

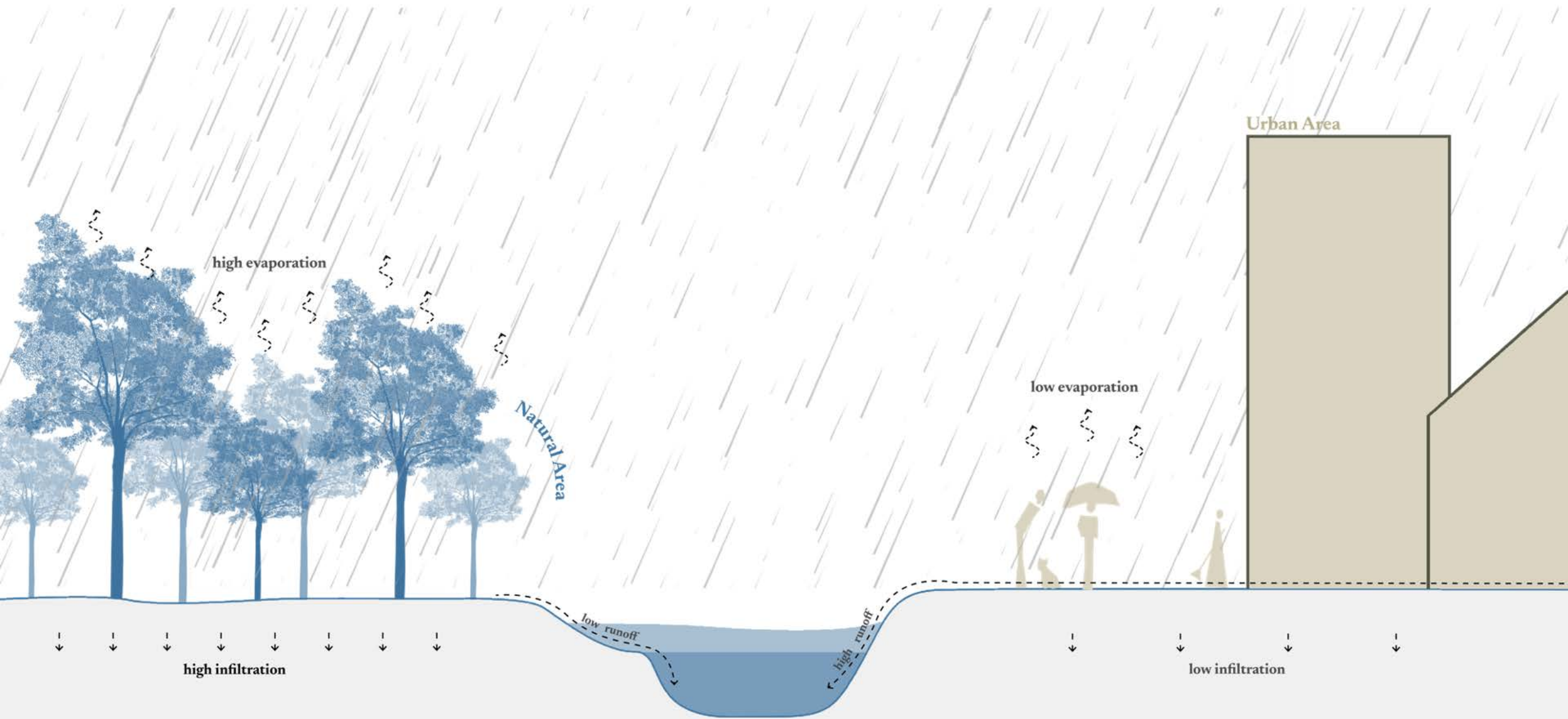
The background features a light beige color with large, flowing, white wavy lines that create a sense of movement. Overlaid on these are several vertical bars of varying heights and widths. Each bar has a blue-to-black gradient, with the blue at the top and black at the bottom. The bars are positioned at different intervals along the left and center of the page.

Grounded Resilience

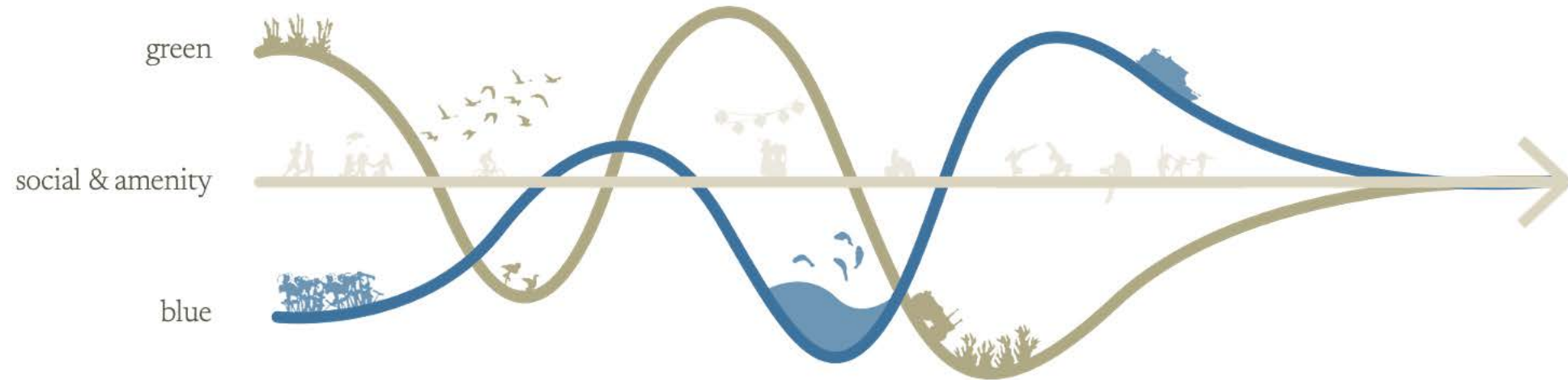
a Rainwater Simulation Framework for
Improving Building Flood Resilience through
Blue-Green Infrastructure Design Strategies

a Graduation Project by **Vadya Dzauqiah**
MSc Building Technology | ABE TU Delft

First Mentor **Simona Bianchi**
Second Mentor **Daniele Cannatella**



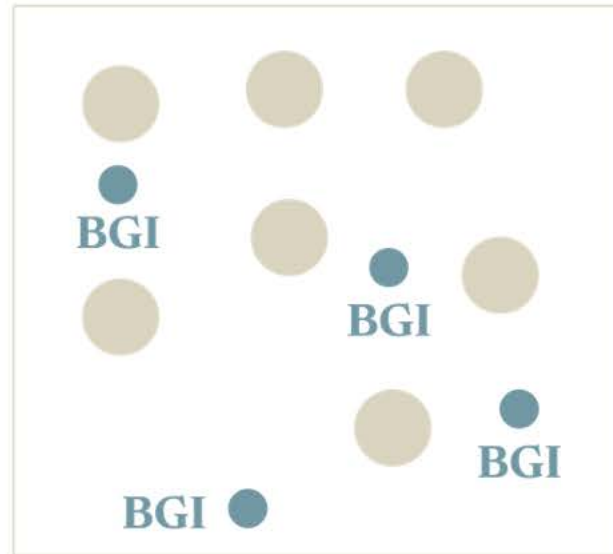
Blue Green Infrastructure (BGI)





Ground Based BGI

Ground Based BGI Adaptations

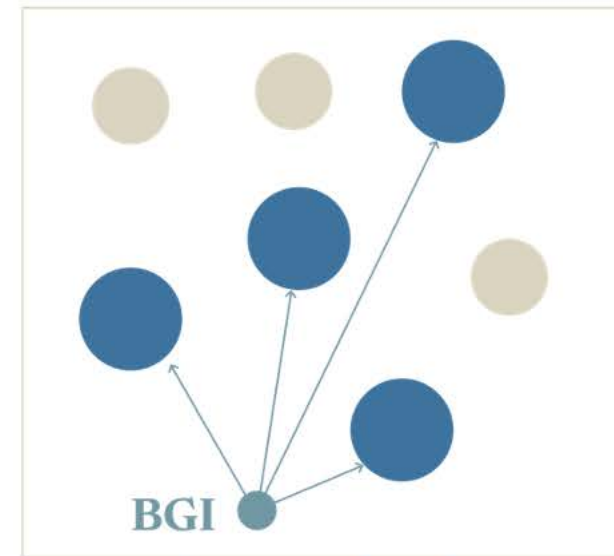


how to reduce hazard

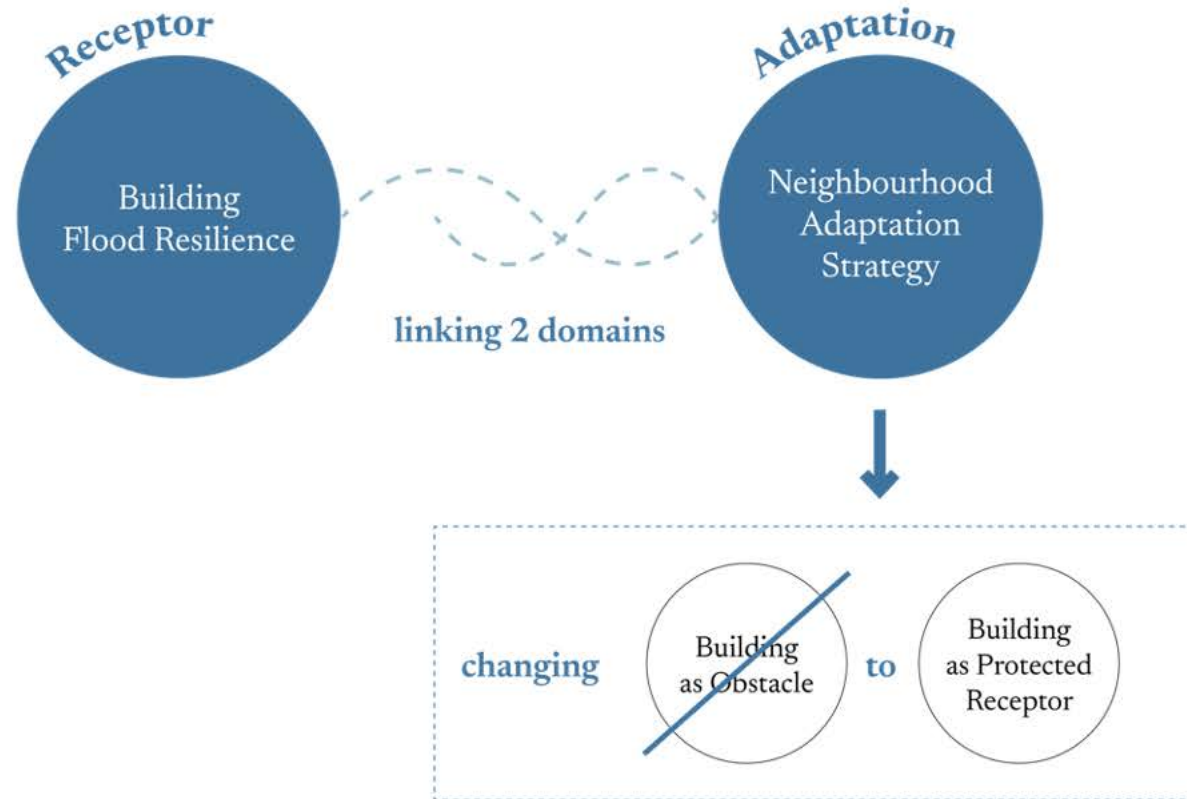
Ground Based BGI Adaptations



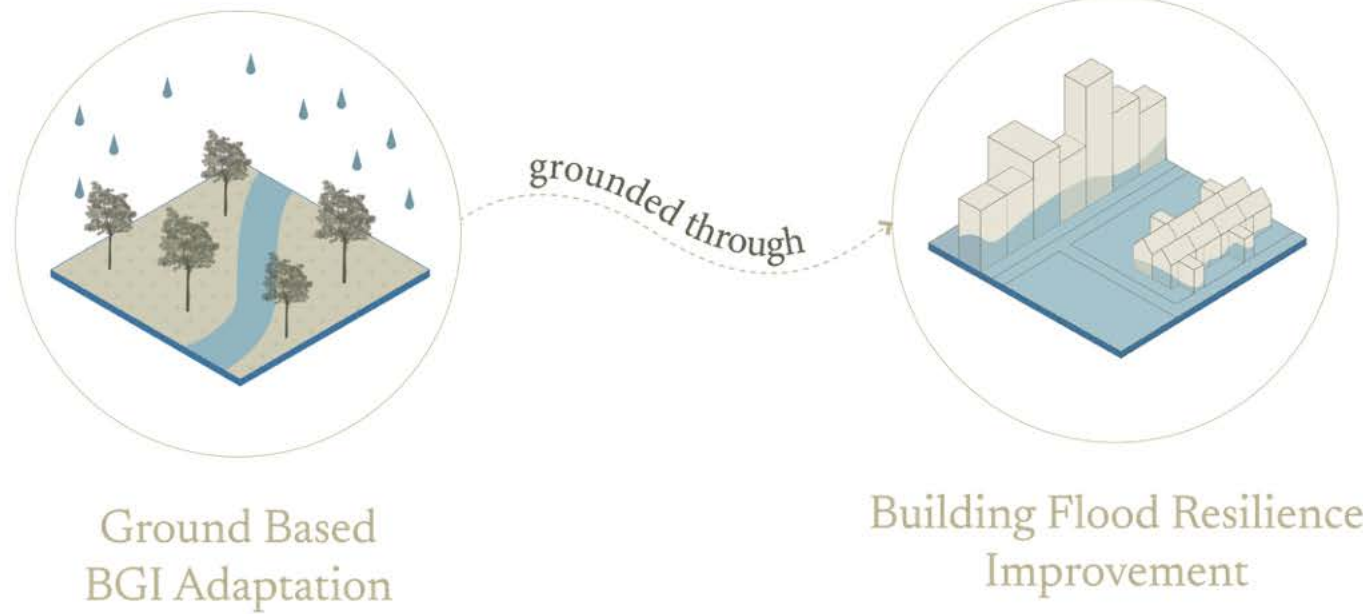
how to reduce hazard

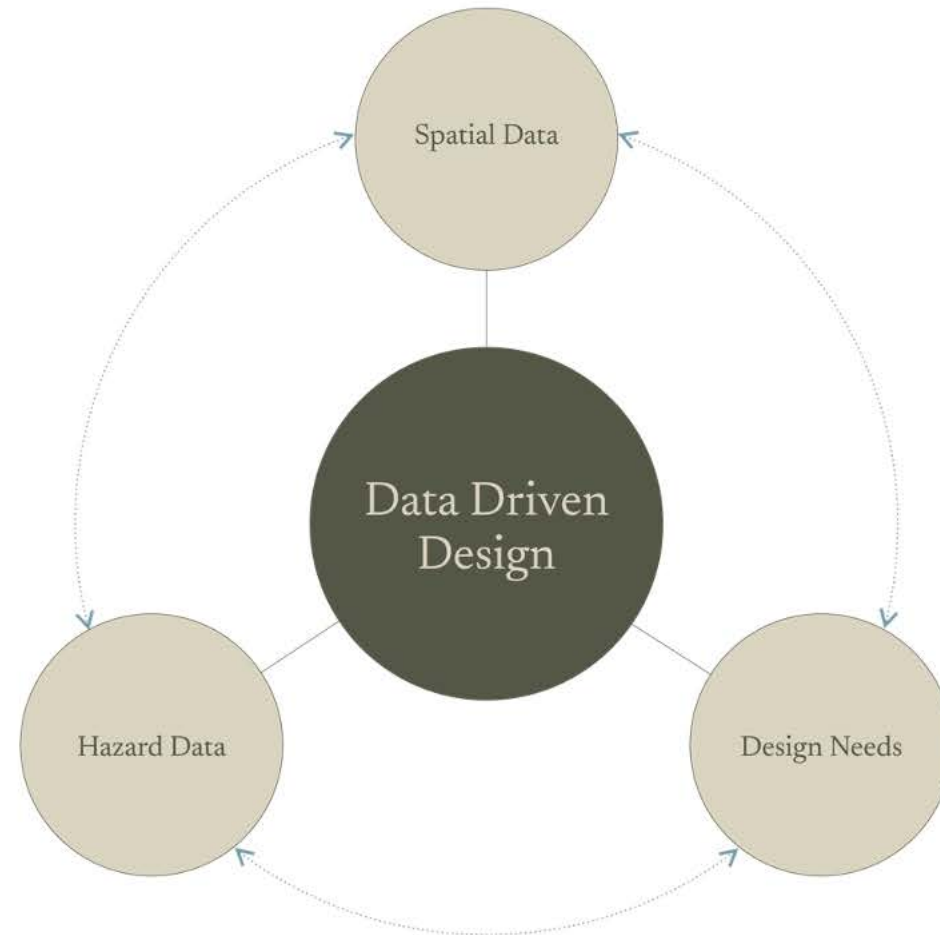


where reduction
matters most

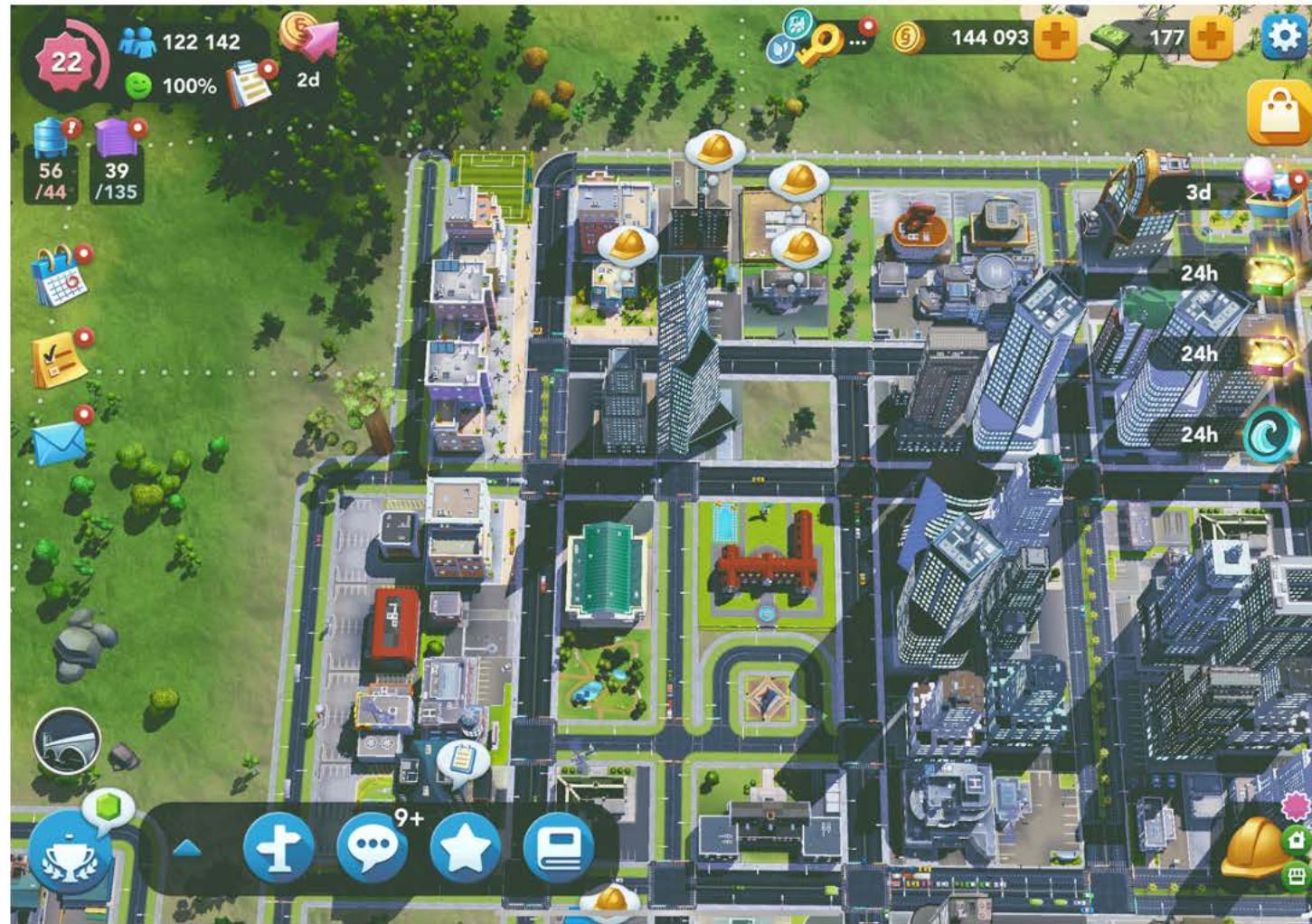


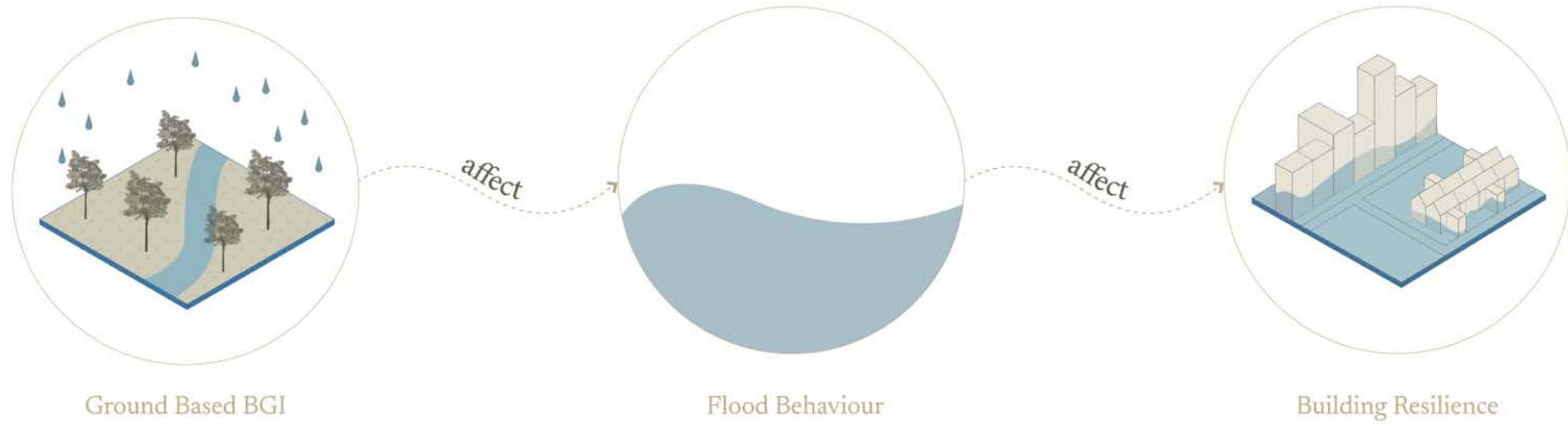
Grounded Resilience







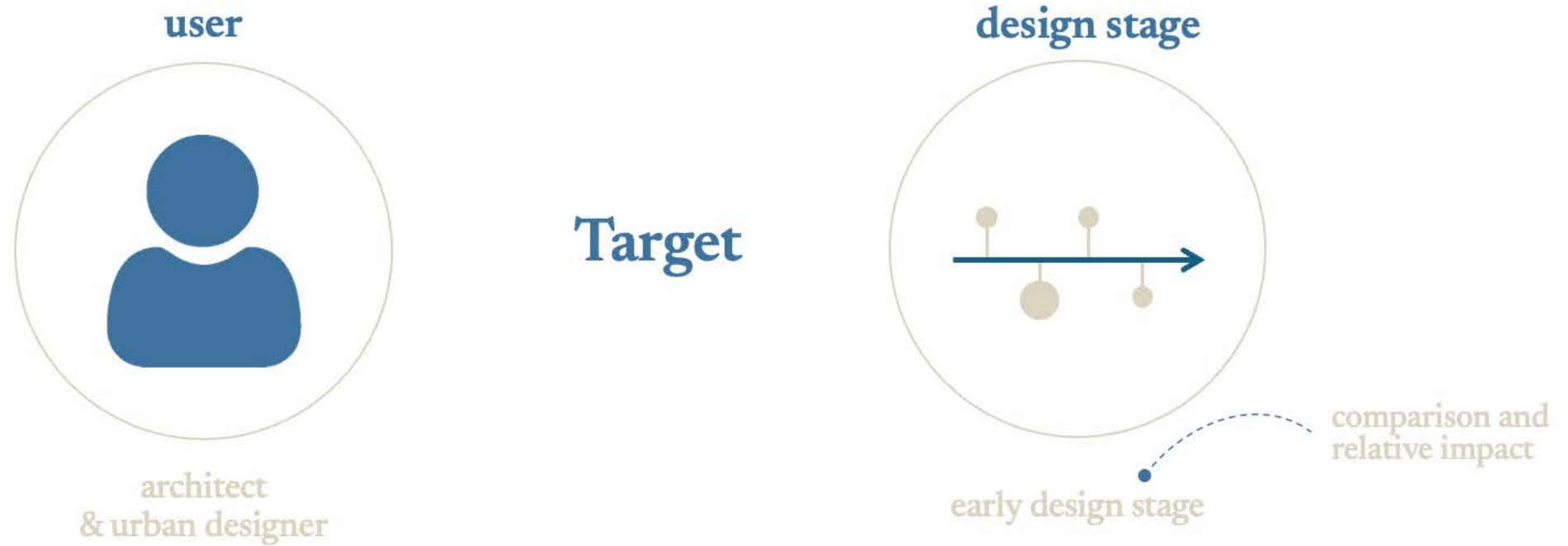


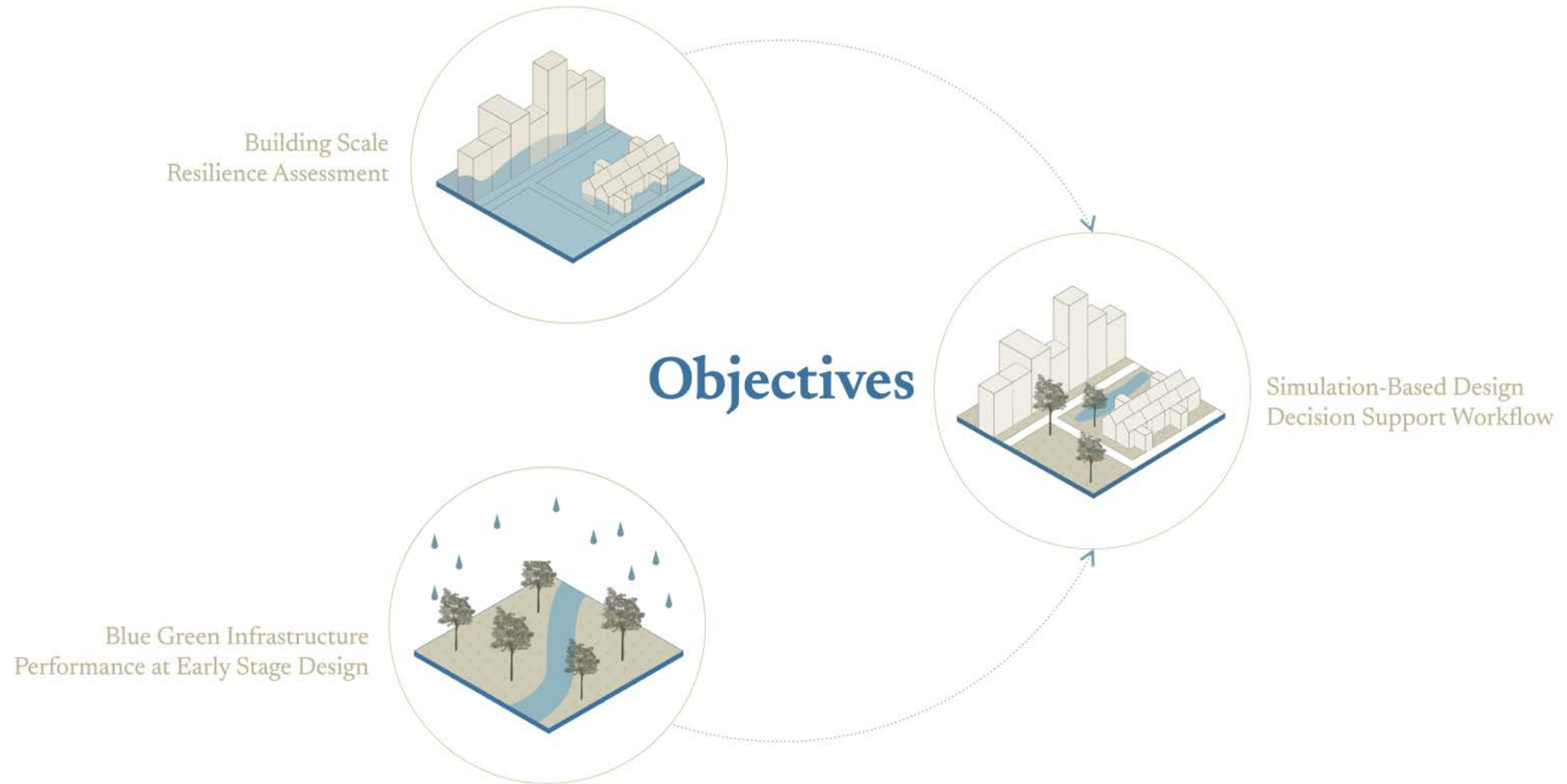


Research Question

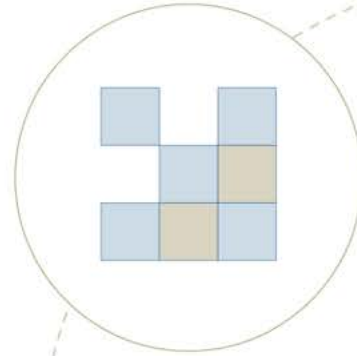
How can a rainwater data-driven simulation framework be developed to improve building flood resilience through Blue-Green Infrastructure design strategies at the neighbourhood scale?





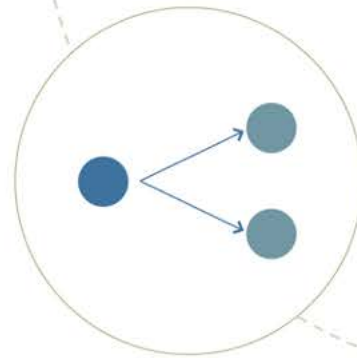


Computational Load
& Simulation Resolution

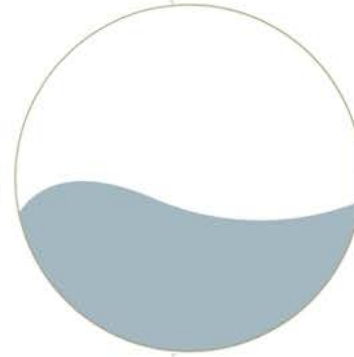


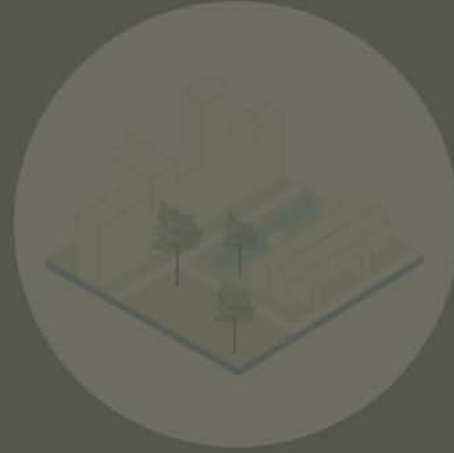
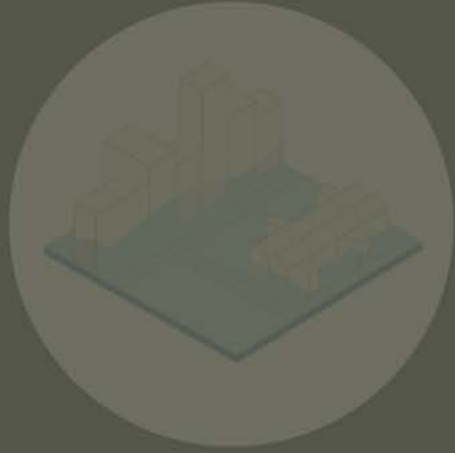
Boundary Condition

Deterministic
Rainfall Scenario

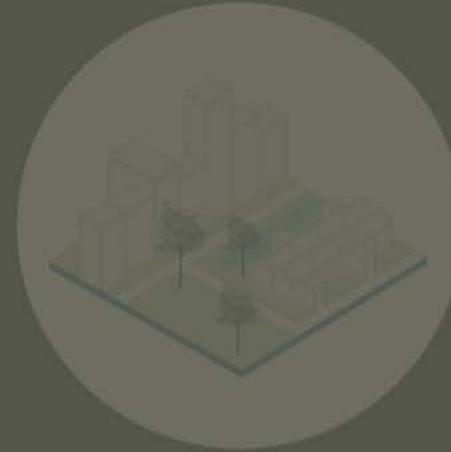
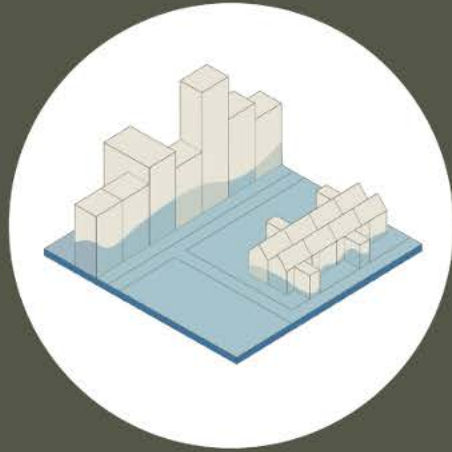


Rainfall Volume
Accumulation Instead of
Time-Based Simulation





From Player to Builder

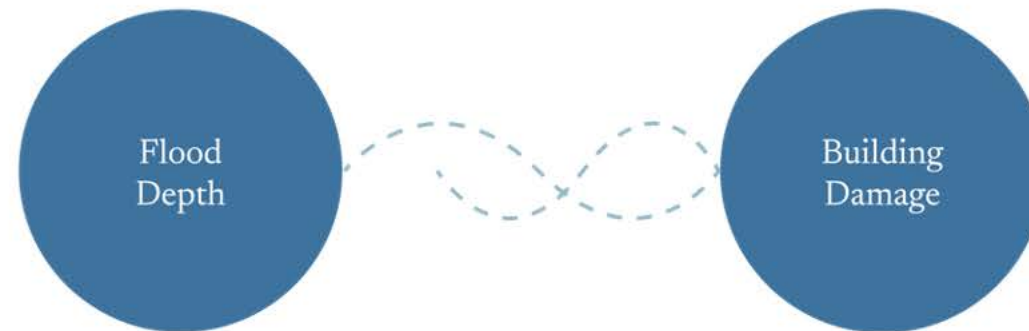


Building Resilience

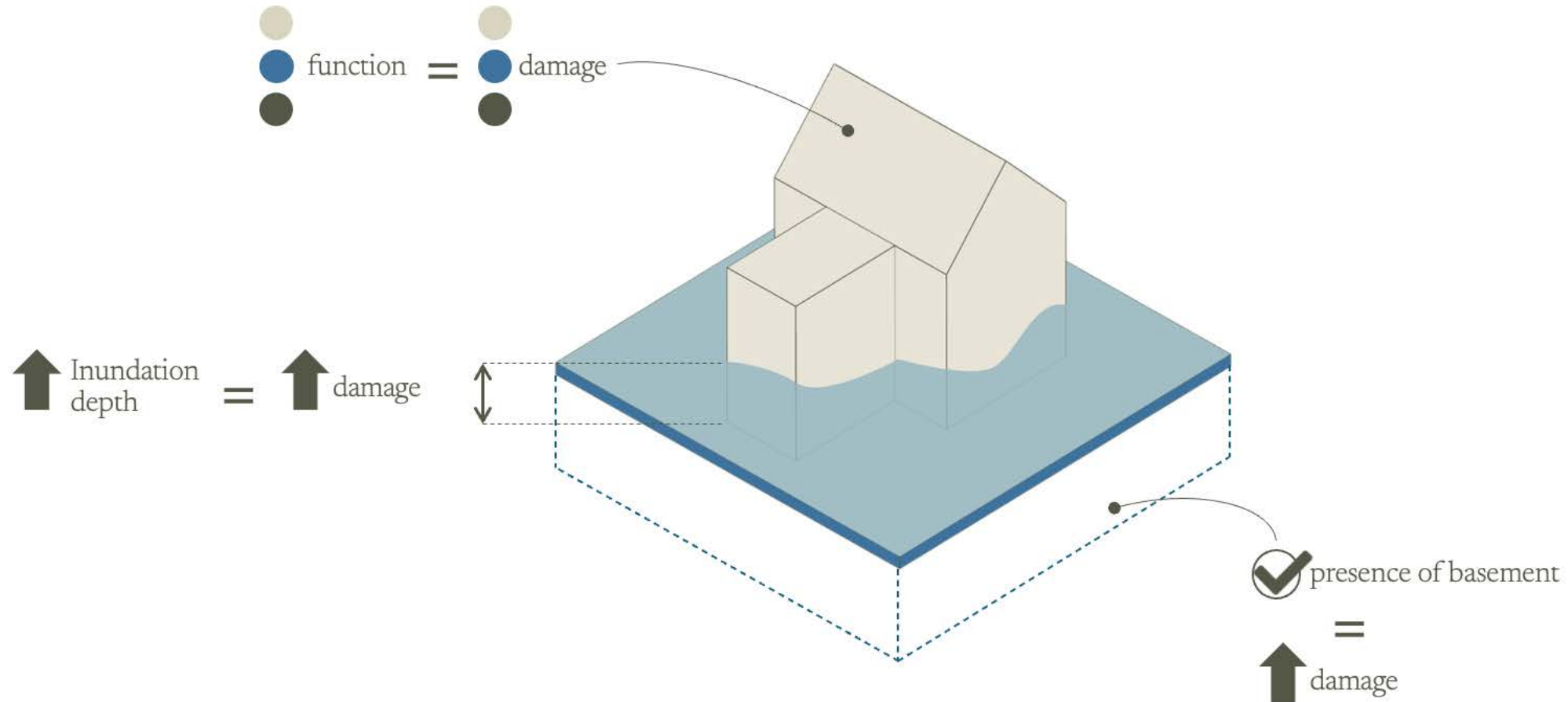
What is Building Resilience?

“the ability to resist, absorb or recover from a shock.”

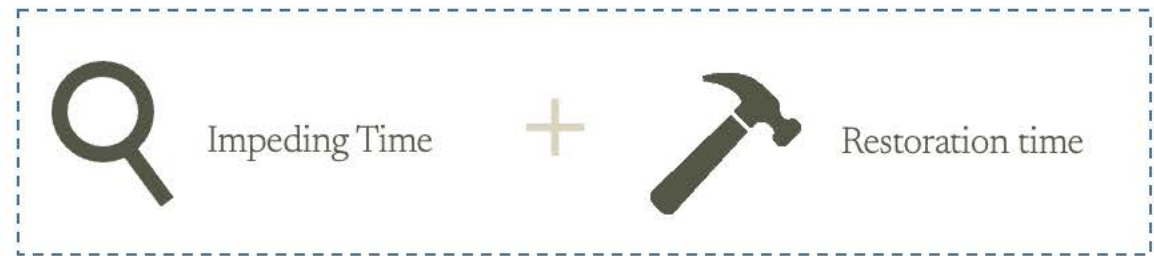
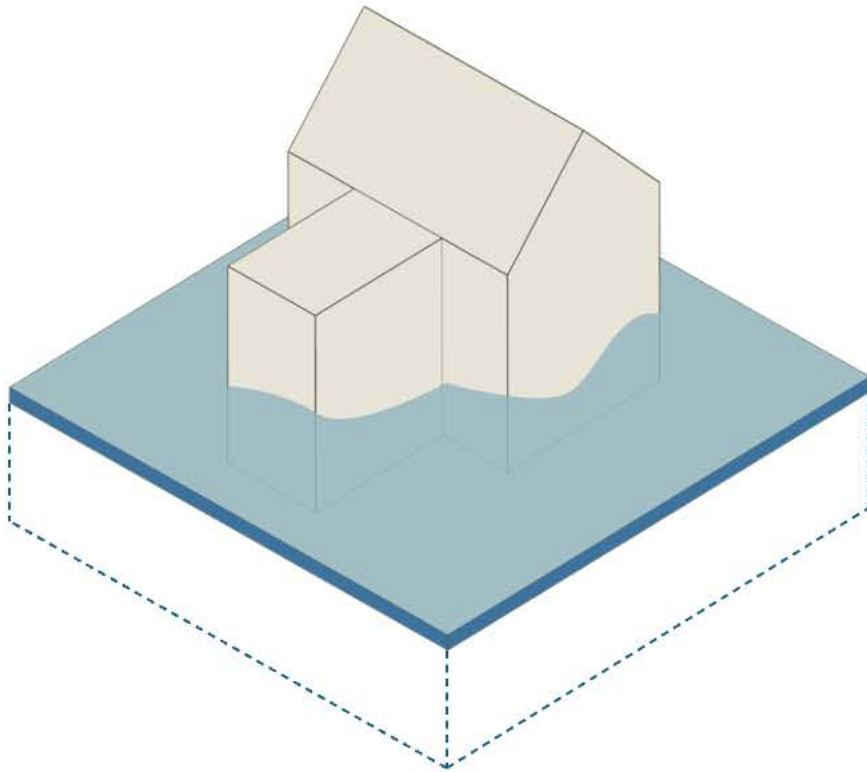
State of the Art



How Flooding Impacts Buildings

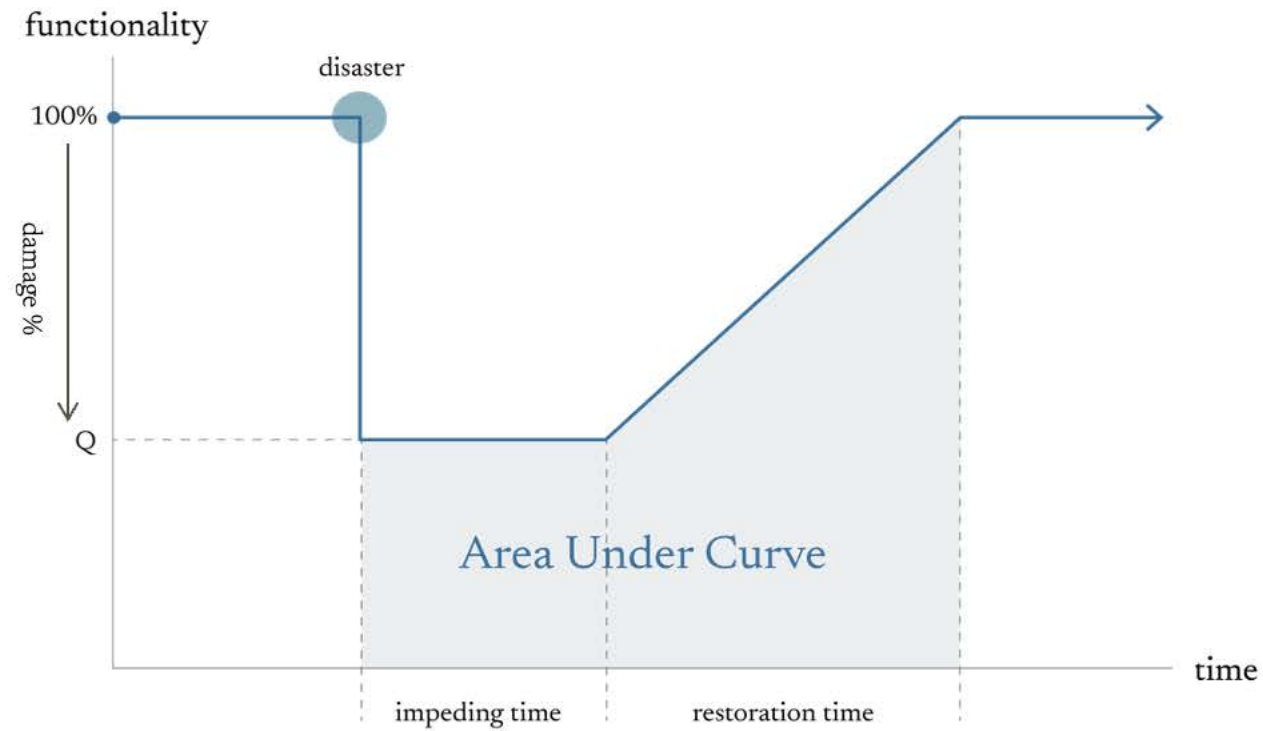


Recovery Process

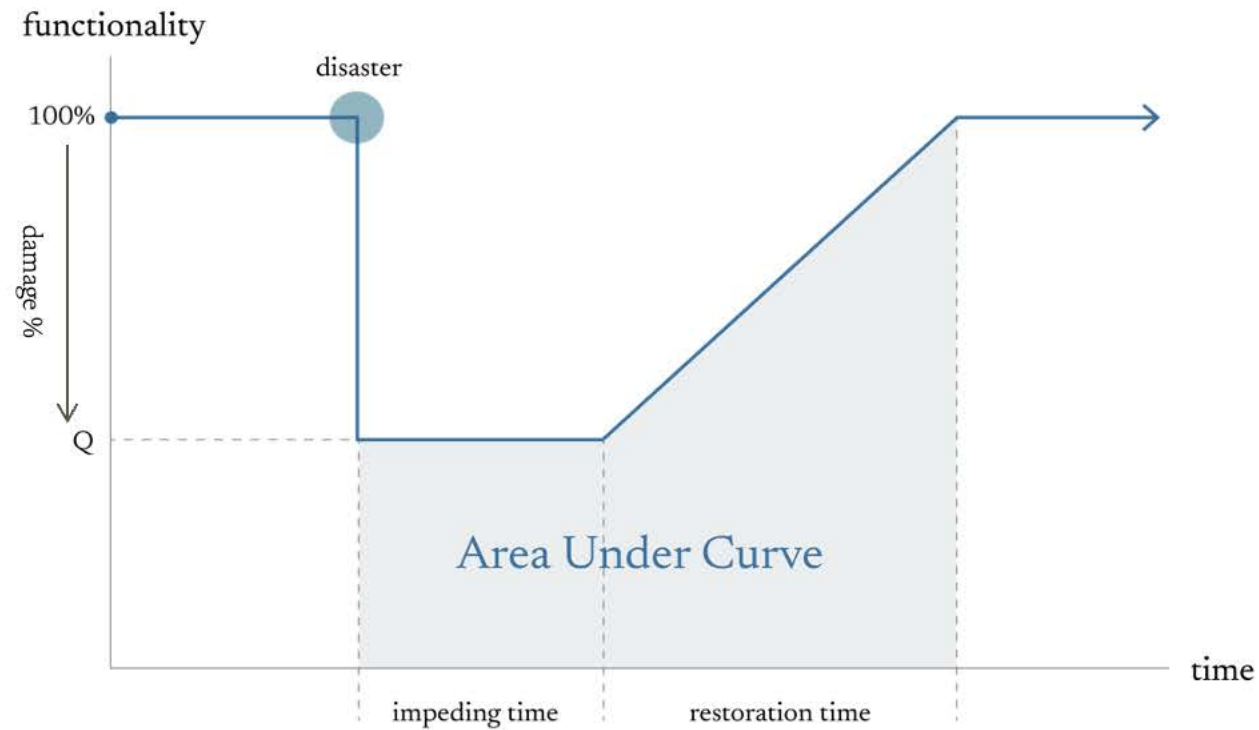


● ● ● depends on function & damage level

Resilience Curve

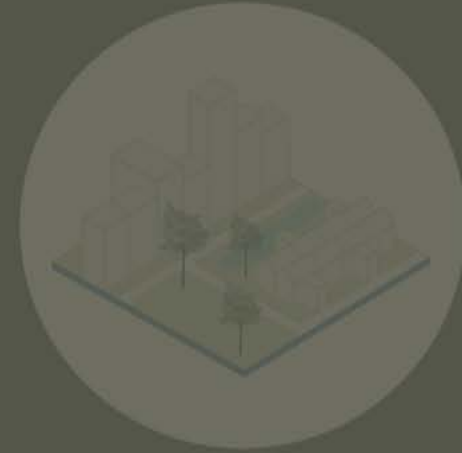
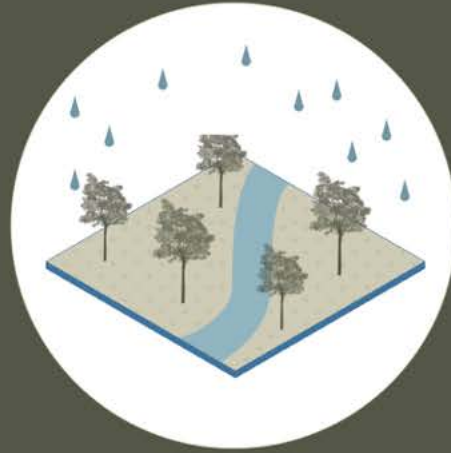
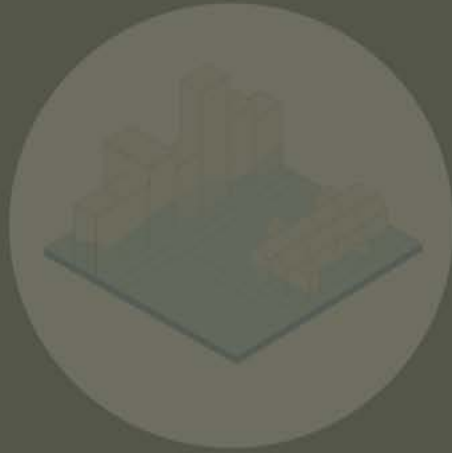


Resilience Score Quantification

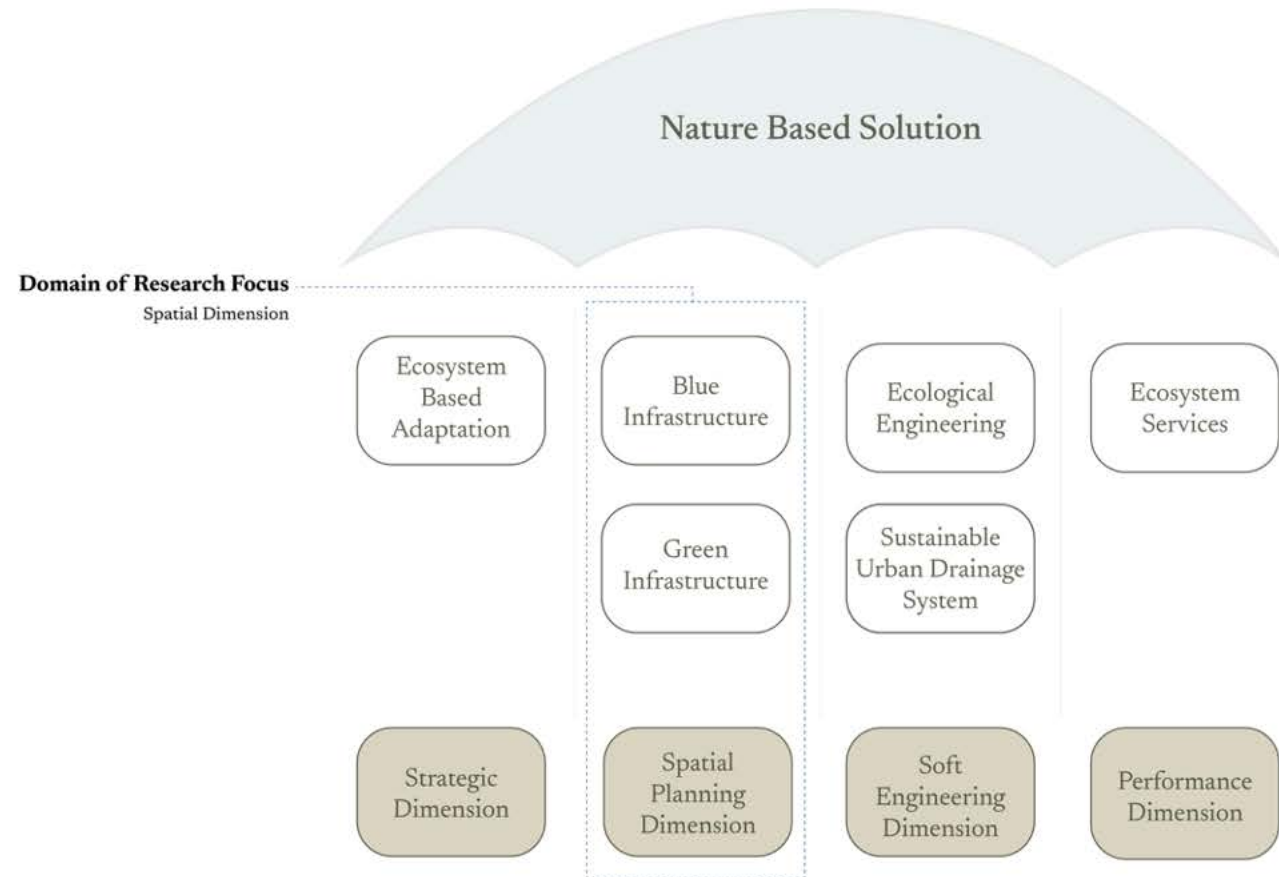


$$\text{Resilience} = \frac{\text{Area Under Curve}}{\text{Perfect Area}}$$



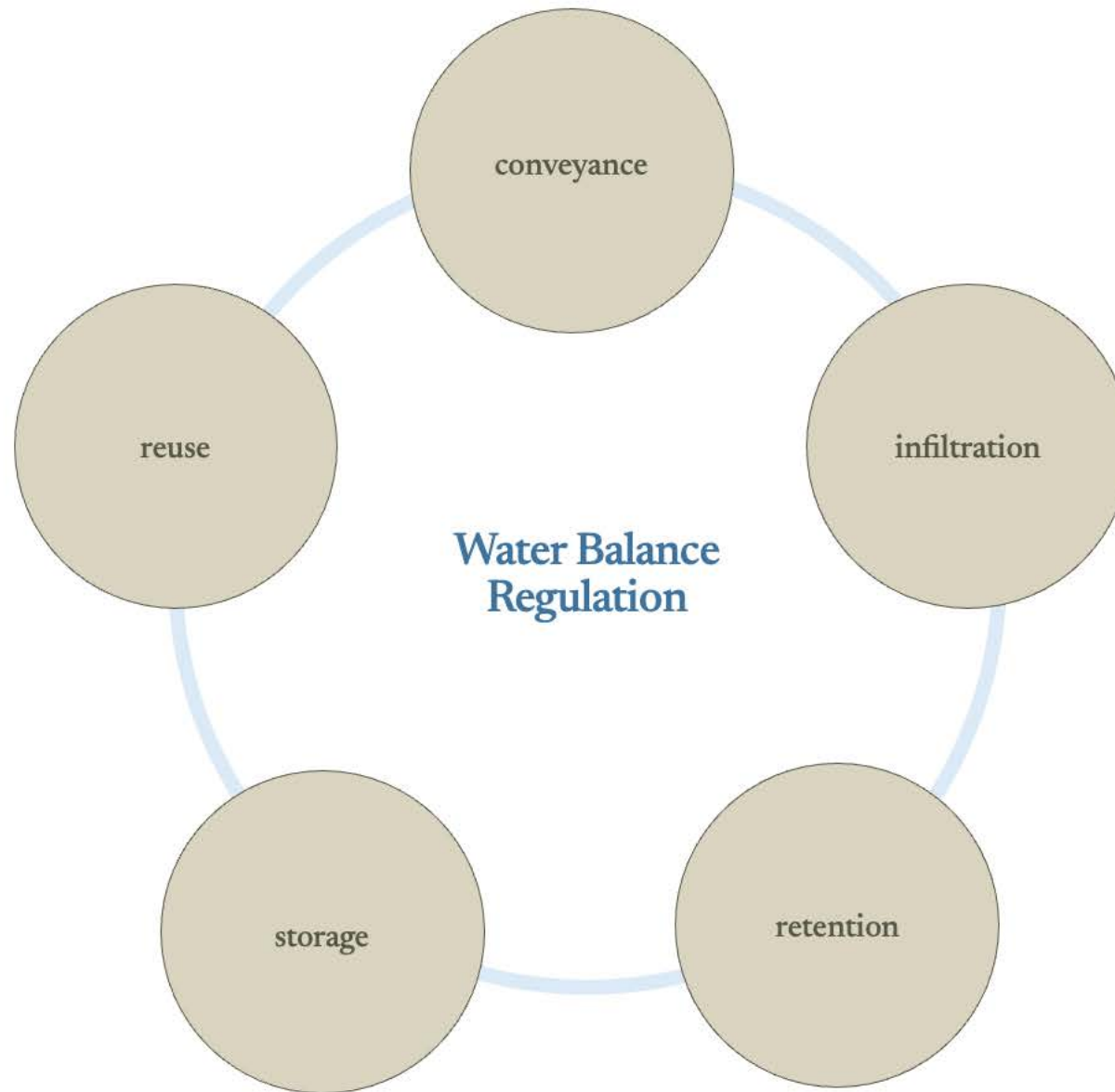


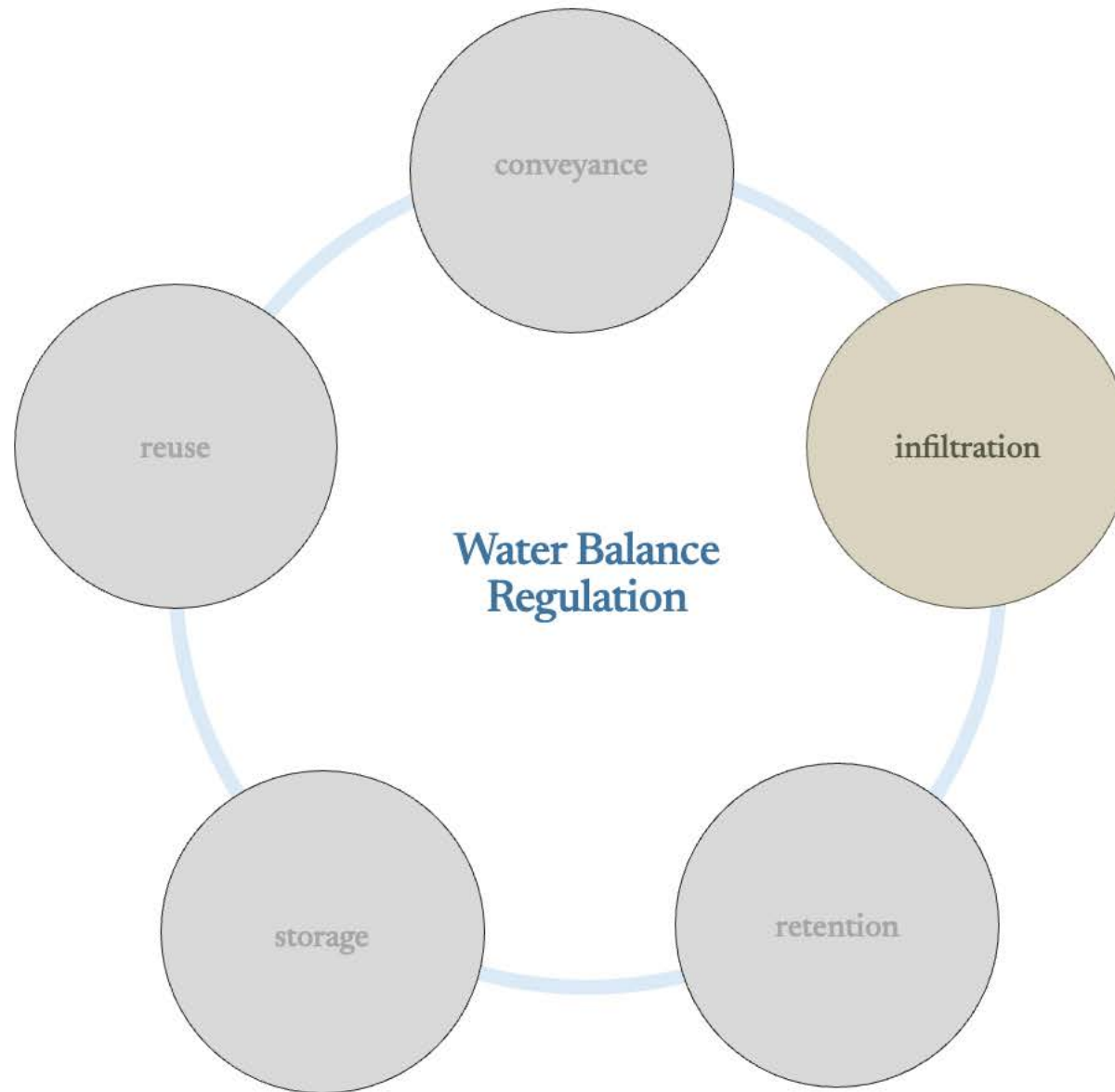
Blue Green Infrastructure

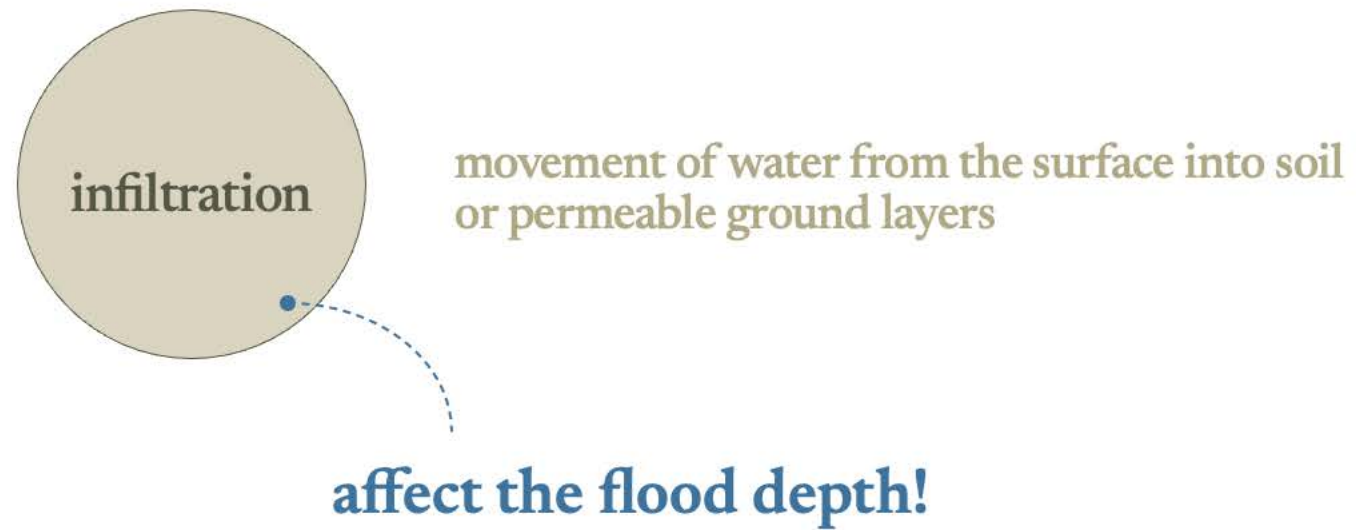


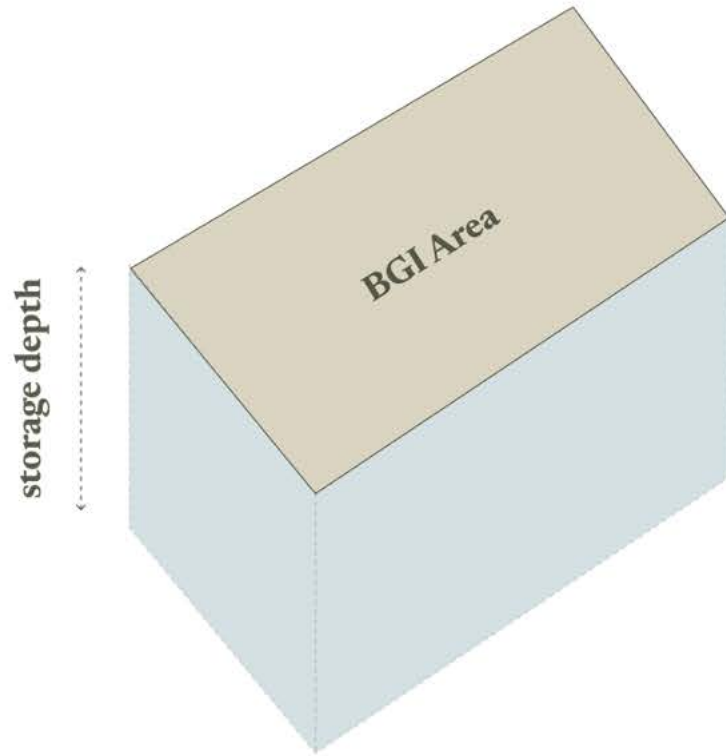


Source: Ramboll Nederland BV





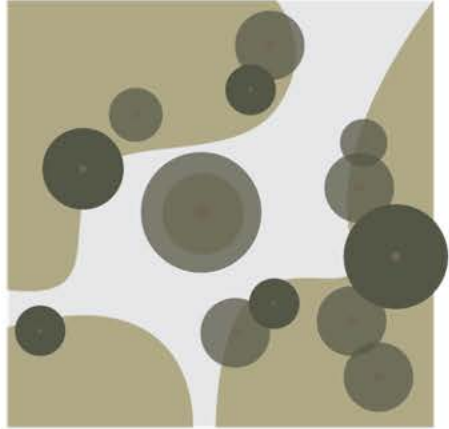




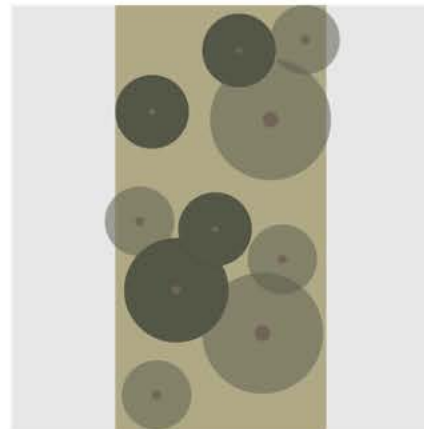
Storage Depth Method

$$\text{BGI Capacity (m}^3\text{)} = \text{BGI Area} \times \text{Storage Depth}$$

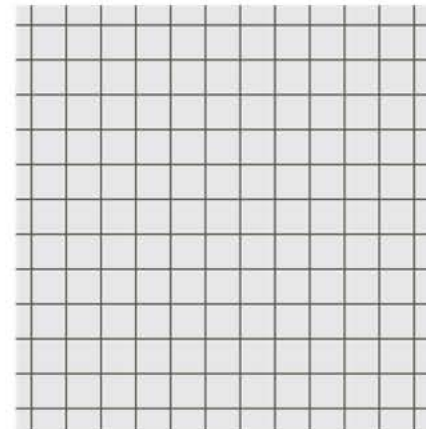
Urban Park



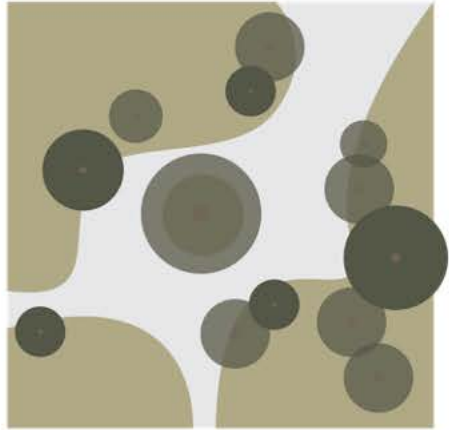
Bioswale



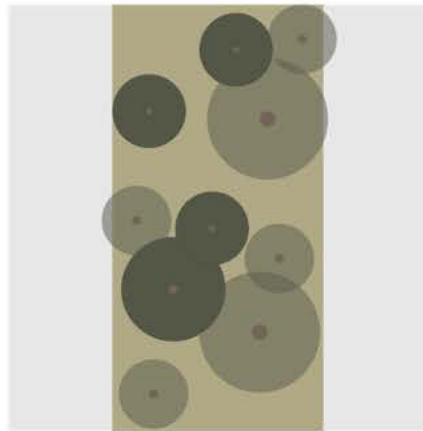
Permeable Pavement



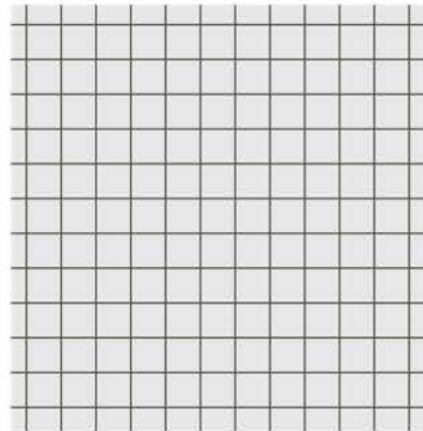
Urban Park



Bioswale



Permeable Pavement

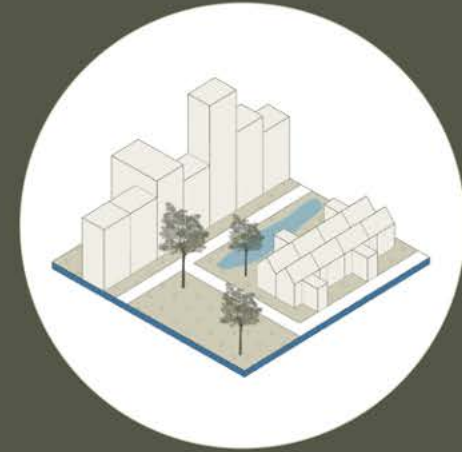


Spatial Aspect



Quantitative Aspect





**Constructing the
Rainwater Simulation**

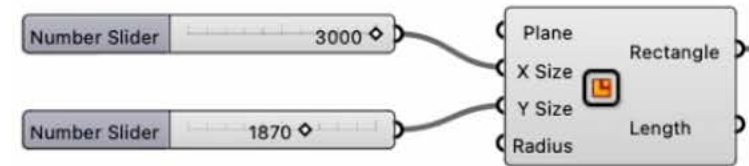


Familiar for
Designers

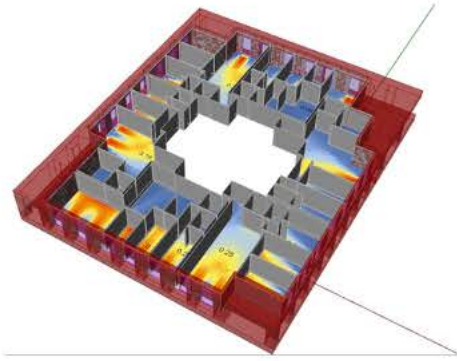
Allow Interactive
Design Changes

User don't need
to install External
Simulation Software

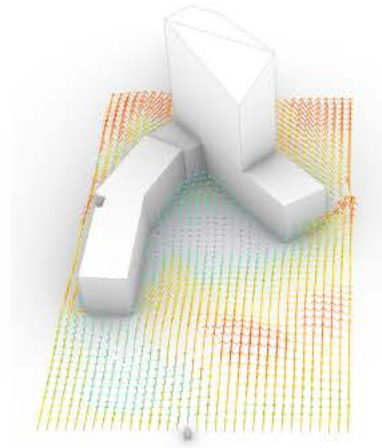
What's Grasshopper?



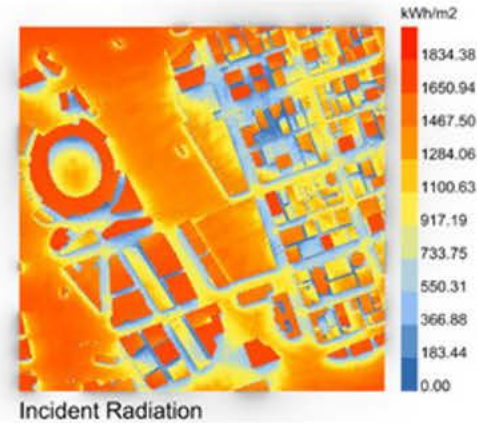
Grasshopper Simulation Plugins for Architecture & Urban



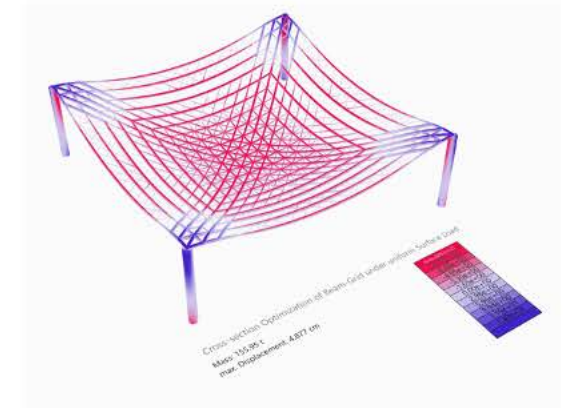
daylighting simulation



wind simulation



thermal comfort

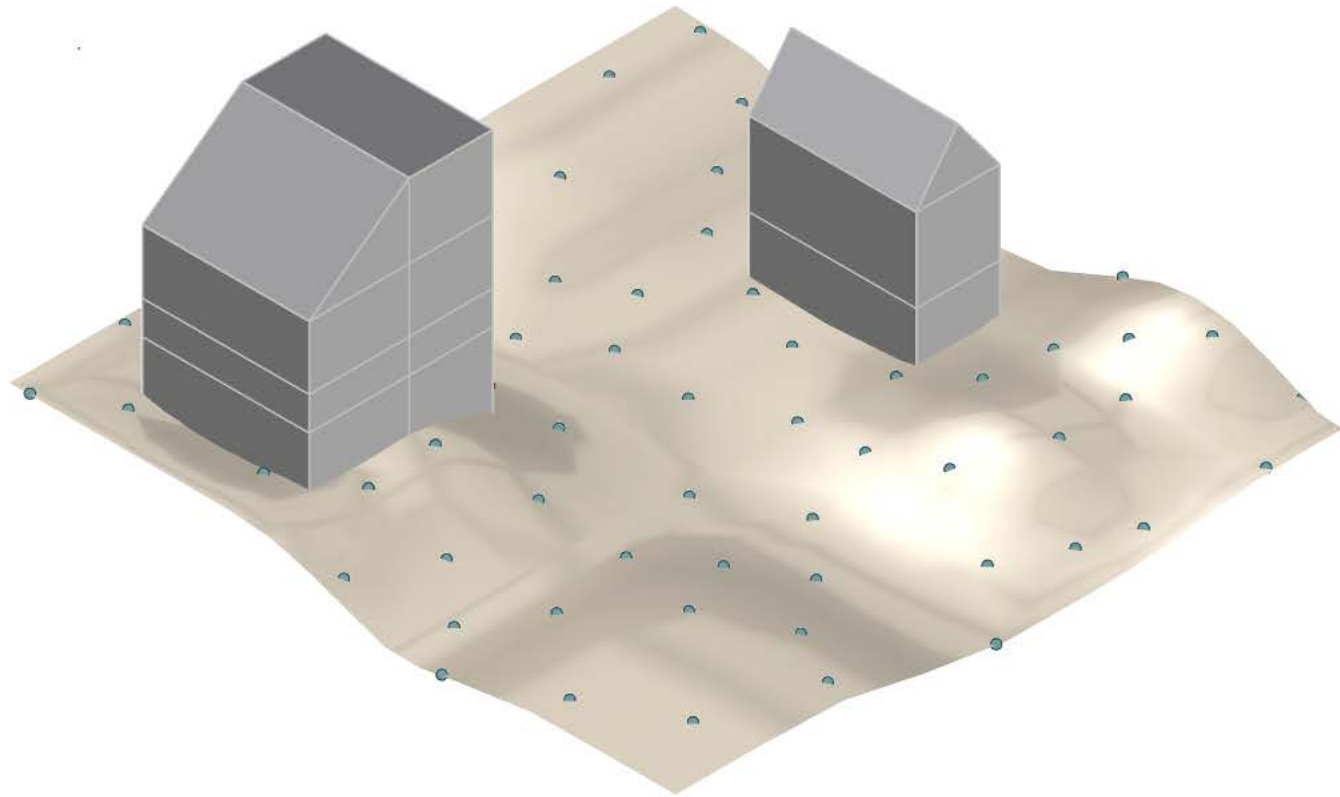
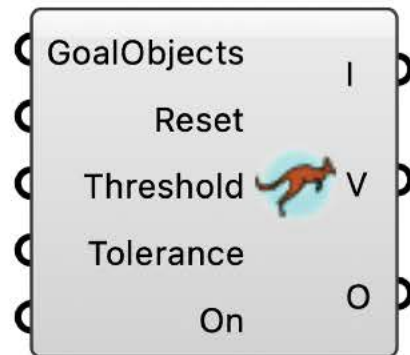


Structural analysis

Plot Twist

~~Proper Flood Depth Simulation~~

Kangaroo Particle Movement

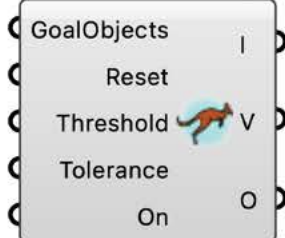


Main Grasshopper Components Overview

custom grasshopper component made by this research *Scripted using Python3 for Grasshopper

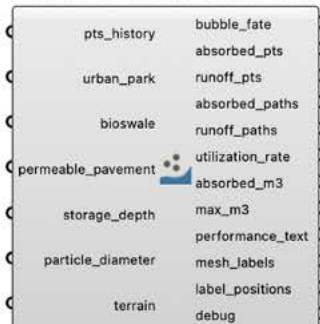
Kangaroo

Kangaroo Particle



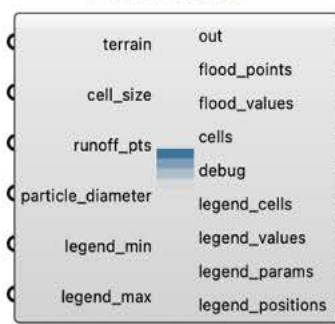
Component A

Particle Classification



Component B

Area Flood Values Estimation



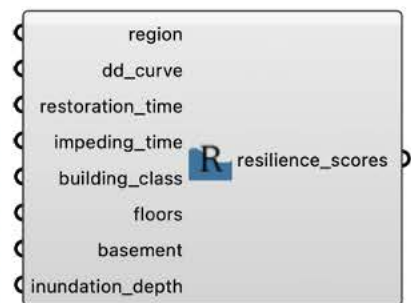
Component C

Building Inundation Depth Estimation



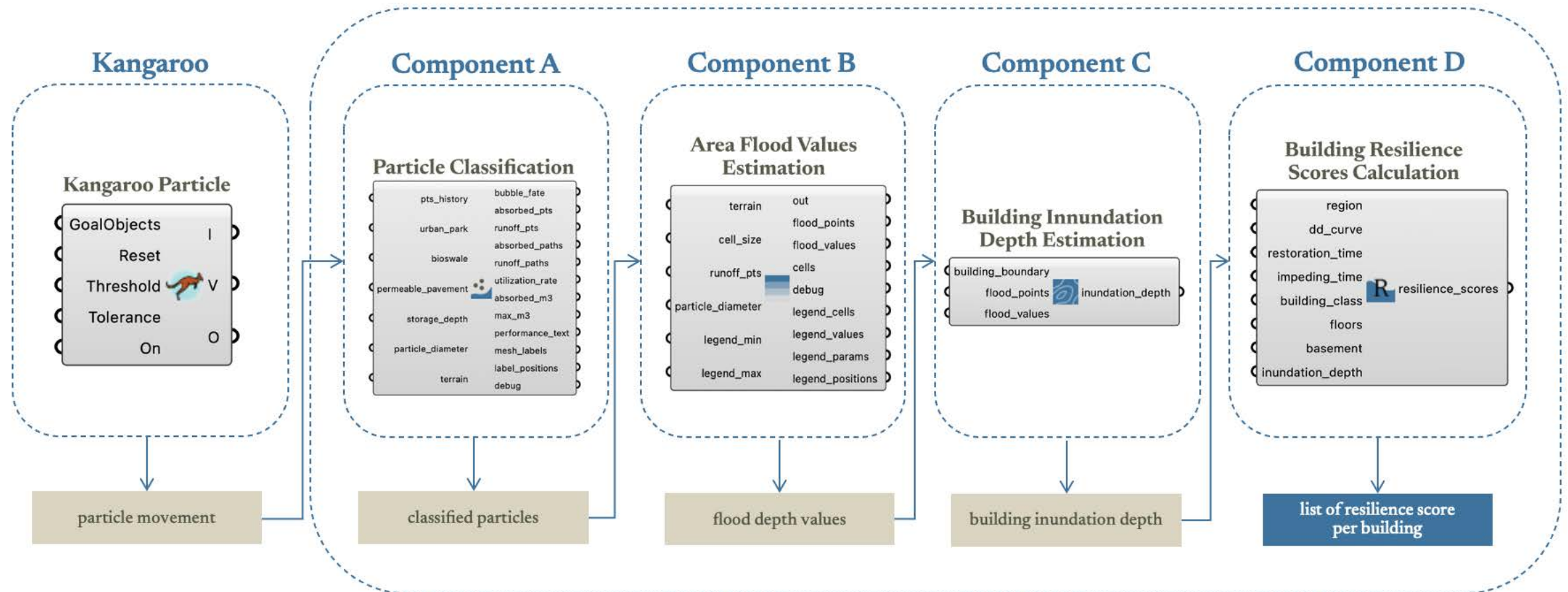
Component D

Building Resilience Scores Calculation



Main Grasshopper Components Overview

custom grasshopper component made by this research *Scripted using Python3 for Grasshopper





KANGAROO



COMPONENT A



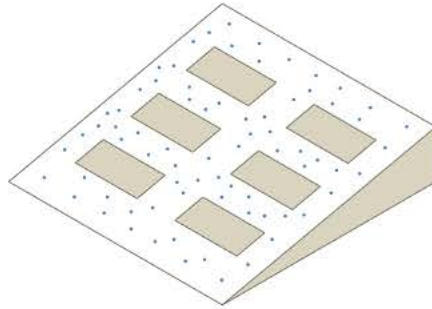
COMPONENT B



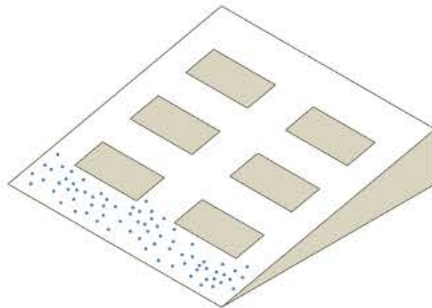
COMPONENT C



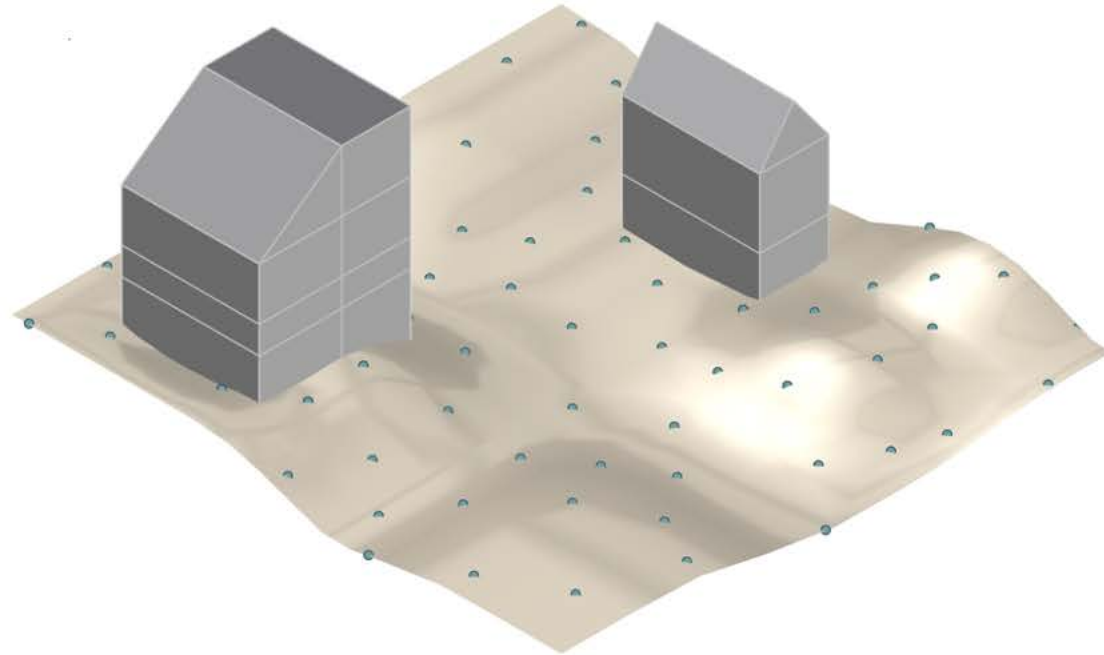
COMPONENT D



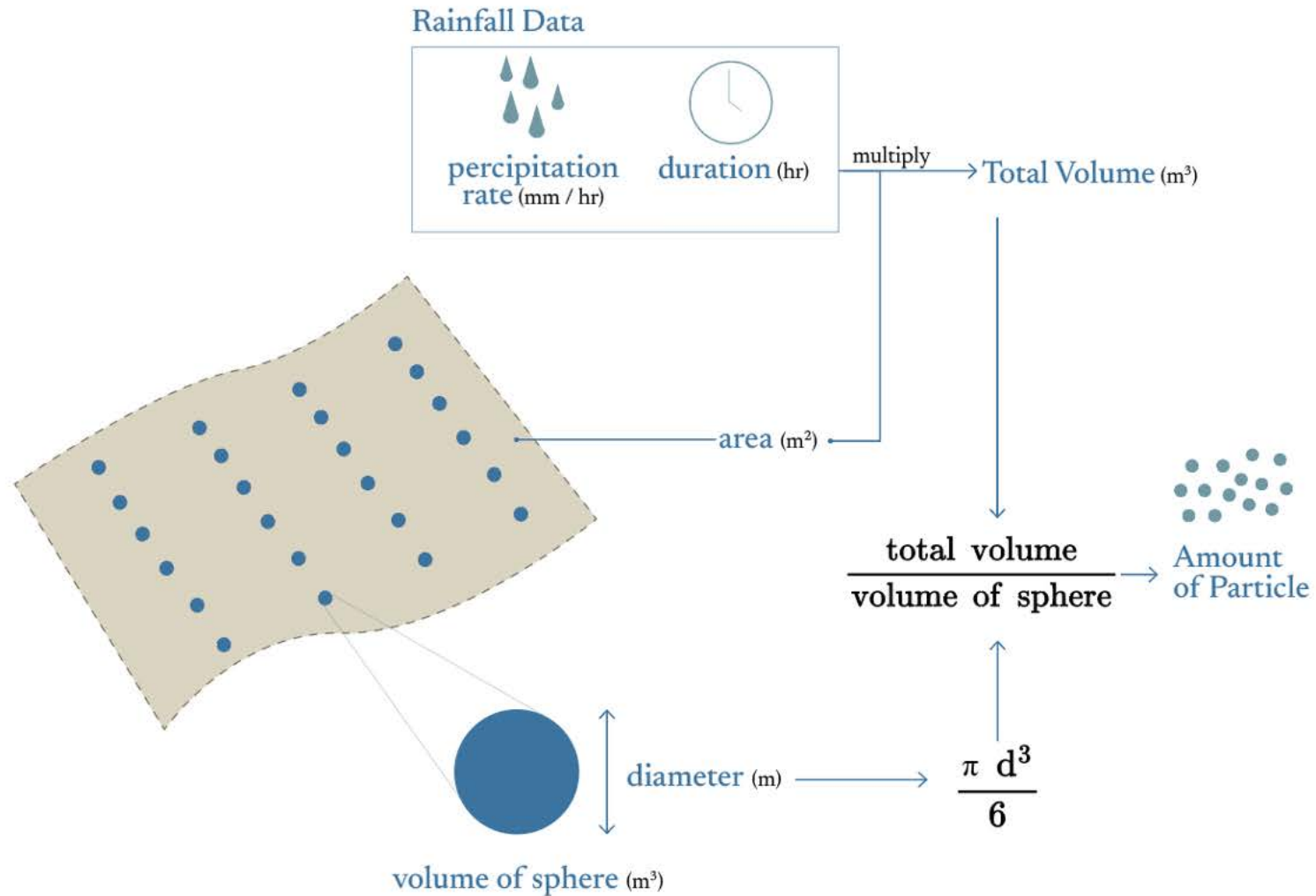
1 populate the terrain with points



2 when activated, the Kangaroo iterates until the particle movement stabilizes



Kangaroo Particle Movement Simulation







KANGAROO



COMPONENT A



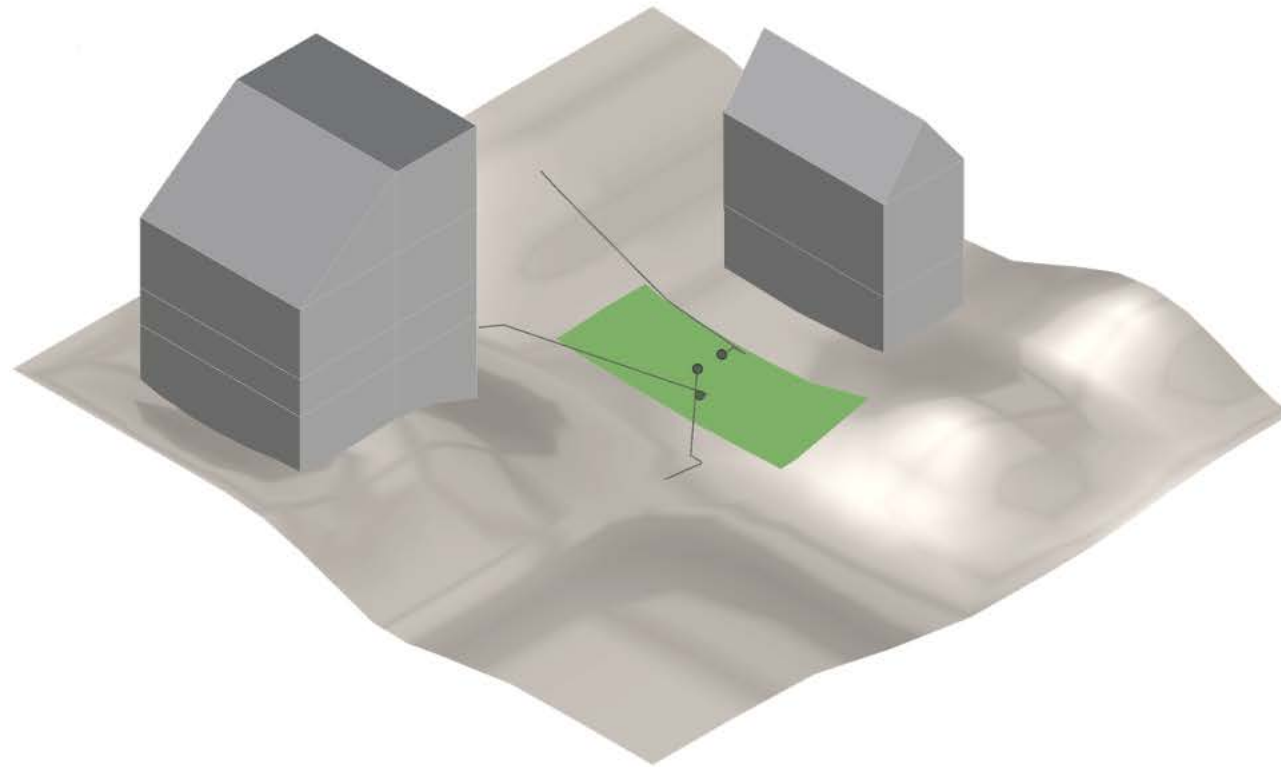
COMPONENT B



COMPONENT C



COMPONENT D



Particle Classification

- Urban Park 50-75% Grass Cover
- Bioswale
- Permeable Pavement



KANGAROO



COMPONENT A



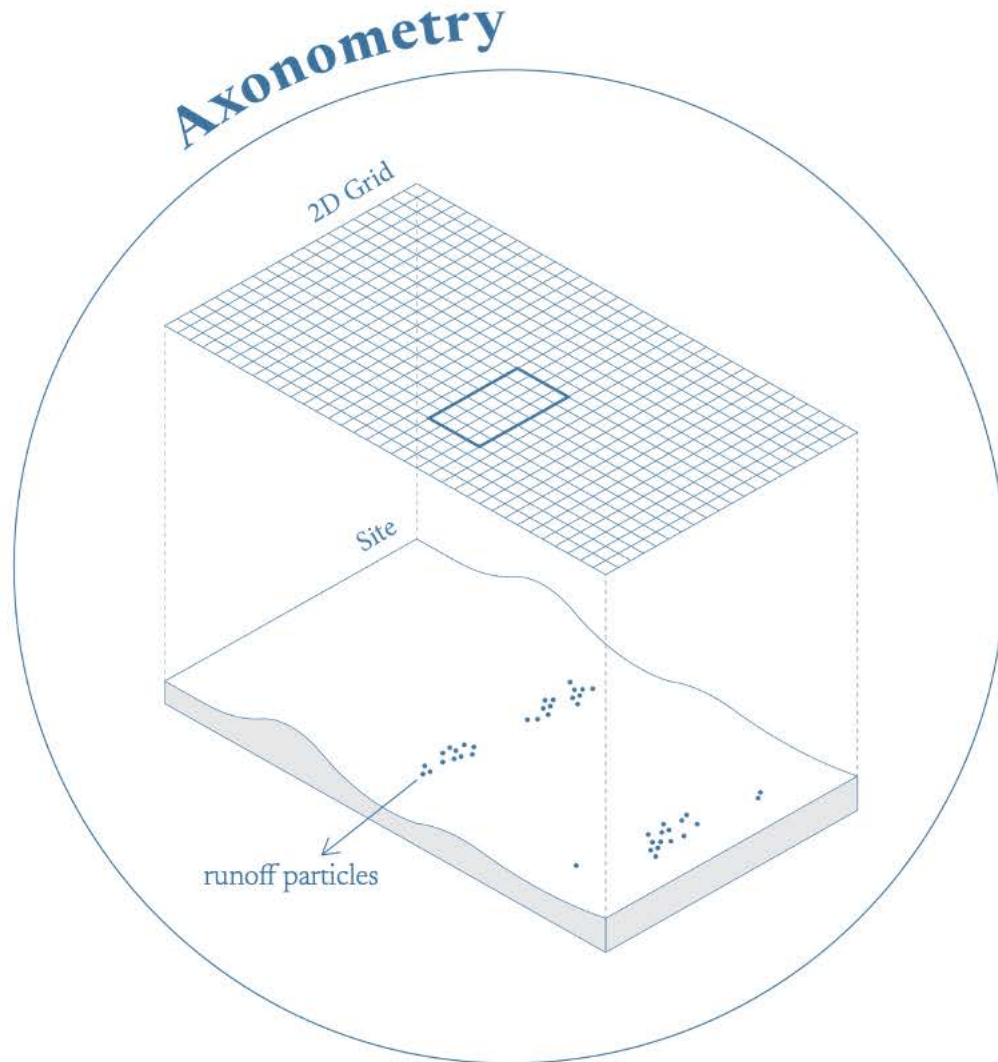
COMPONENT B



COMPONENT C



COMPONENT D



From Particles to Flood Depth Values



KANGAROO



COMPONENT A



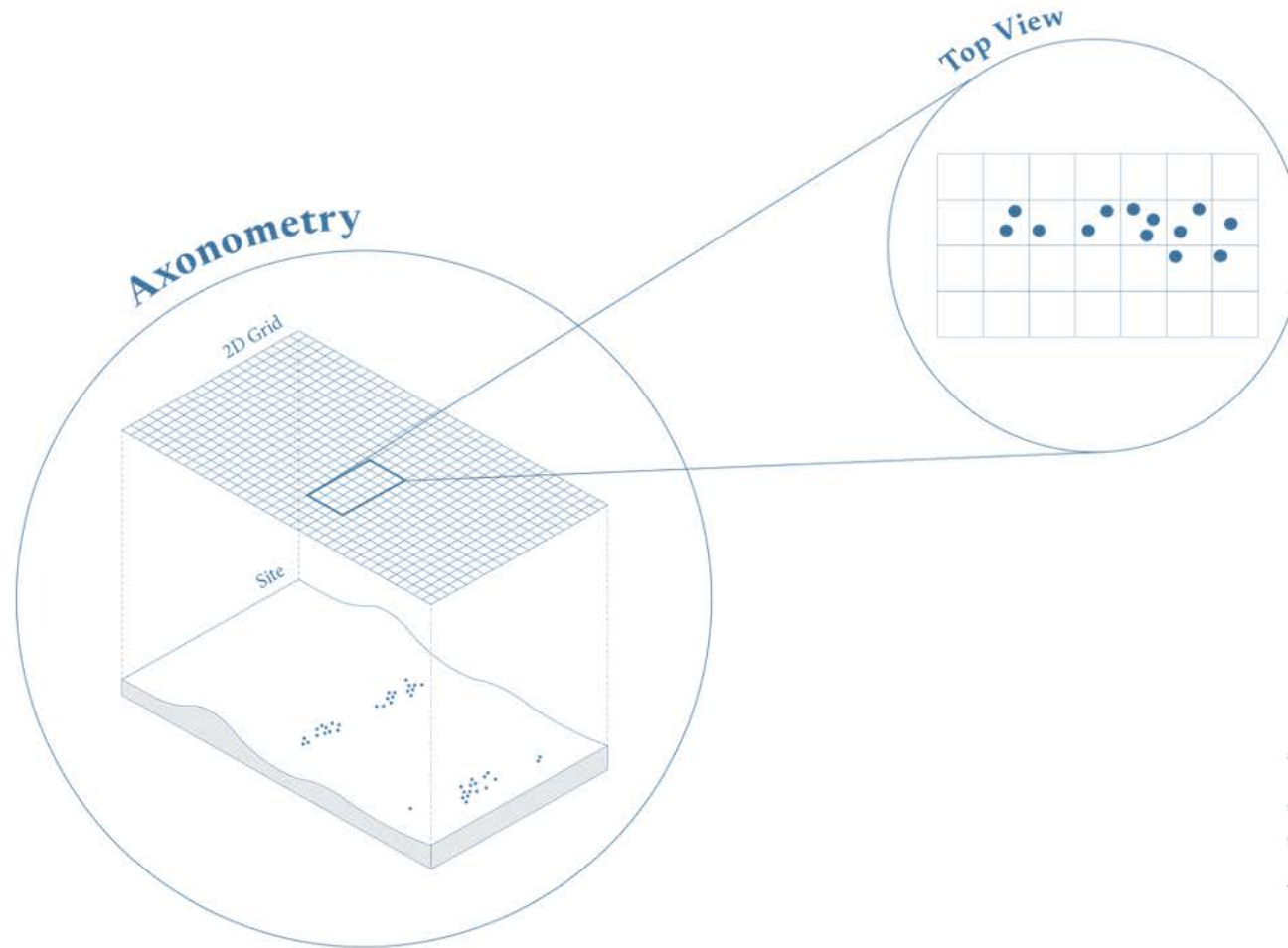
COMPONENT B



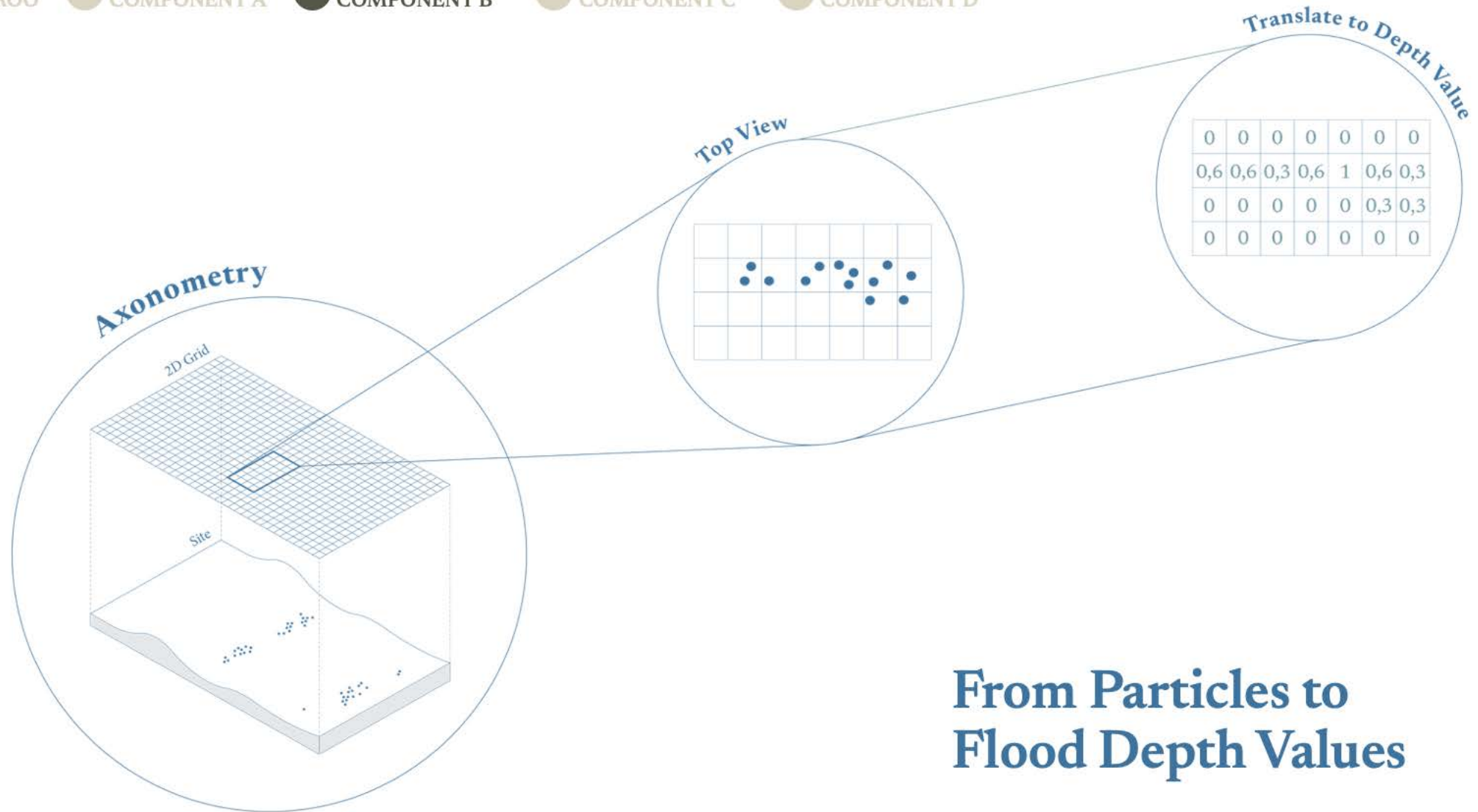
COMPONENT C



COMPONENT D



From Particles to Flood Depth Values





KANGAROO



COMPONENT A



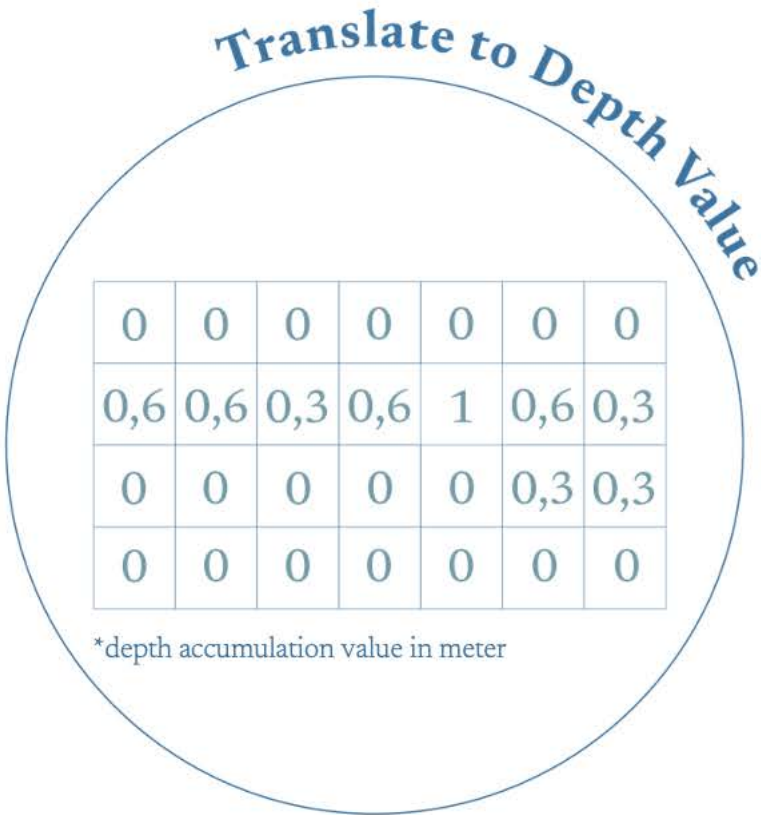
COMPONENT B



COMPONENT C



COMPONENT D





KANGAROO



COMPONENT A



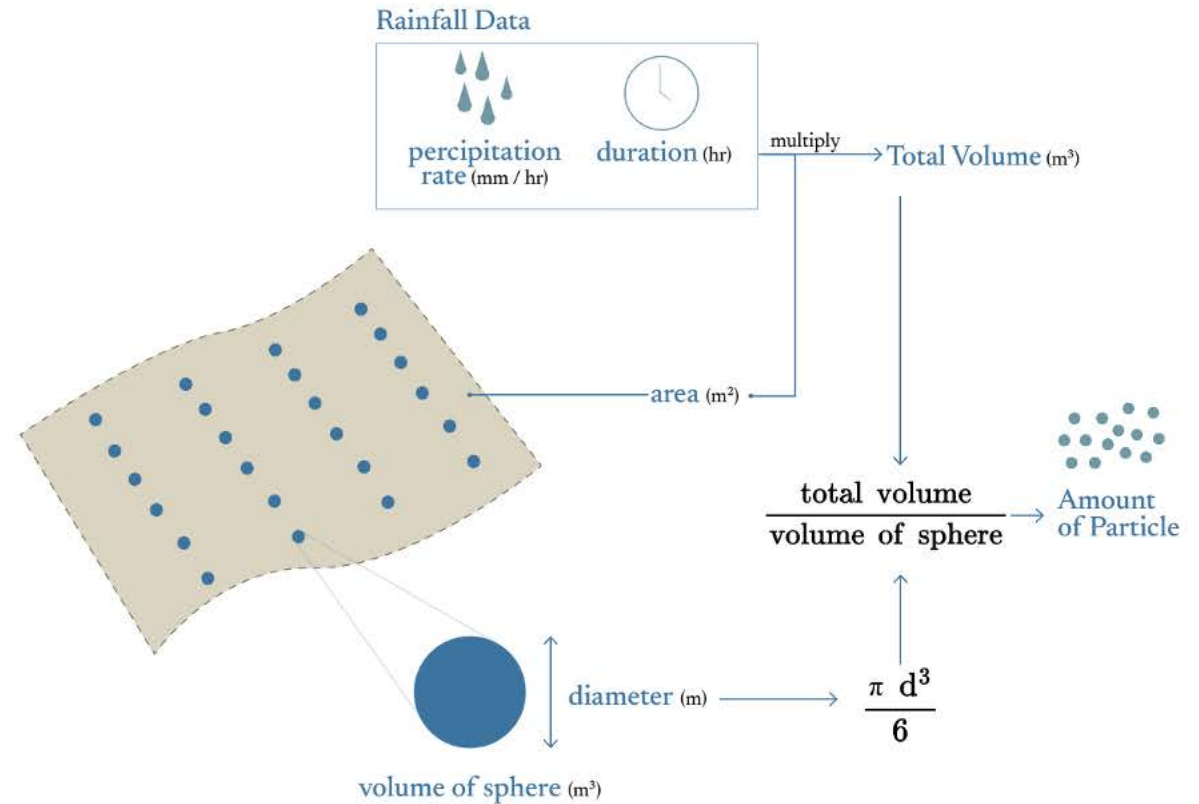
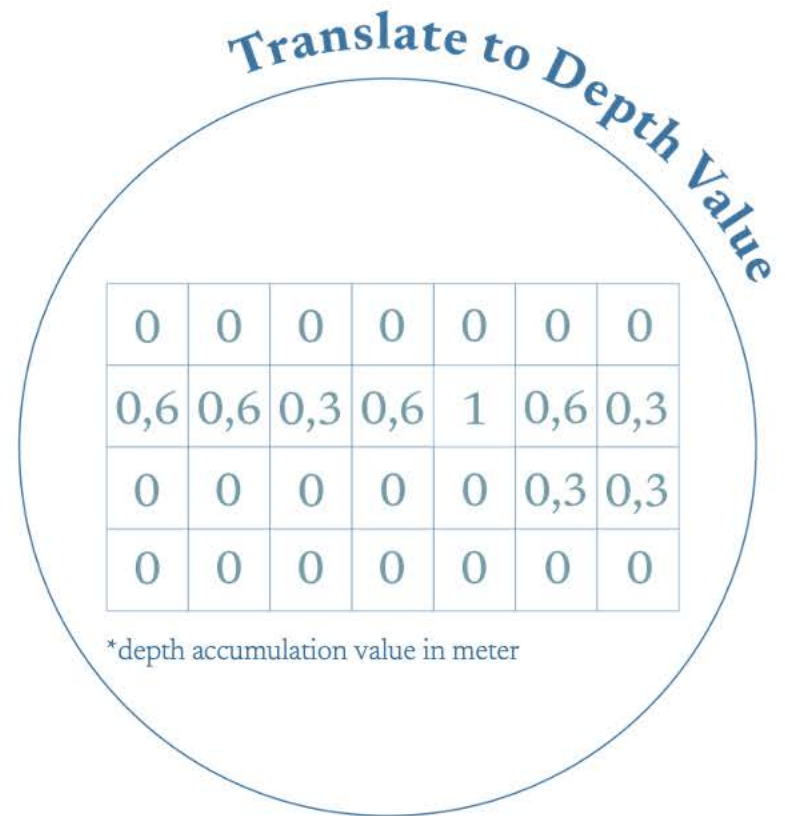
COMPONENT B



COMPONENT C



COMPONENT D





KANGAROO



COMPONENT A



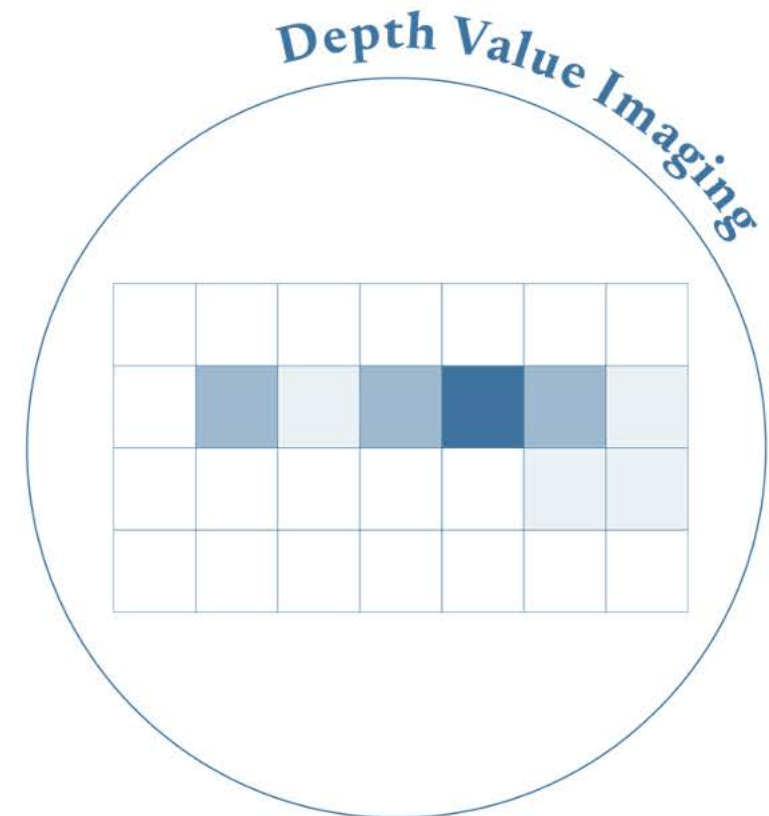
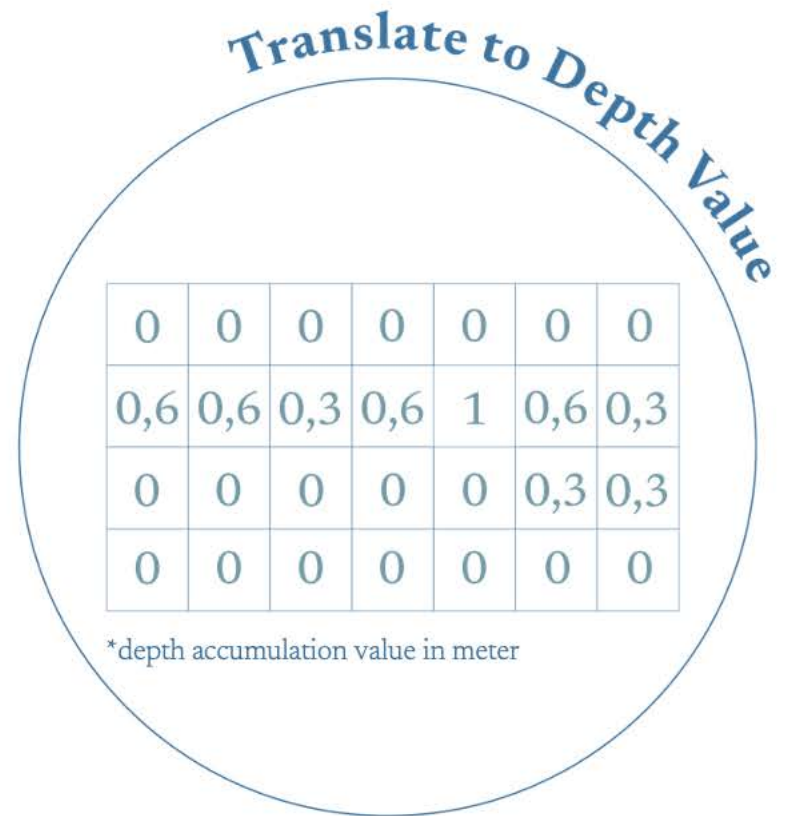
COMPONENT B



COMPONENT C



COMPONENT D





KANGAROO



COMPONENT A



COMPONENT B

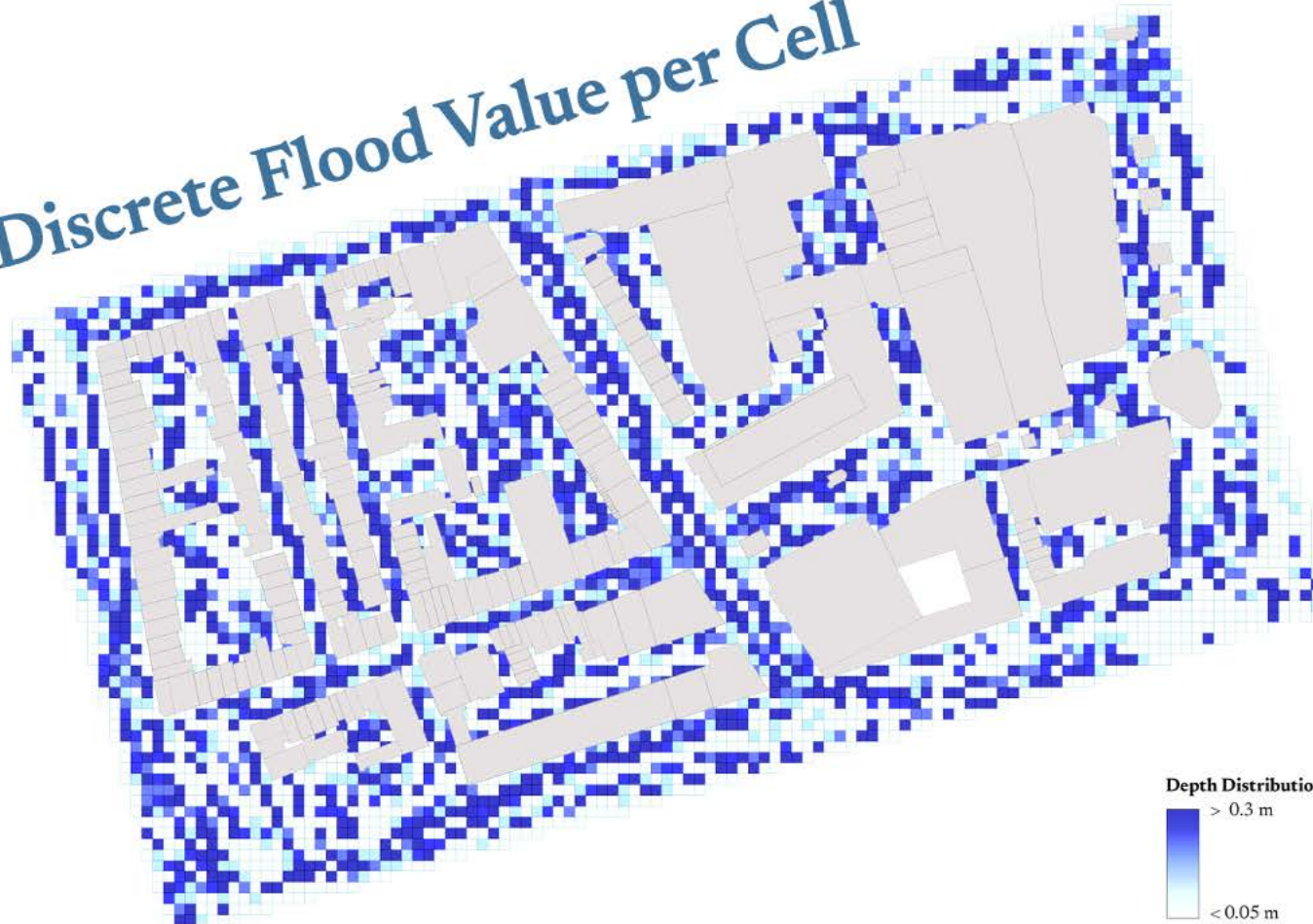


COMPONENT C



COMPONENT D

Discrete Flood Value per Cell





KANGAROO



COMPONENT A



COMPONENT B

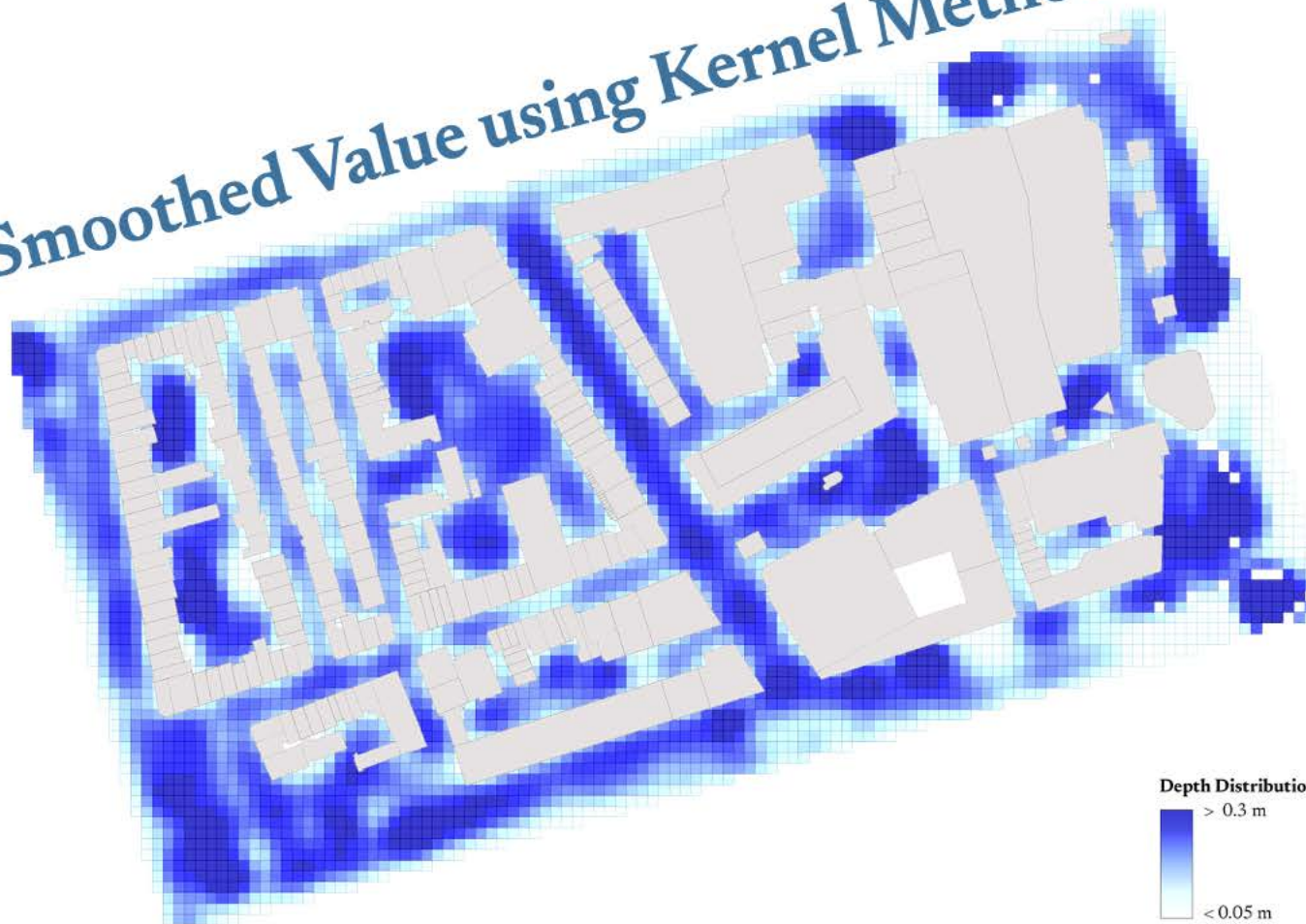


COMPONENT C



COMPONENT D

Smoothed Value using Kernel Method





KANGAROO



COMPONENT A



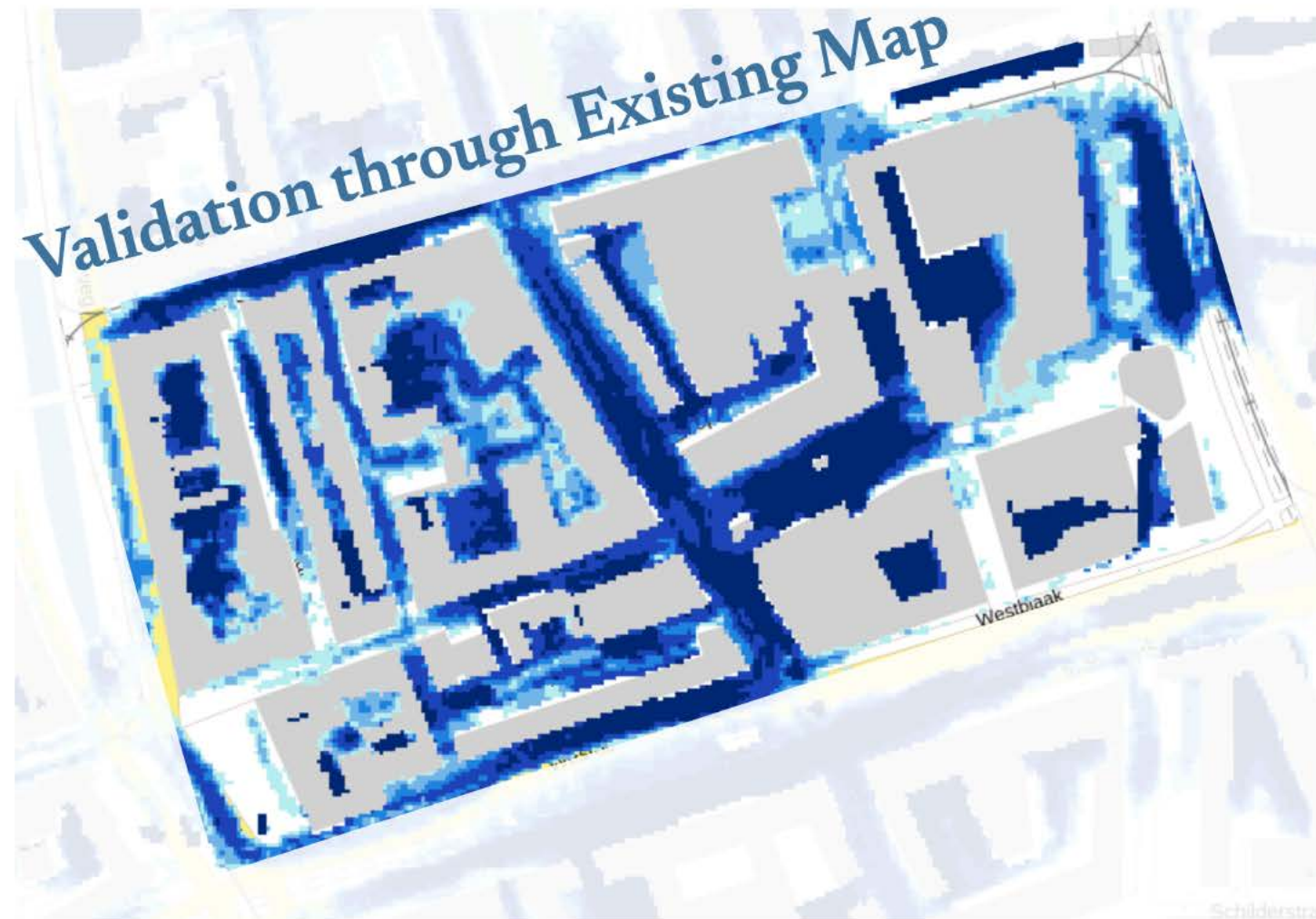
COMPONENT B



COMPONENT C

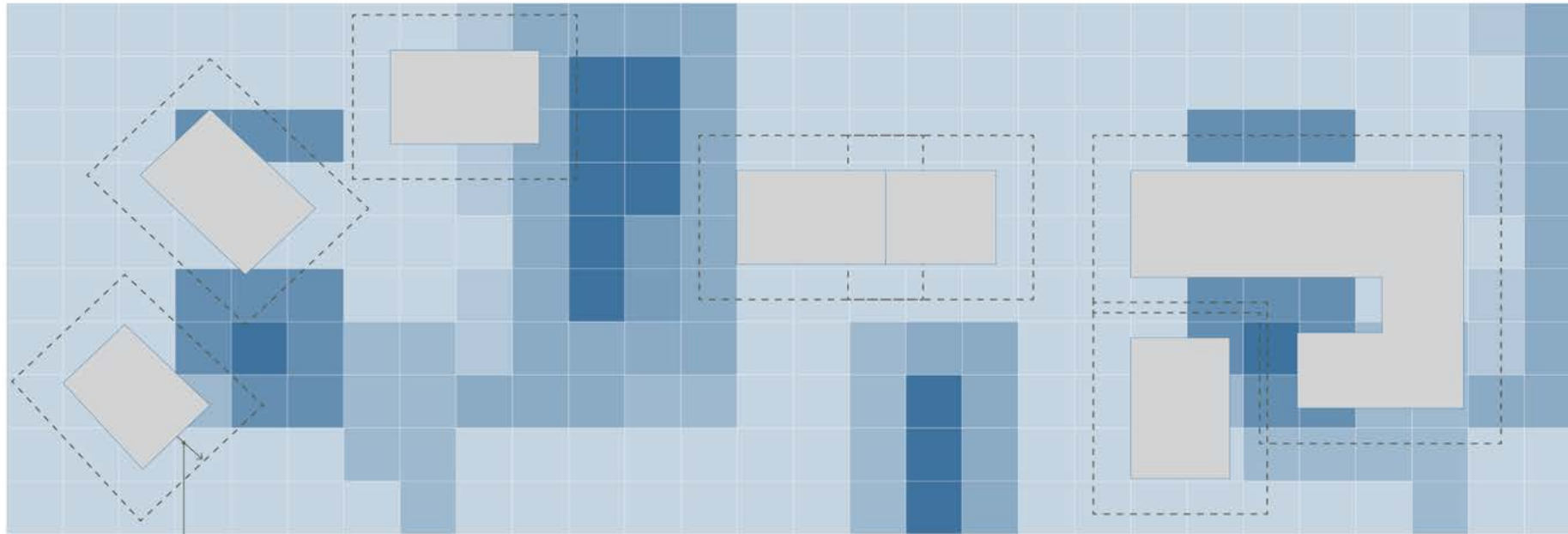


COMPONENT D

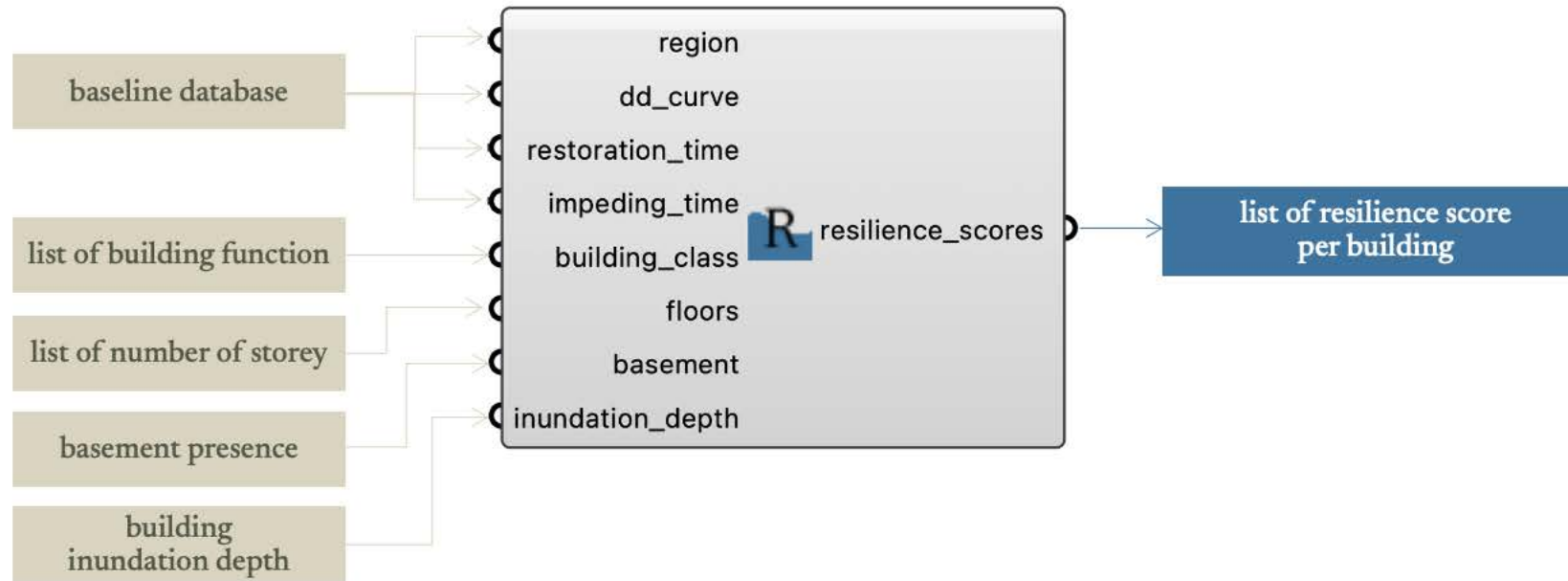




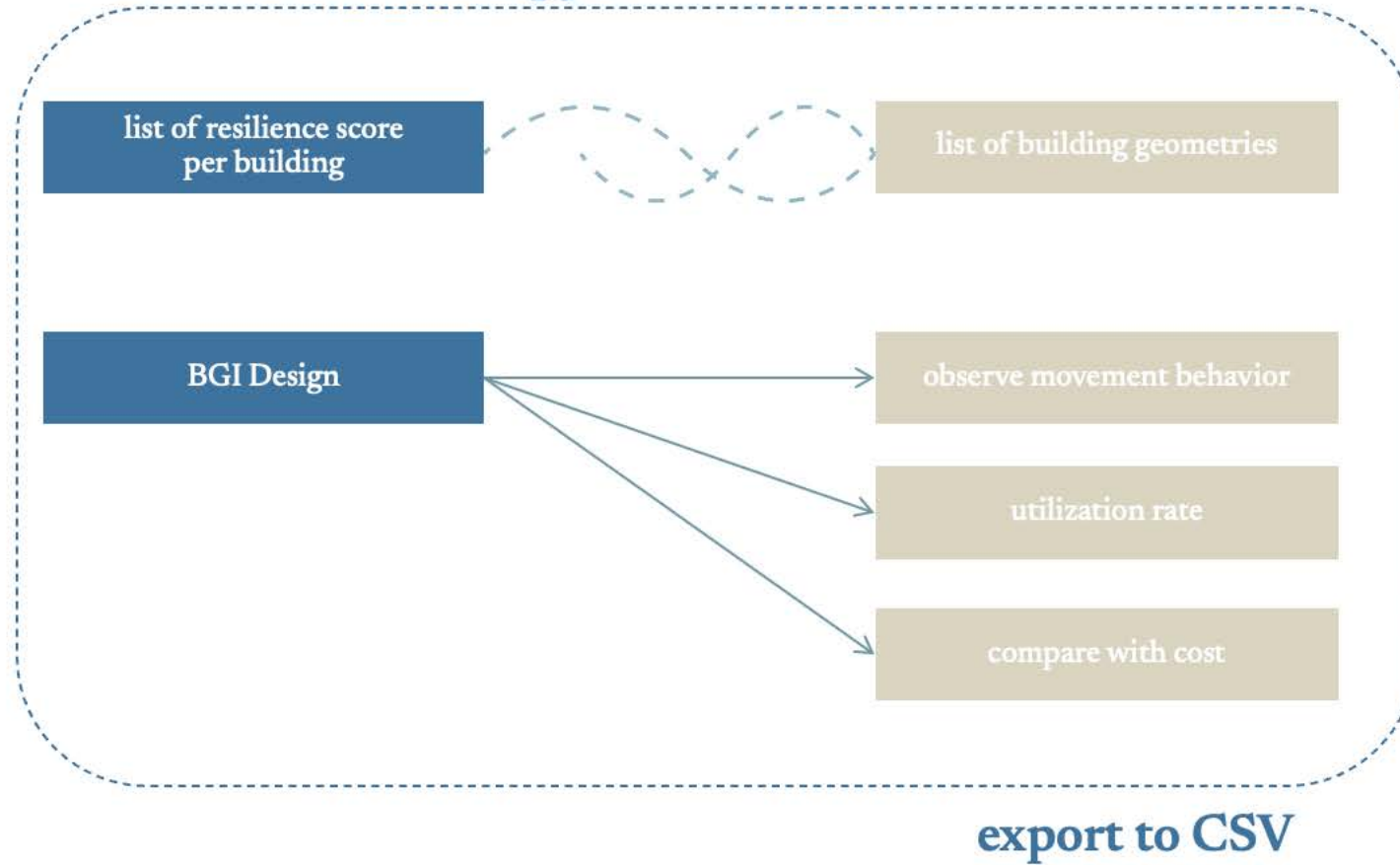
From Flood Depth Values to Building Inundation Depth



Offset Boundary
an be adjusted by the user through number slider



observe in Grasshopper



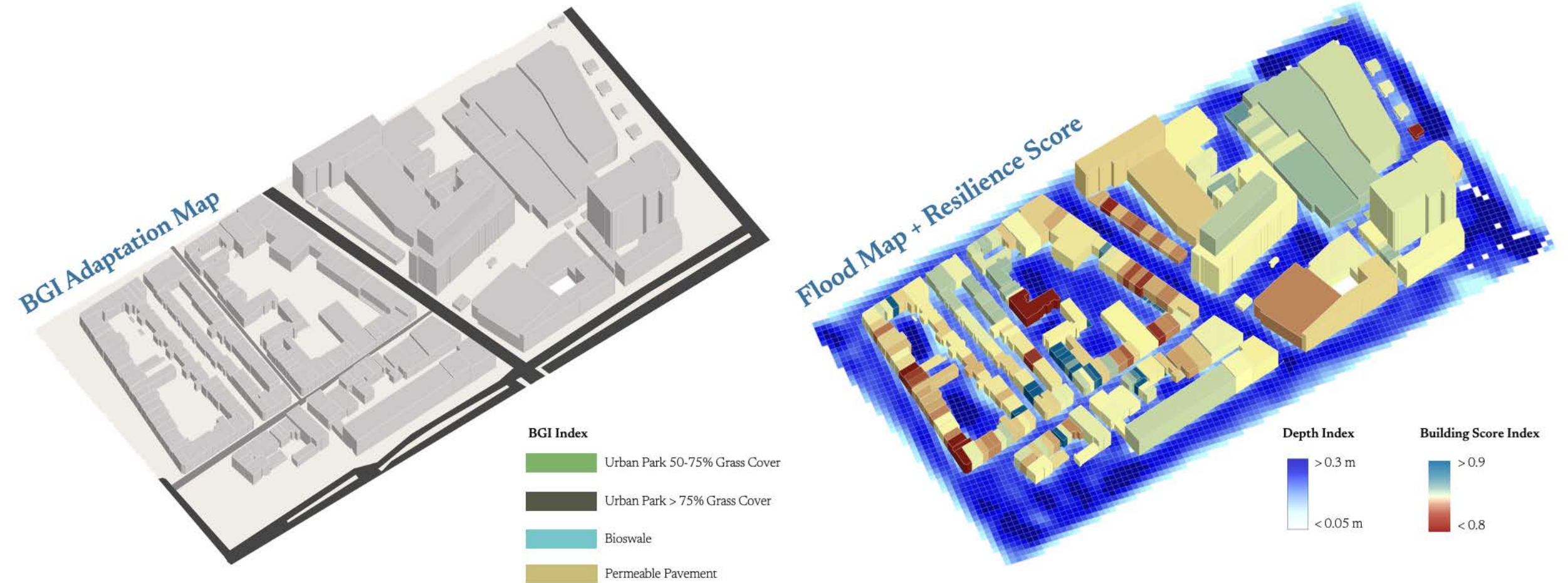
NEW GAME





Case Study: Lijnbaan Rotterdam

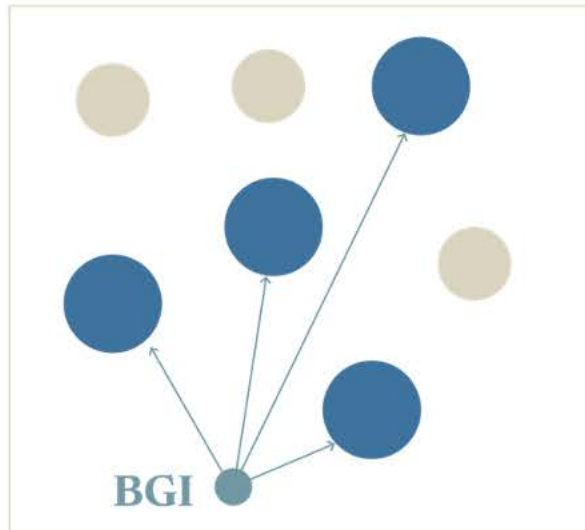
No BGI Adaptation



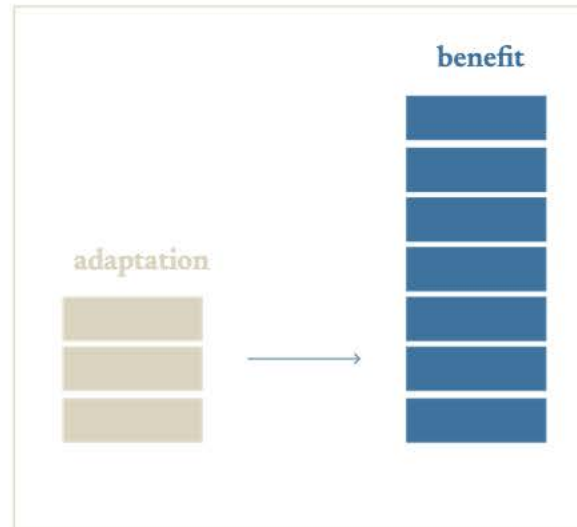
PAUSE



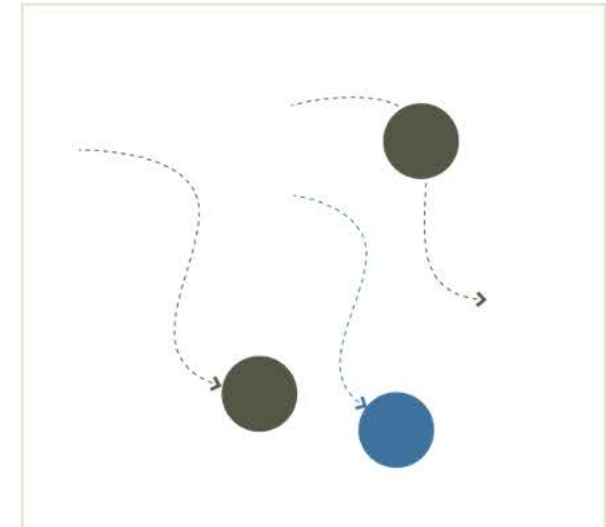
What Can the Workflow Reveal?



strategic spatial
configuration insight



prioritization & investment
insight

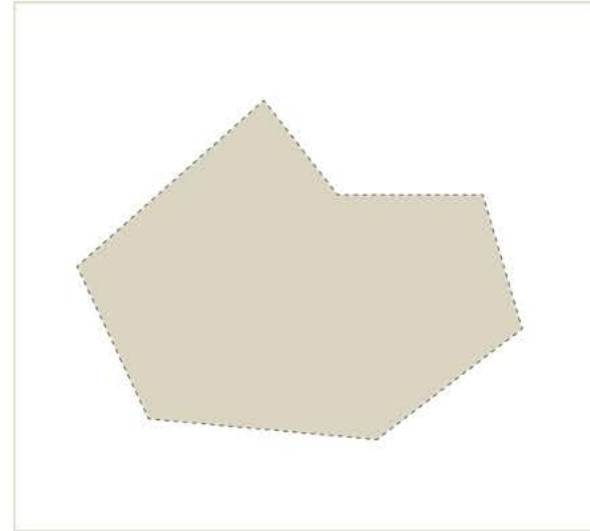


using water-behaviour insight
for strategic placement

Key Workflow Limitations



no pluvial flooding specific
resilience assessment yet

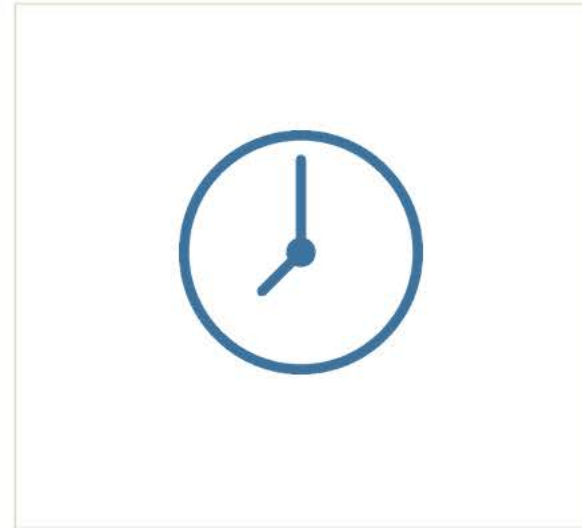


boundary bias

Future Work



incorporate pluvial flood
specific assessment when available

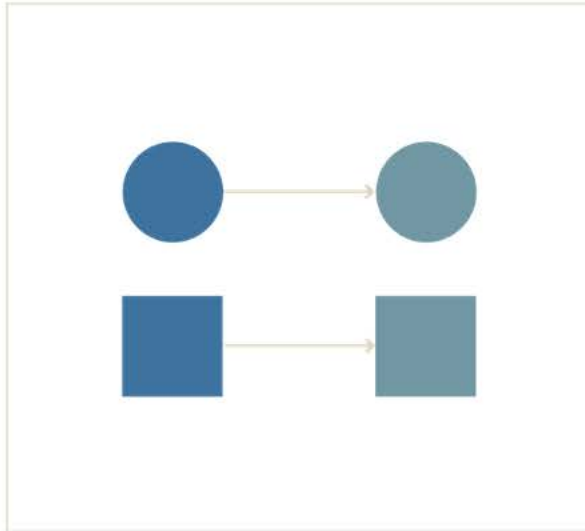


incorporate temporal dimension
aspect of BGI

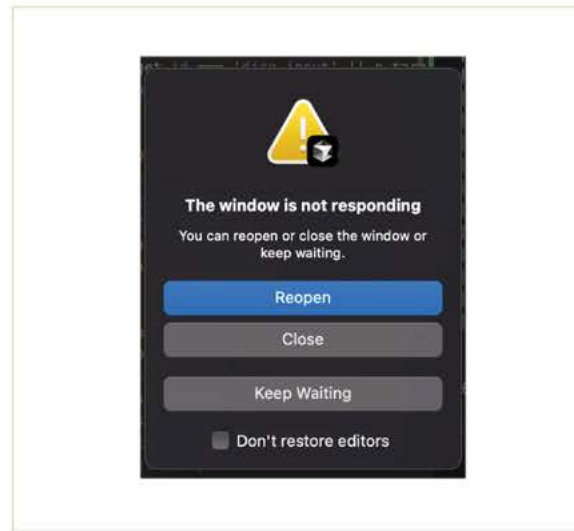


**Hi, I want to use your workflow!
Any suggestion on what to consider?**

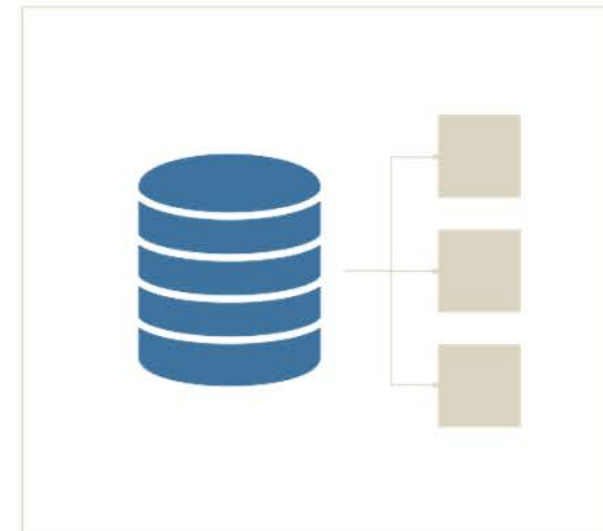
More Challenges



output quality depends on input



computational load

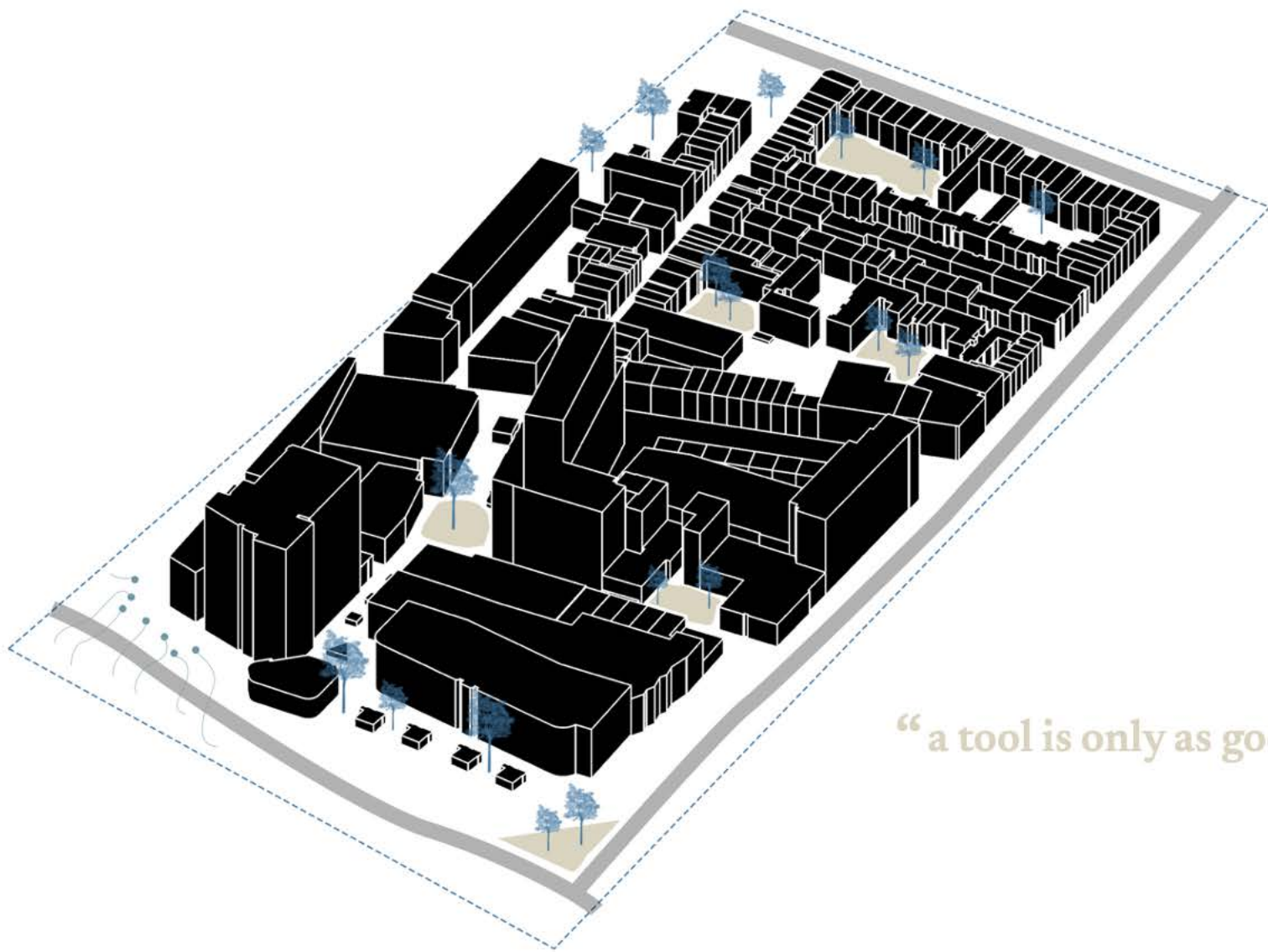


availability of building data

Food for Thoughts

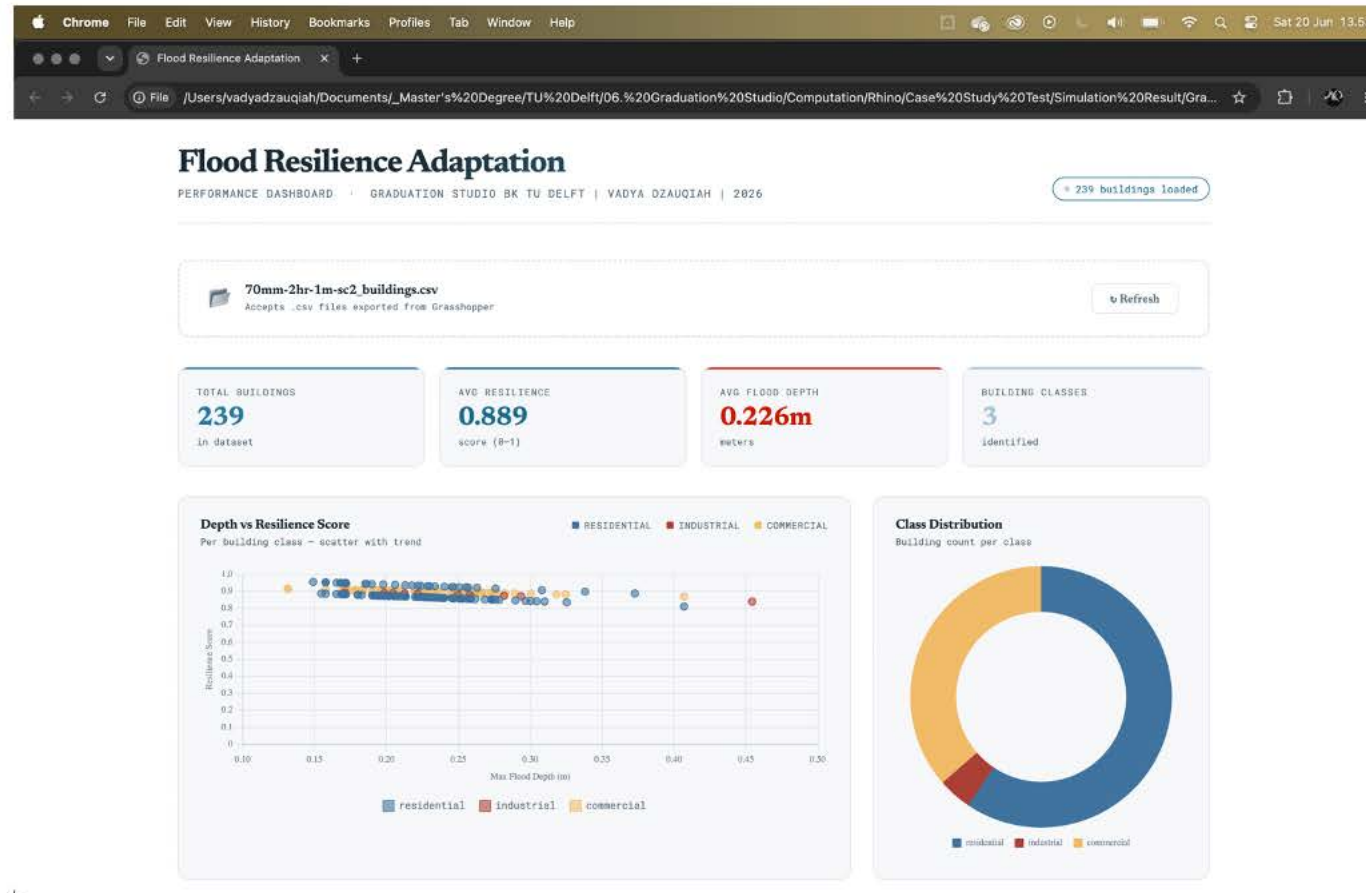


data driven design
is a luxury

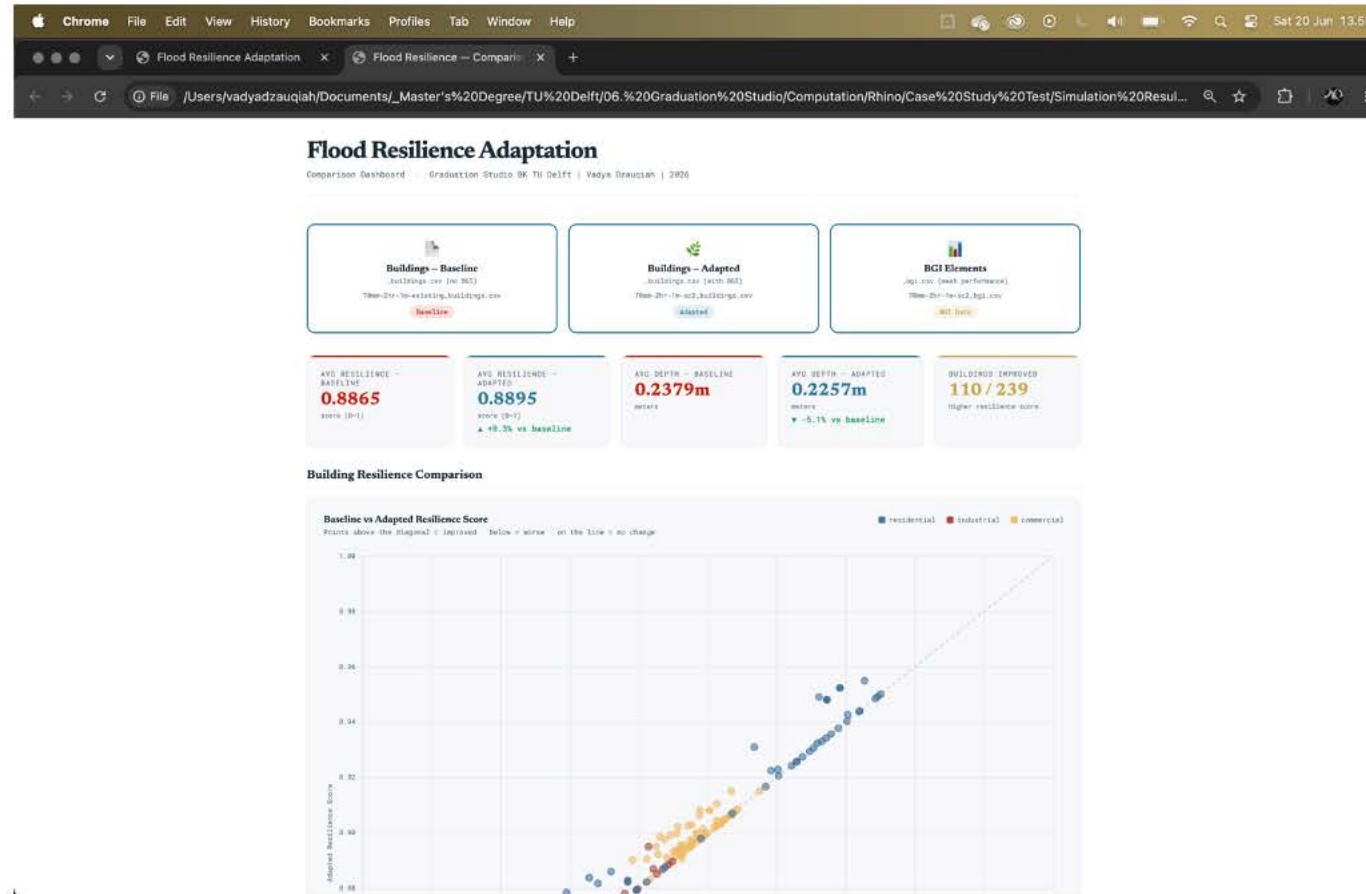


“a tool is only as good as the hands that wield it.”

HTML Companion for Data Visualization



HTML Companion for Data Visualization





The Grasshopper custom components, workflow examples, and supporting scripts developed for this thesis are available soon in the project repository.

github.com/vadyadzauqiah/Grounded-Resilience