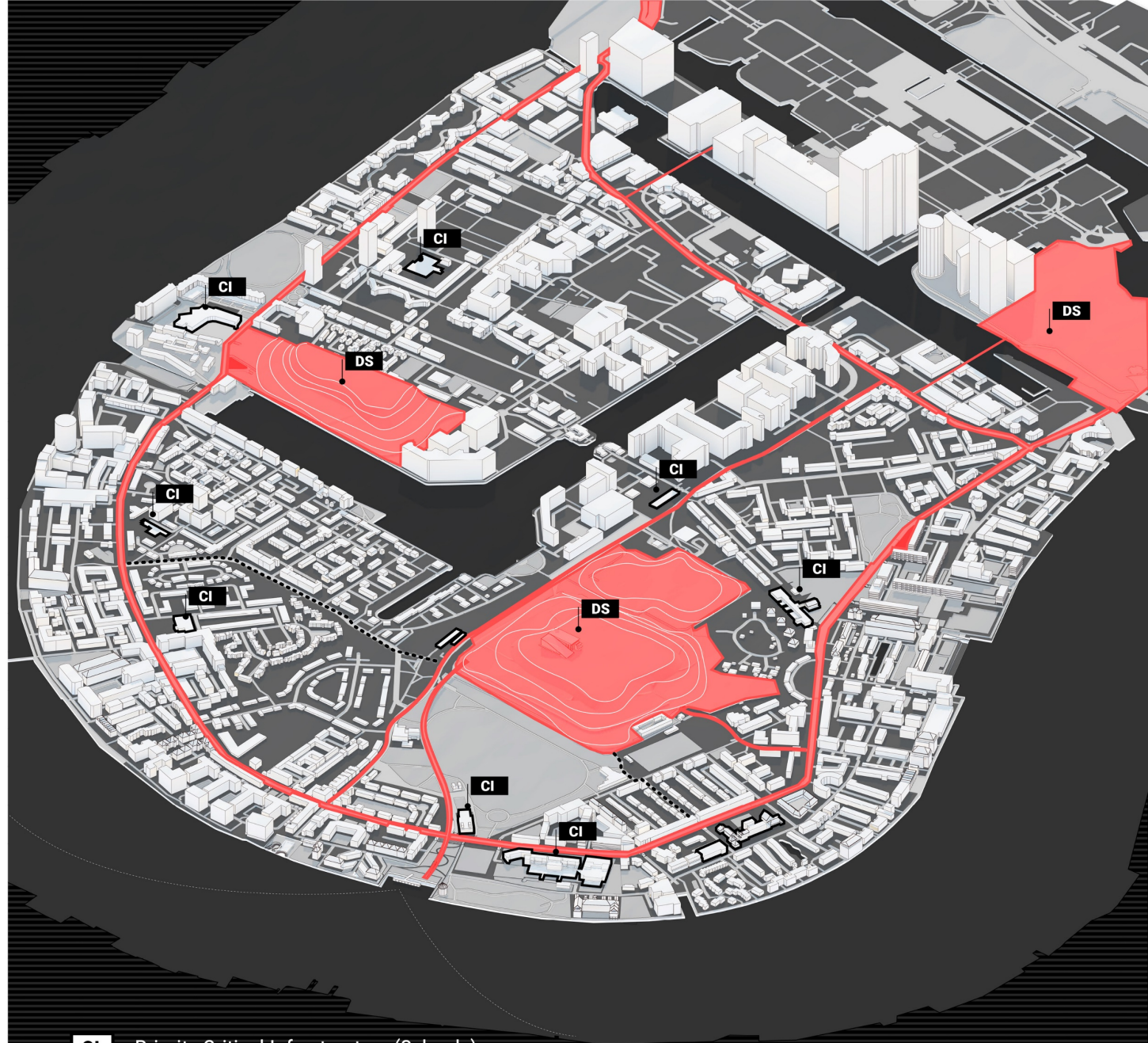
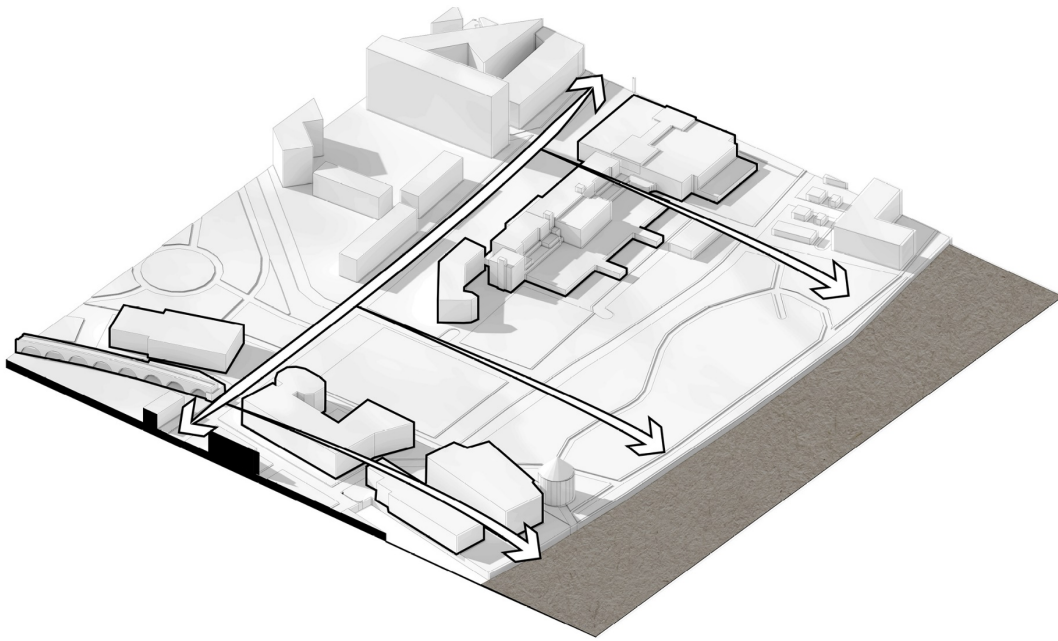
Roads to have increased porosity to store/direct water



**CI** Priority Critical Infrastructure (Schools)

**DS** Designated Safe Grounds - Permanent Public Access

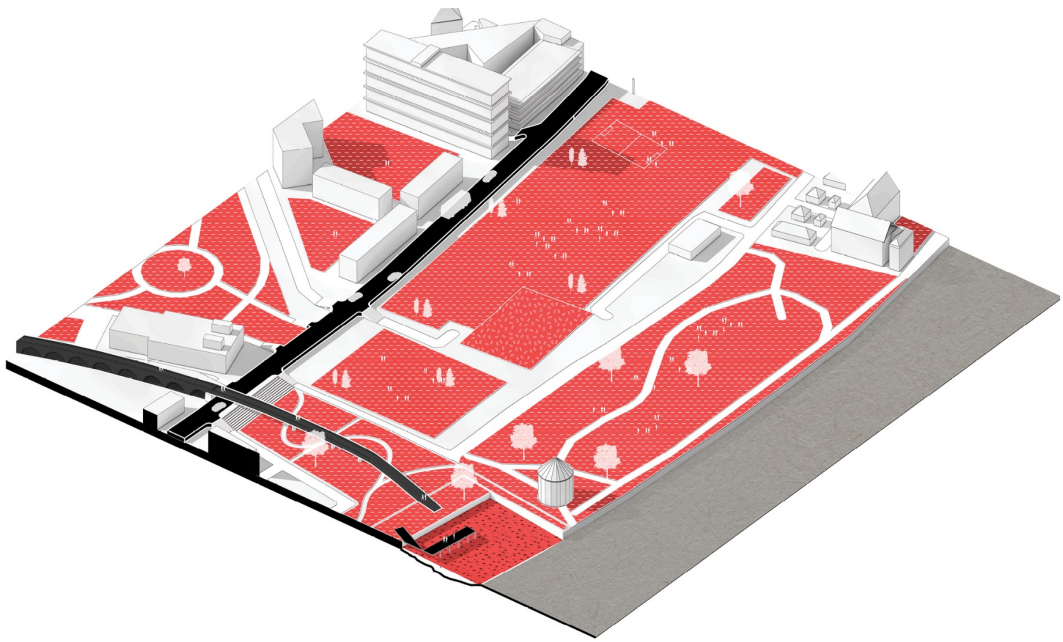
# Proposed Changes to Critical Infrastructure **Option 2**



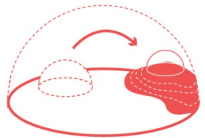
**CI** Priority Critical Infrastructure (Schools)

**DS** Designated Safe Grounds - Permanent Public Access

# Proposed Changes to Critical Infrastructure **Option 2**

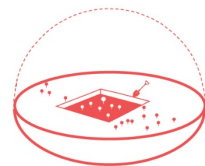


.....● **Option 01: Relocation**



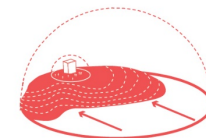
Transferring to higher grounds

.....● **Option 02: Excavating**

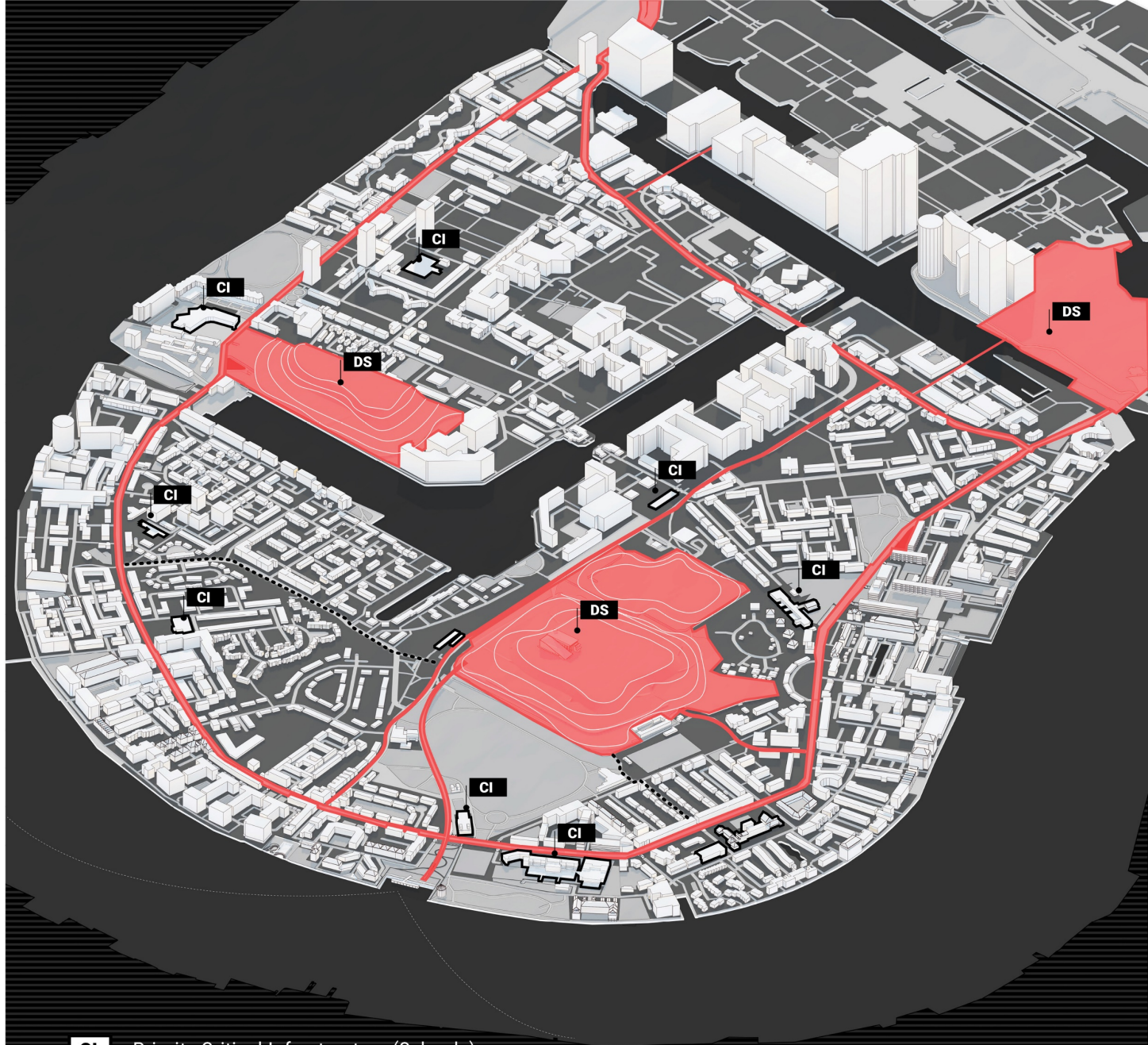


Excavating green space to increase water capacity

.....● **Option 03: Elevating**



Elevating open spaces to create safe grounds + new facility with back up systems



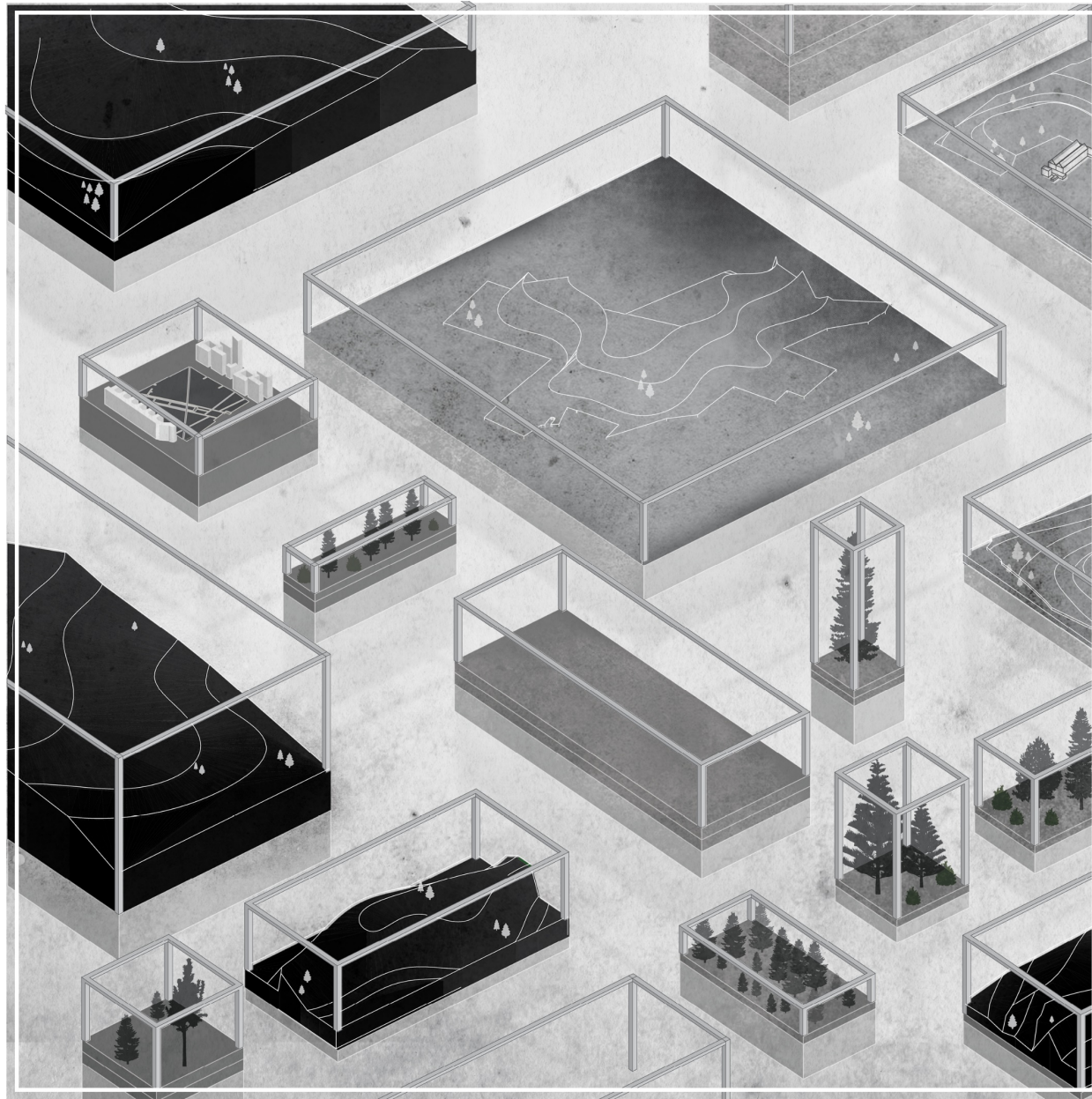
**CI** Priority Critical Infrastructure (Schools)

**DS** Designated Safe Grounds - Permanent Public Access



**Aspect 2: Designing Exclusively for Environmental Risks: Limiting Stresses to the Existing System**

And truly is there a limit to how much you can stress the system and do cities have a chronic problem?



# Managed Retreat vs. Business as Usual



Wandsworth to Deptford



Isle of Dogs

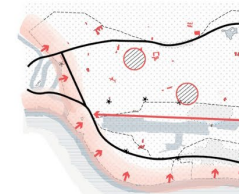
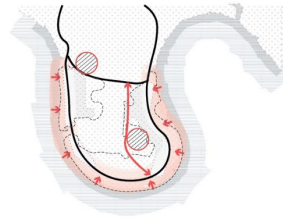


Royal Docks

Managed Retreat



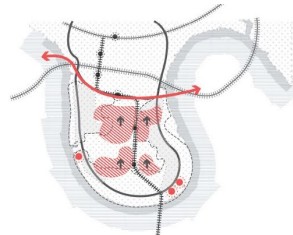
- Large scale strategy
- Identifying areas to start the phasing



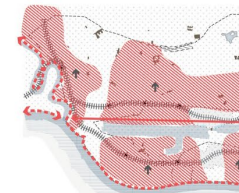
Business as Usual



Intensification: Center

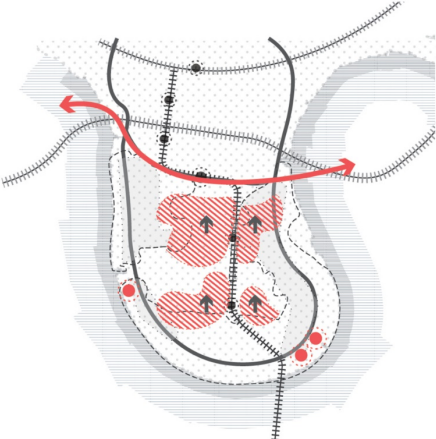
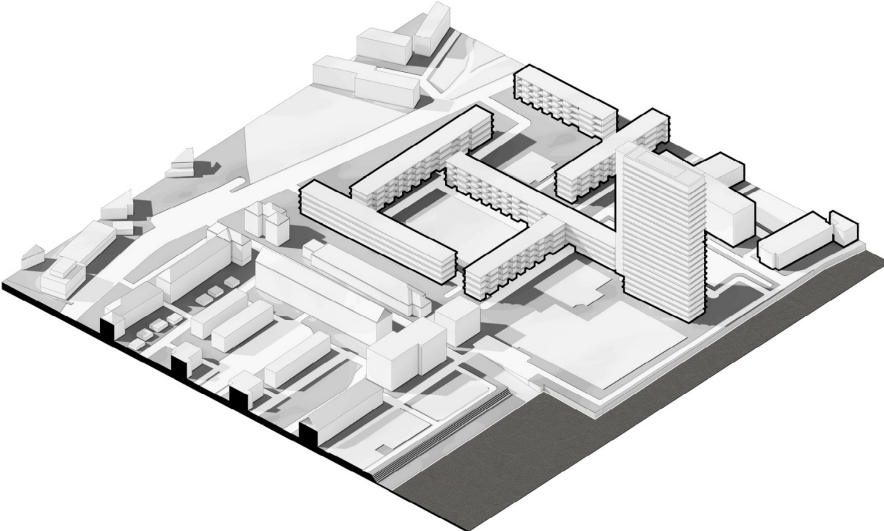


Intensification: Extension of Canary Wharf – Next business hub

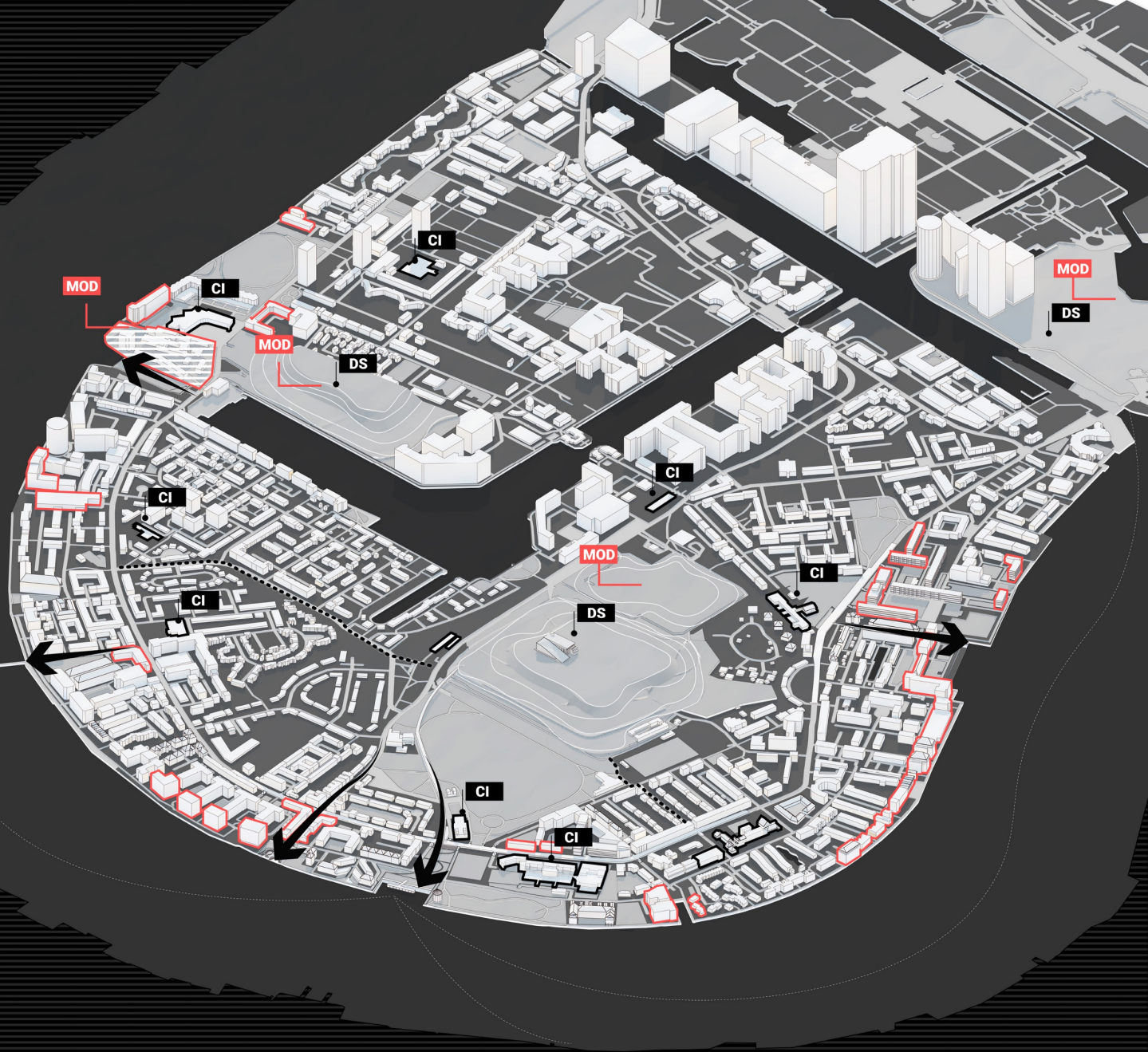


Intensification: Large Urban Renewal planned

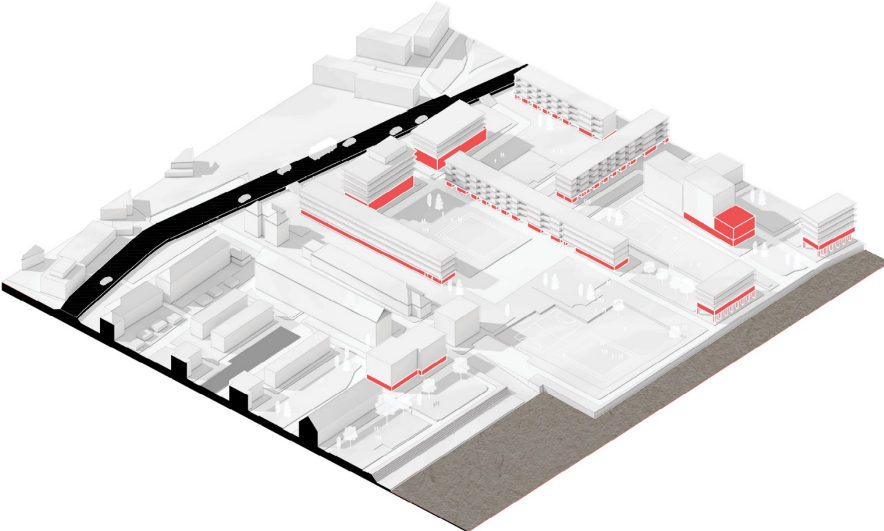
# Business As Usual – Land Use




Continued intensification and pressures on the floodplain




# Business As Usual – Land Use




- .....● **Option 1A: Change ground floor amenities**

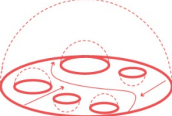

- .....● **Option 2A: New developments**



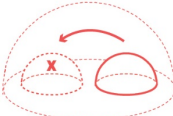
Porous or elevated
- .....● **Option 3A: Retrofit**




Integrate smart grid systems
- .....● **Option 4A: New connections**



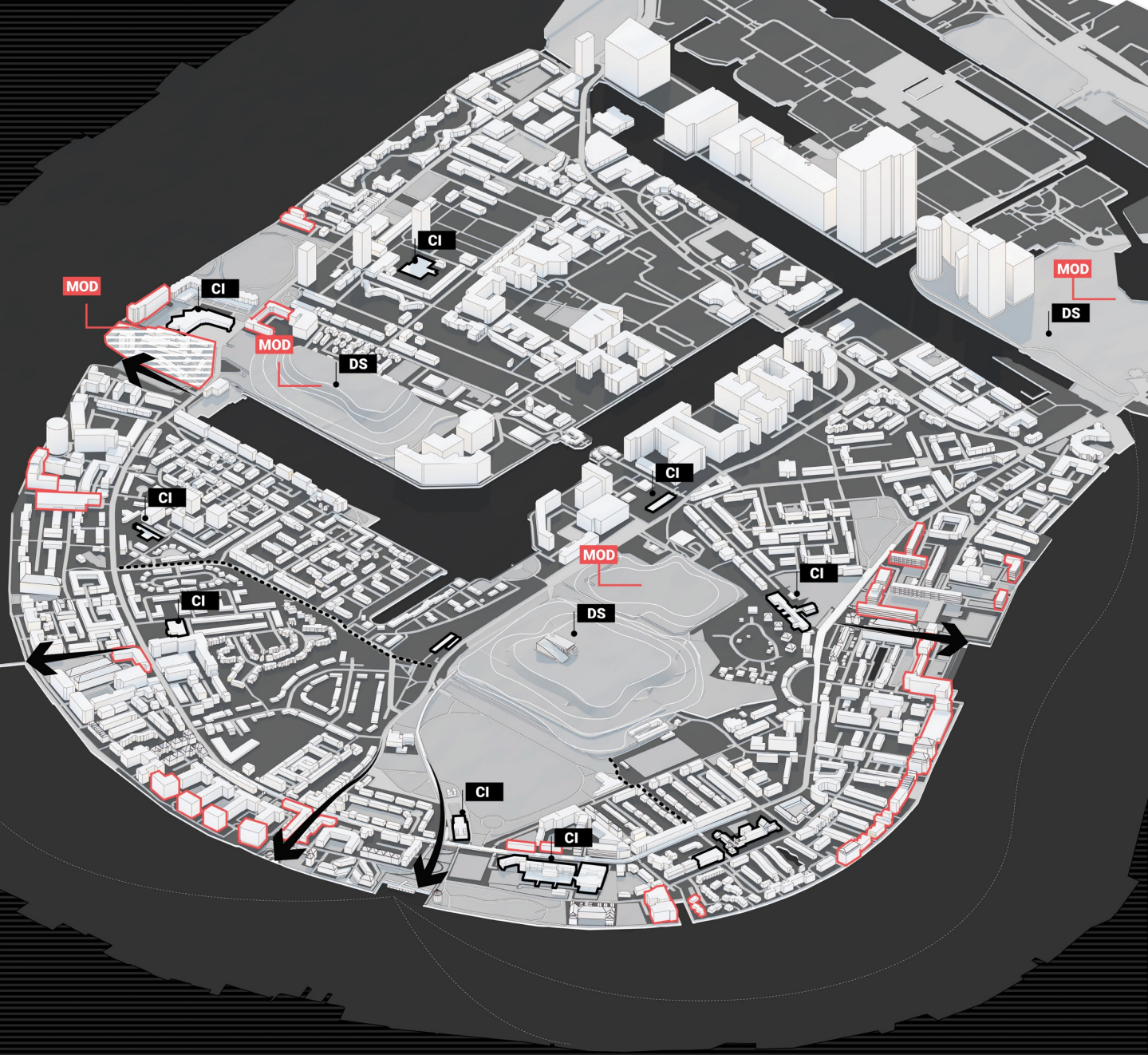
Manipulate spaces for increased accessibility
- .....● **Option 5A: Remove & replace**



Replace with less vulnerable usages ie. retail/recreation
- .....● **Option 6A: Decentralize**

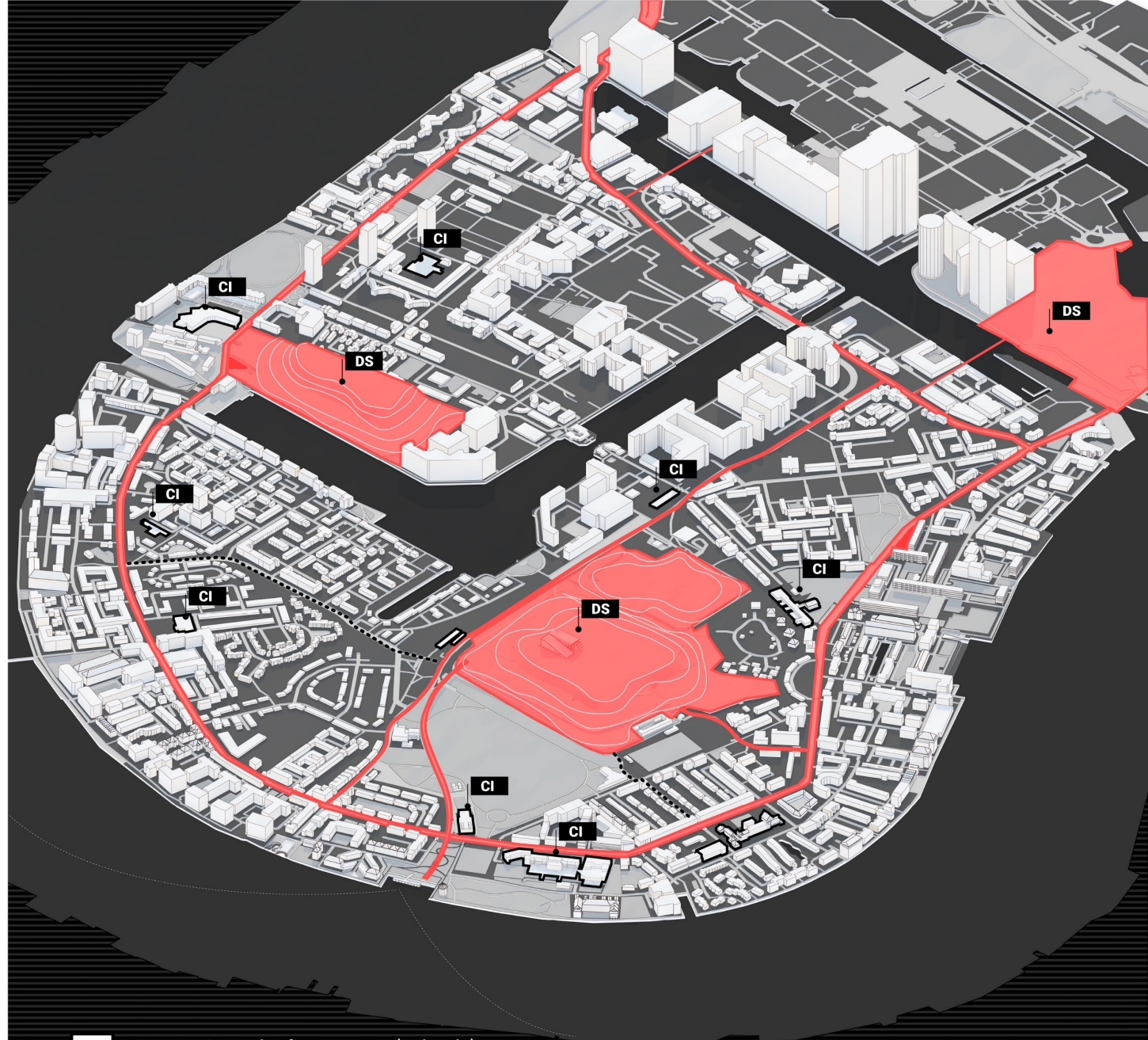
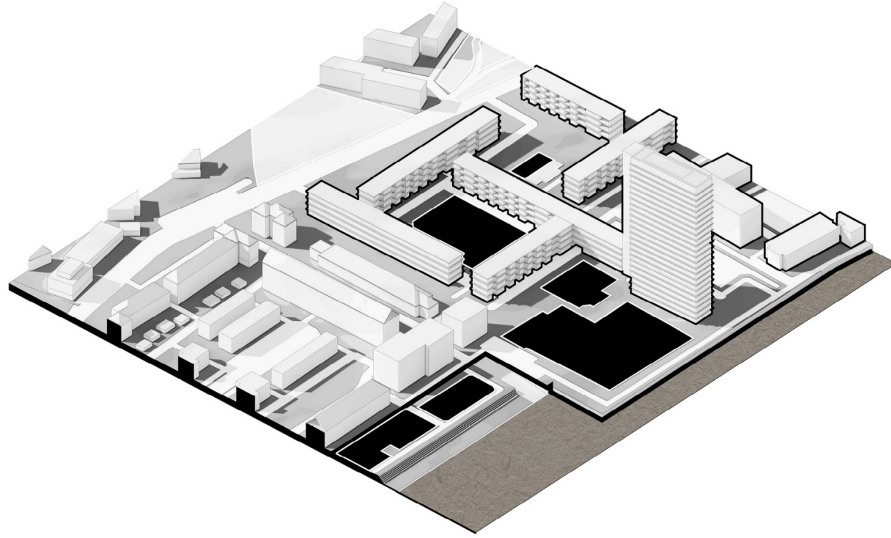


Integrate back-up systems



# Business As Usual – Open

## Space

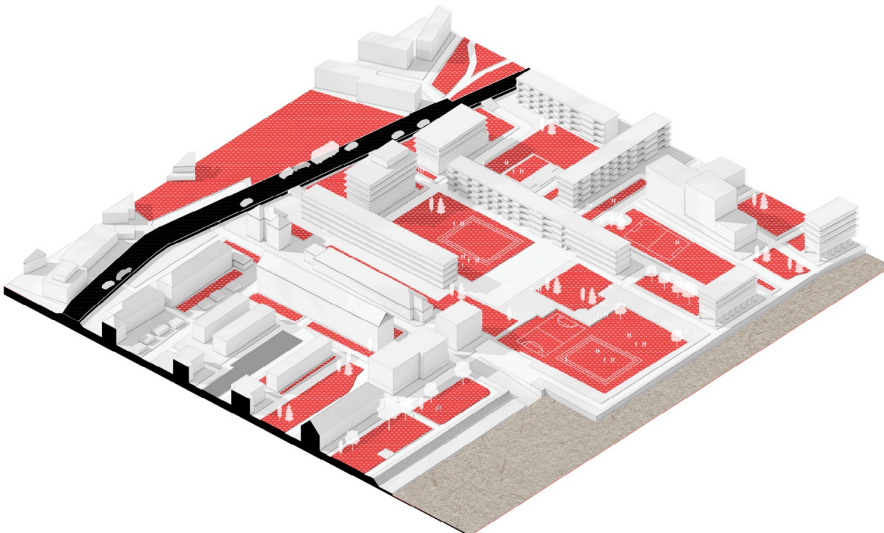


**CI** Priority Critical Infrastructure (Schools)

**DS** Designated Safe Grounds - Permanent Public Access

# Business As Usual – Open

## Space



- Option 1B: Retrofit

Convert amenities to increase water capacity
- Option 2B: Private Spaces

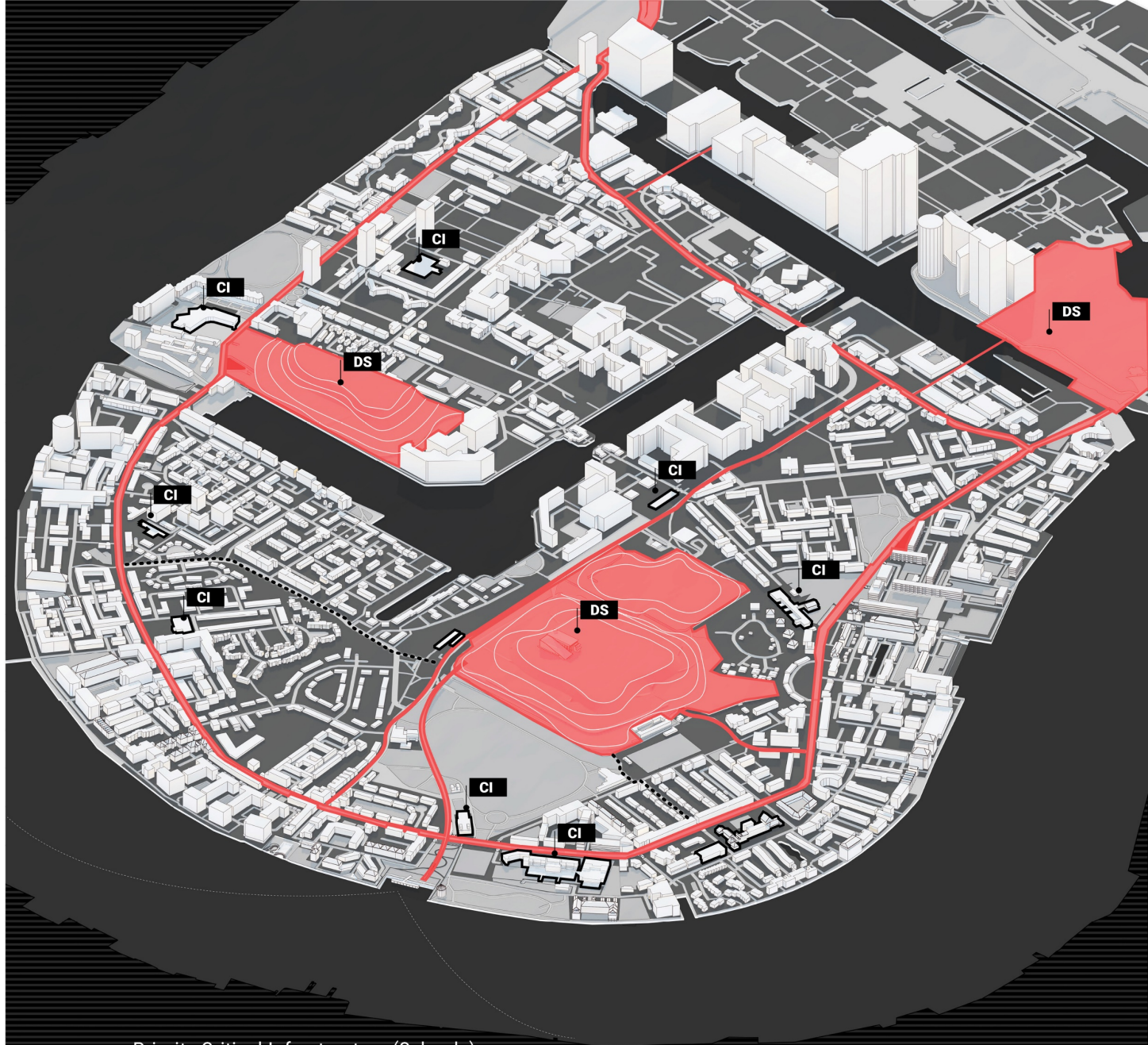
Collective vegetative depressions
- Option 3B: Breach

Create living edges, tidal parks or enlargement of natural defences
- Option 4B: Expand

Expand park size and amenities
- Option 3B: Remove

Remove infrastructure and relocate density
- Option 4B: Expand Networks

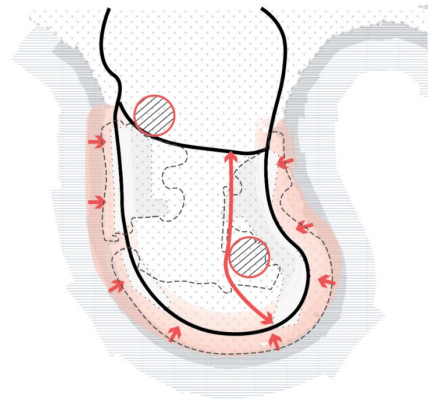
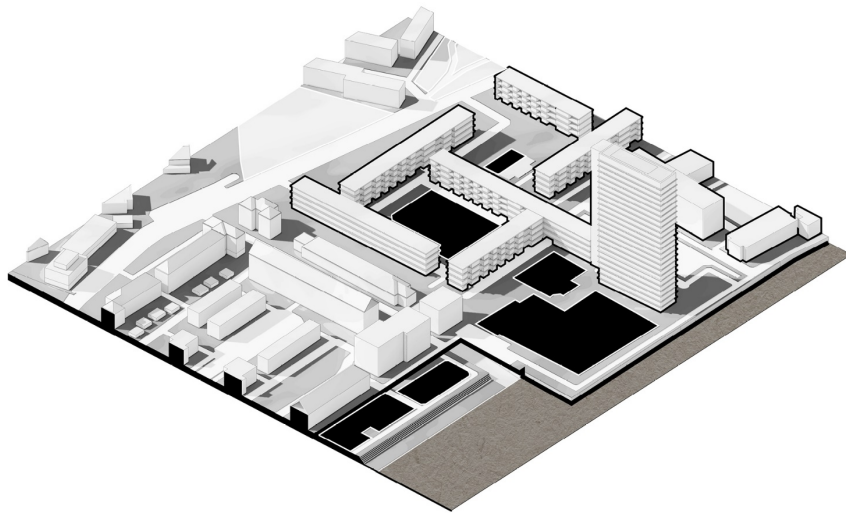
Expand green networks and accessibility



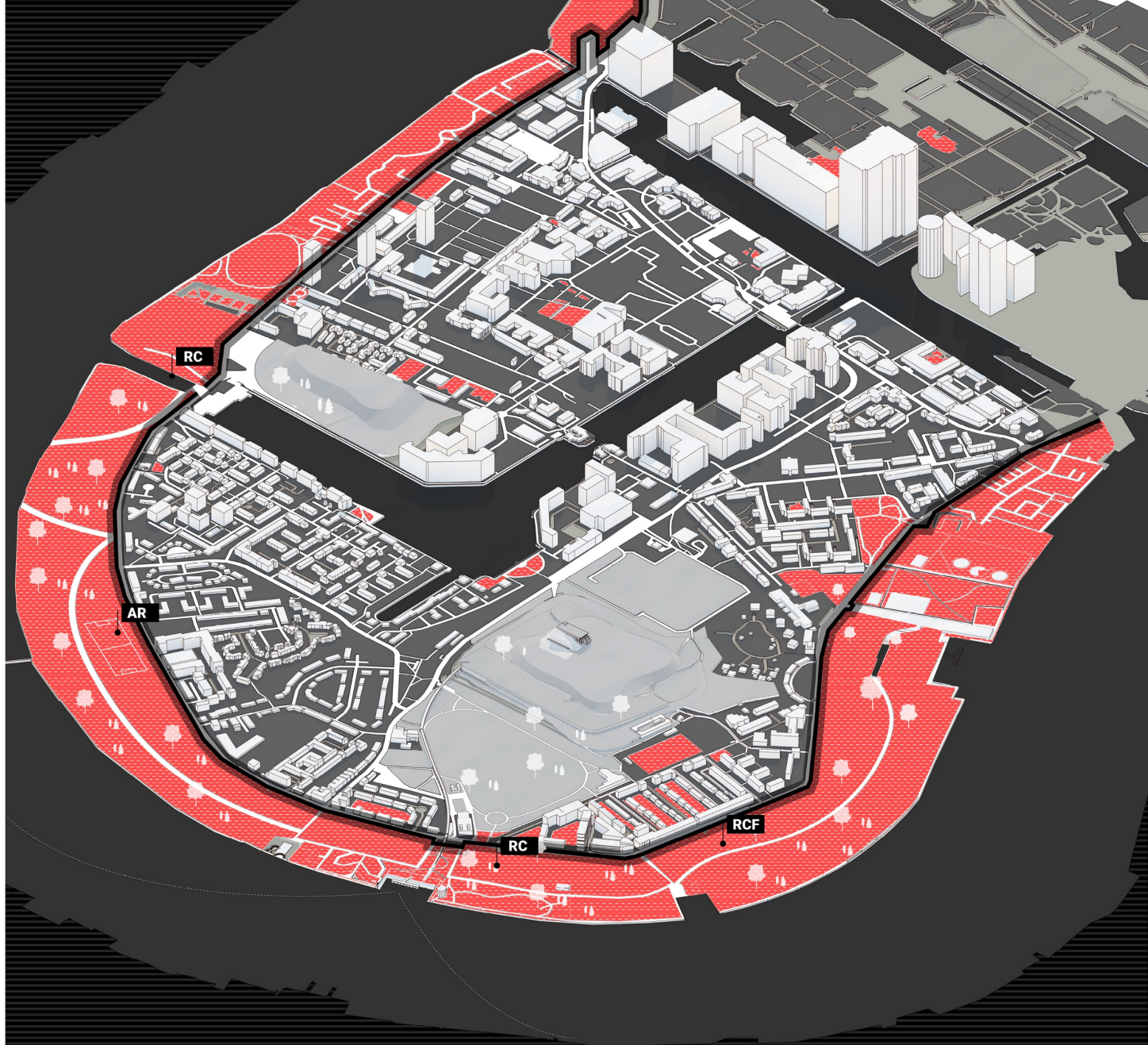
Priority Critical Infrastructure (Schools)

Designated Safe Grounds - Permanent Public Access

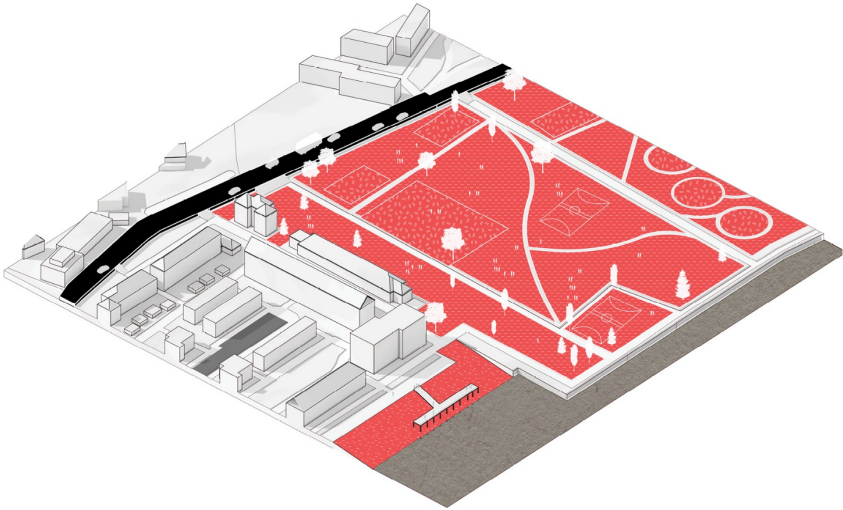
# Managed Retreat– Land Use



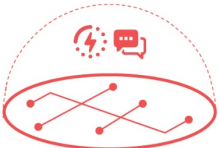
*Intrusion of water and nature while receding the land and infrastructure*



# Managed Retreat- Land Use

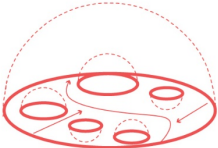


Option 1A: Retrofit



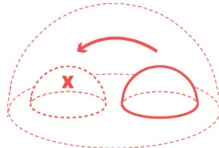
Integrate smart grid systems

Option 2A: New connections



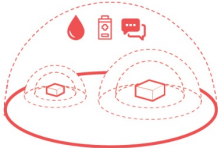
Manipulate spaces for increased accessibility

Option 3A: Remove & replace

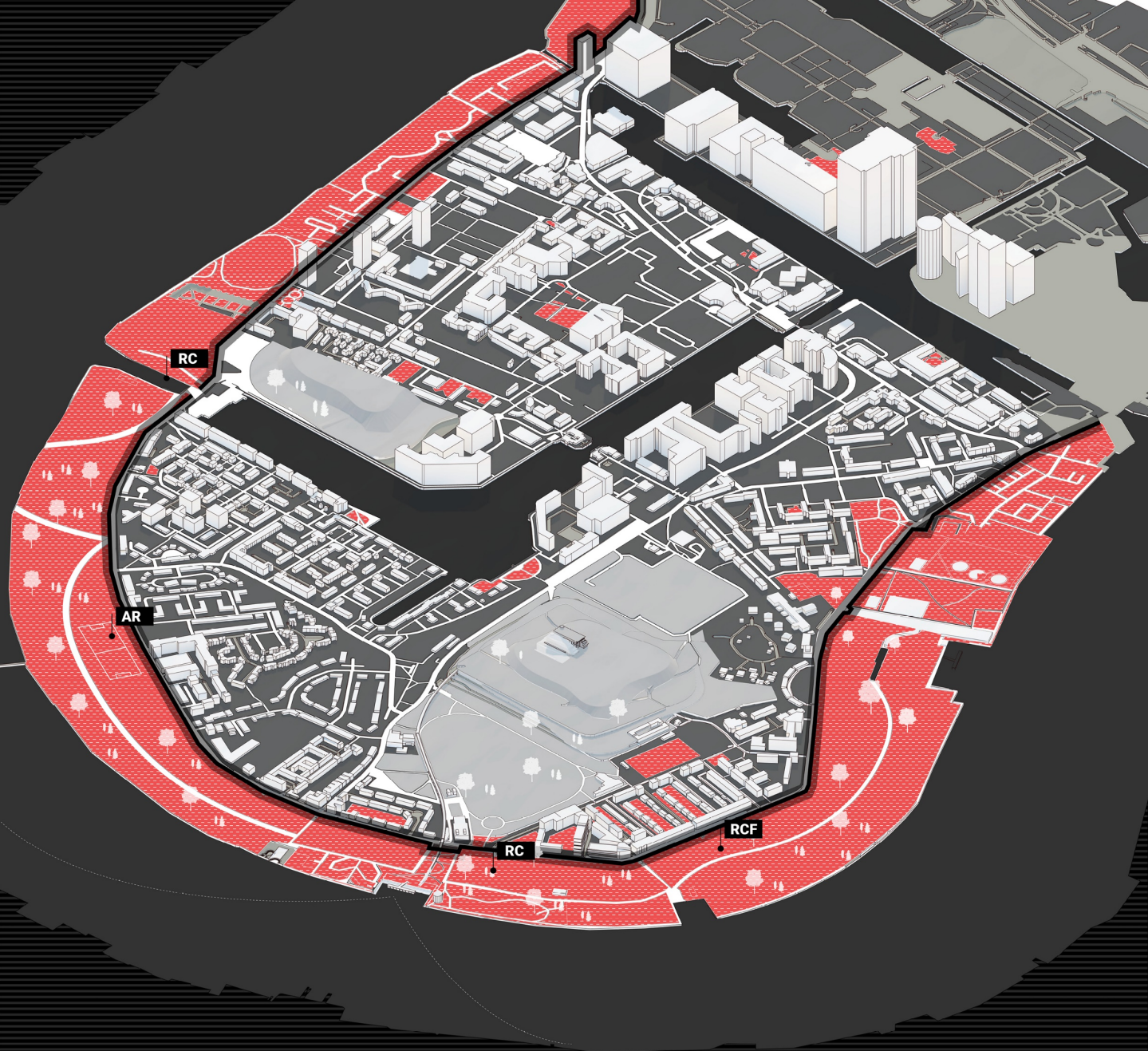


Remove infrastructure and replace with riverfront amenities and green space

Option 4A: Decentralize

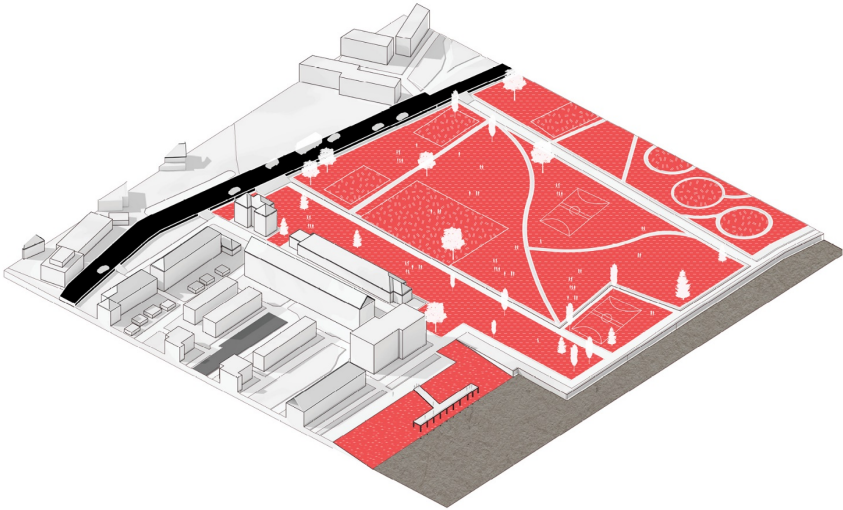


Integrate back-up systems

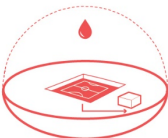





# Managed Retreat – Open Space



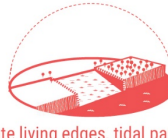
- .....● **Option 1B: Retrofit** .....● **Option 2B: Private Spaces**




Convert amenities to increase water capacity



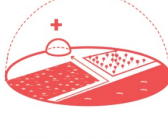
Increase in collective vegetative depressions and gardens
- .....● **Option 3B: Breach** .....● **Option 4B: Expand**



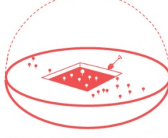
Create living edges, tidal parks or enlargement of natural defences



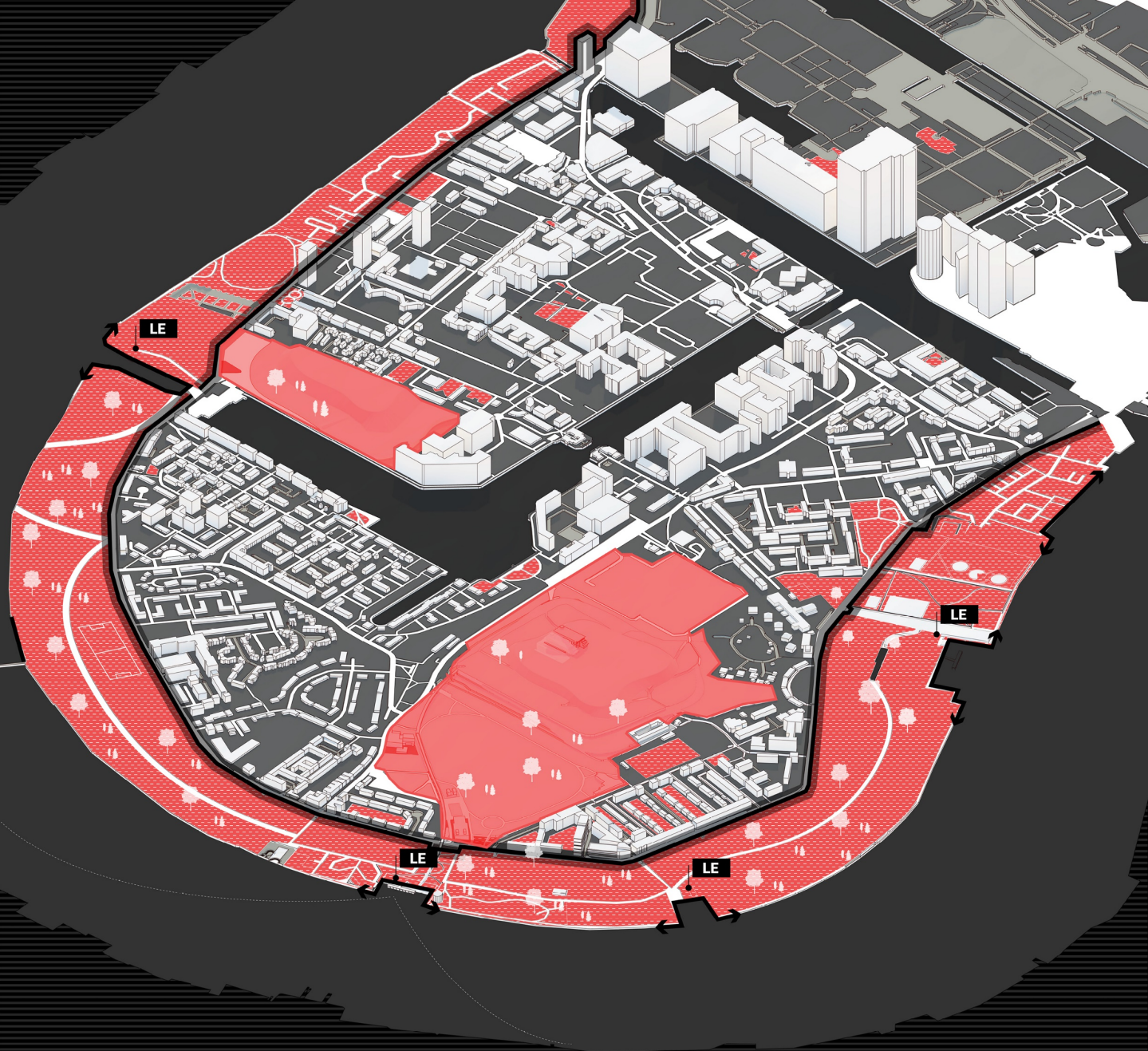
Expand park size and amenities
- .....● **Option 5B: Expand Networks** .....● **Option 6B: Excavate**



Expand green networks and accessibility



Increase water capacity



# Implementation: Lifespan of Assets & Land Use

Problem Definition  
 Multi-Criteria Analysis  
 Design  
 Evaluation



Wandsworth to Deptford

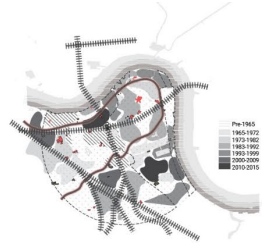


Isle of Dogs

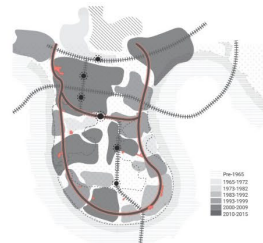


Royal Docks

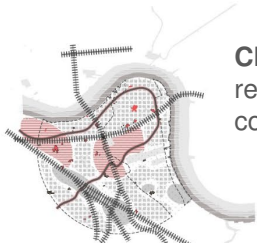
Age of Infrastructure



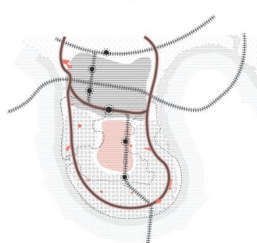
• Lifespan



Land Use



**Character:** extensive residential, industry, commerce



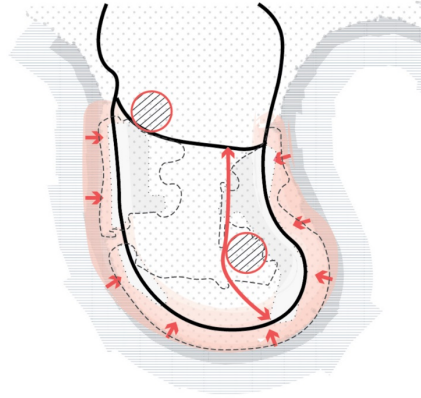
**Character:** highly dense business district with residential units



**Character:** residential and industrial

SCENARIO DEVELOPMENT

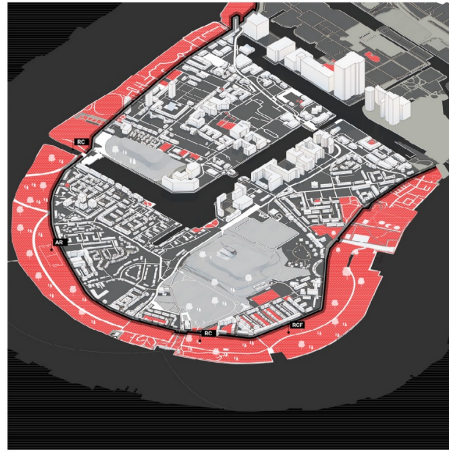
- Scenario 02: Managed Retreat



Intrusion of water and nature while receding the land and infrastructure

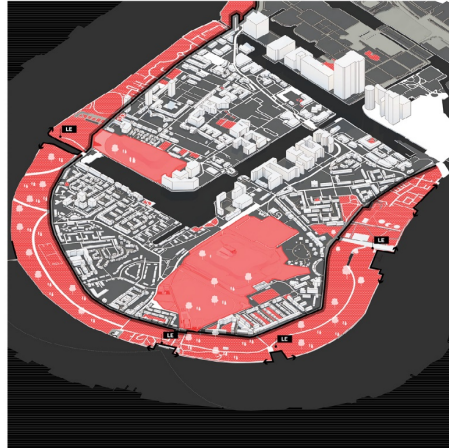
MASTER PLAN & URBAN DESIGN

- Option 01: Modifications in Land-Use



Translation into master plan

- Option 02: Modifications in Open Spaces

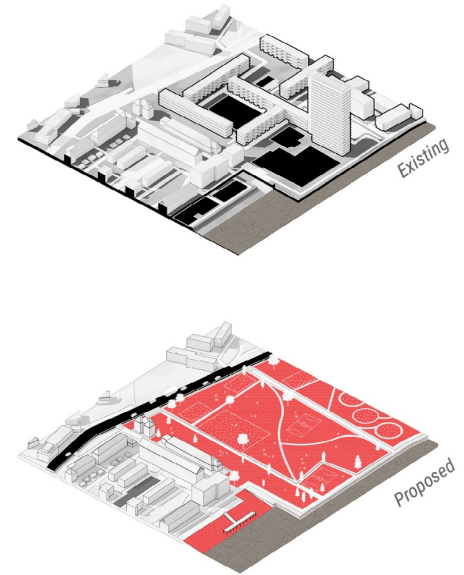


Translation into master plan

IDEATIONS

- Option 1A: Retrofit
  - Integrate smart grid systems
- Option 2A: New connections
  - Manipulate spaces for increased accessibility
- Option 3A: Remove & replace
  - Remove infrastructure and replace with riverfront amenities and green space
- Option 4A: Decentralize
  - Integrate back-up systems
- Option 1B: Retrofit
  - Convert amenities to increase water capacity
- Option 2B: Private Spaces
  - Increase in collective vegetative depressions and gardens
- Option 3B: Breach
  - Create living edges, tidal parks or enlargement of natural defences
- Option 4B: Expand
  - Expand park size and amenities
- Option 5B: Expand Networks
  - Expand green networks and accessibility
- Option 6B: Excavate
  - Increase water capacity

PROTOTYPE



REFINE & INFORM

EVALUATE

Feasibility, Desirability, Viability

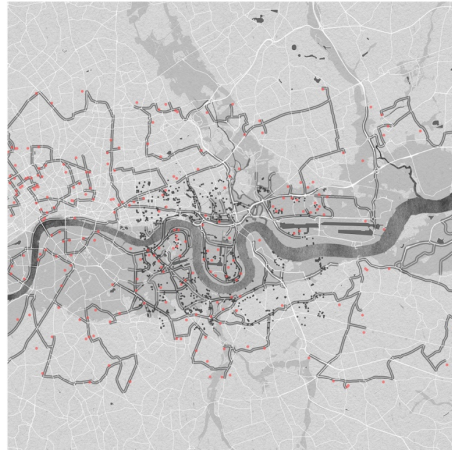
TEST

Combining strategies in site specific

Step 4

**BUILDING THE NETWORK**

Plan informs the creation of safety

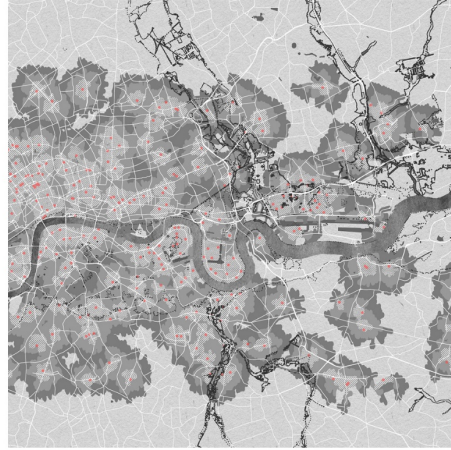


Accounts for designated safety shelters, emergency routes and entrances to designated safe zones

Step 5

**EVALUATING THE NETWORK**

Serviceability of modalities



Shelter serviceability & emergency relief for pedestrians within fixed time frames

Step 7

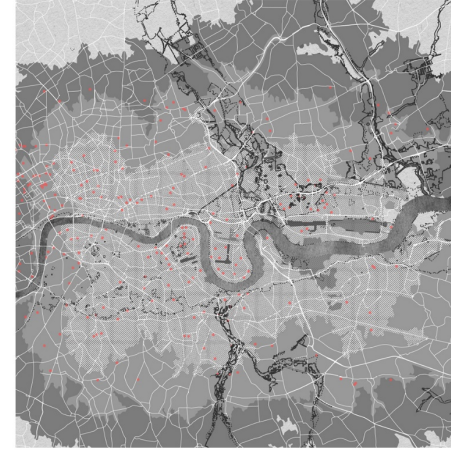
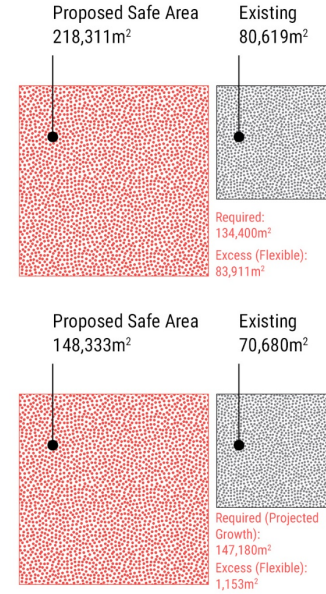
**REFLECT & REPEAT**

Step 6

**EVALUATING THE CAPACITY**

Can the designed safe areas accommodate the

ISLE OF DOGS SHELTER CAPACITY  
ROYAL DOCKS SHELTER CAPACITY



Shelter serviceability & emergency relief for automobiles within

Step 8

**RETURN TO START**

Step 6

**REFINE & INFORM**

If conditions are not met, repeat steps through the scales

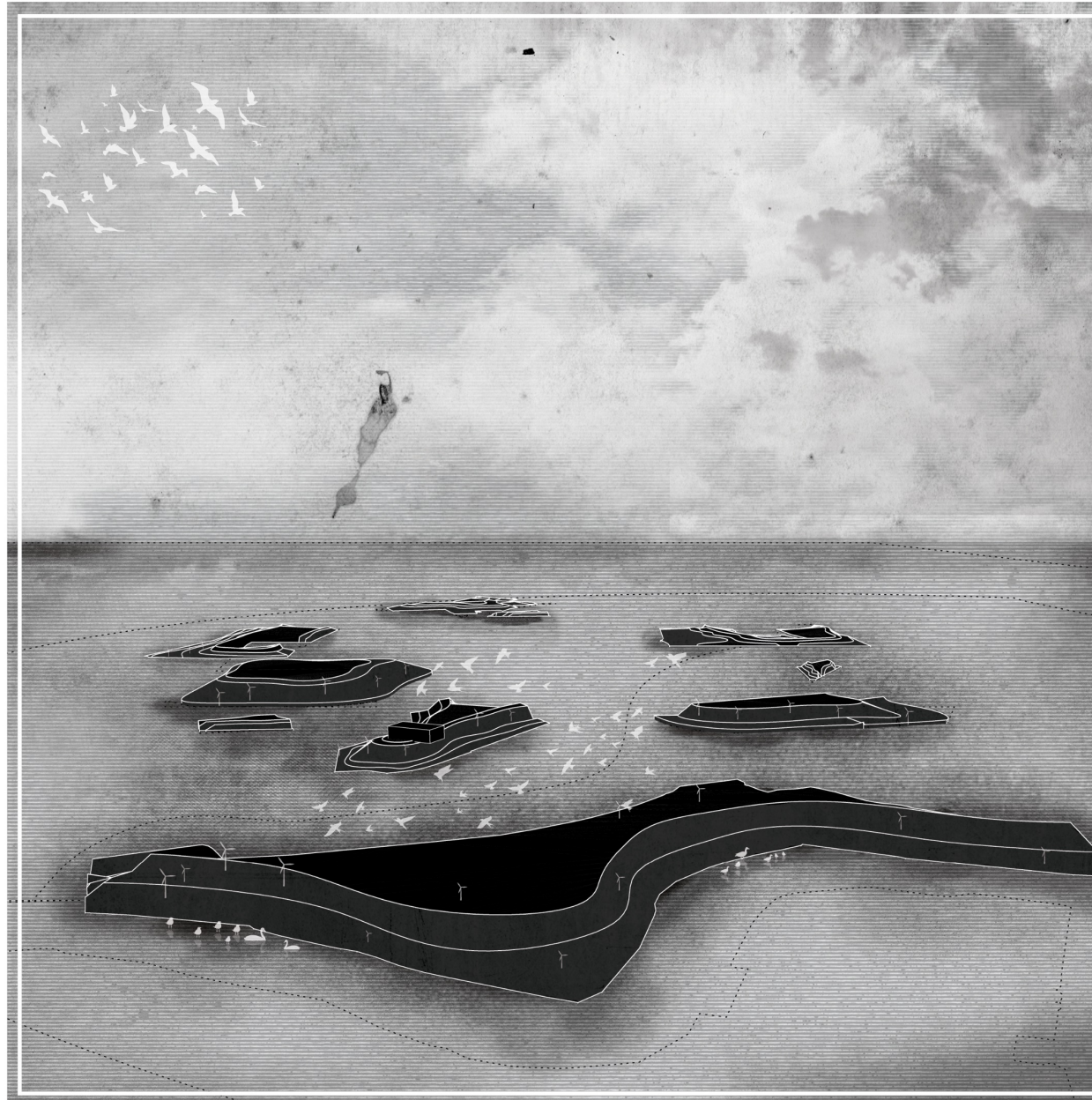
### Aspect 3: Mediating Between the Scales

- Iterations and feedback loop



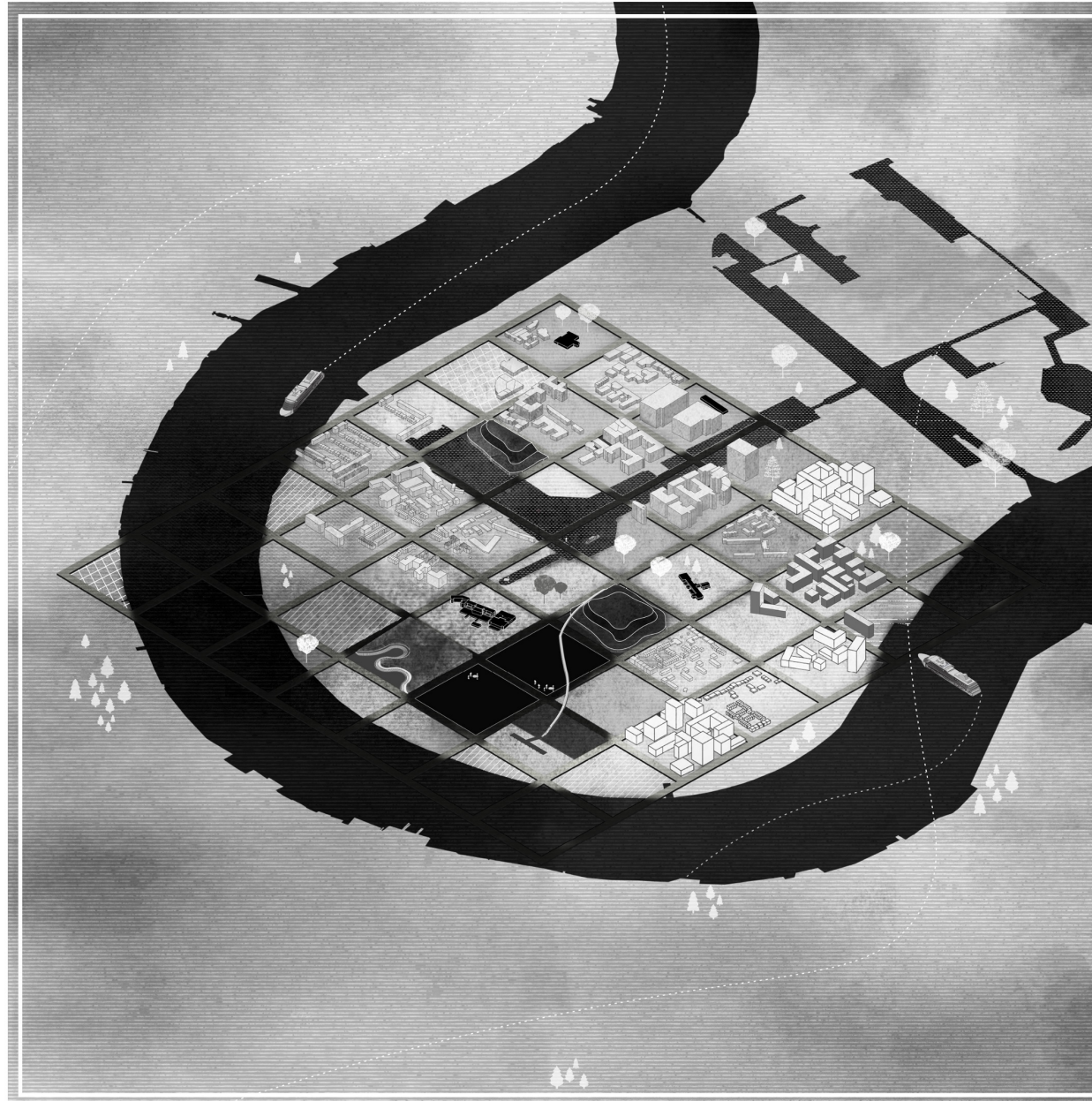
## Aspect 4: States of Isolation

- Safety as the highest priority
- Hybrid and dual functionalities in infrastructure Systems.
- limit the extent of damage
- Decentralize and centralized systems



## Aspect 5: The Capacity to Learn

- Embedding a learning system
- But what if we could design these systems so that the limits could be adjusted or distributed?
- Comparison
- Building back better



**Aspect 6:** The Future of  
Planned Developments:  
Limiting Failure and  
Safe-to Fail Systems

- Economically unfeasible to protect all systems
- Limit failure or set conditions to have the system safely fail





**Thank You**

