

DAR

courtyards and chinampas for
urban water management in Dar es Salaam



EFL STICHTING

TU Delft BK Bouwkunde | Urbanism | TU Delft | Universiteitsfonds

P5 Presentation I TU Delft I Faculty of Architecture and the Built Environment I Department of Urbanism




rapid urbanisation

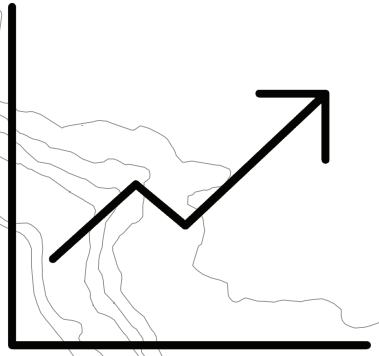



water

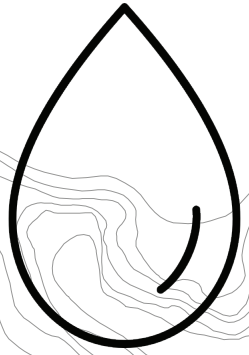



no coping capacity

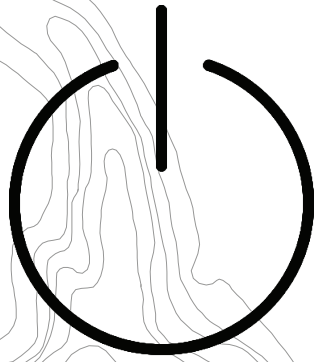
▶ main problems



rapid urbanisation

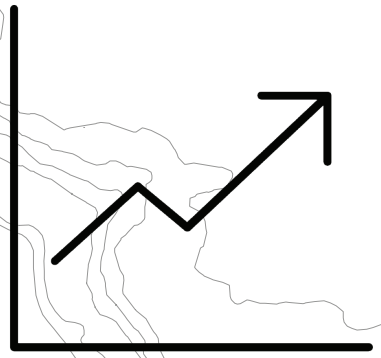


water

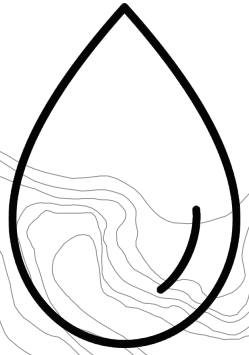


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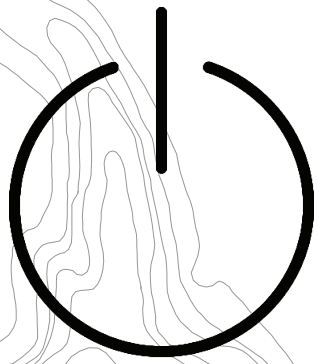
▶ main problems



8%

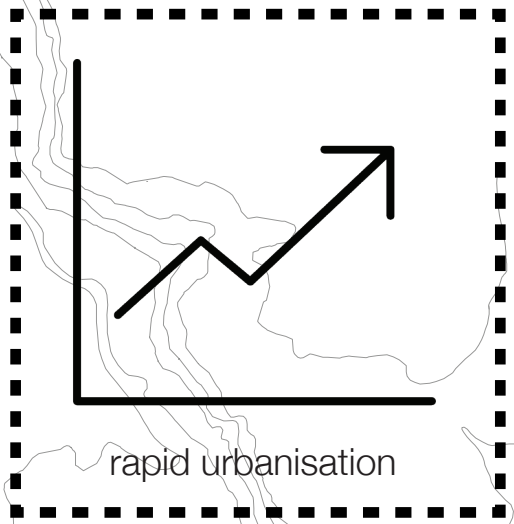


43993 houses

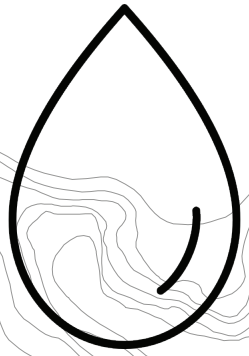


70%

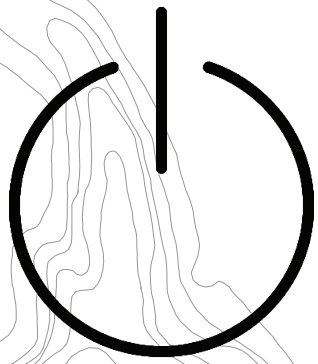
▶ main problems



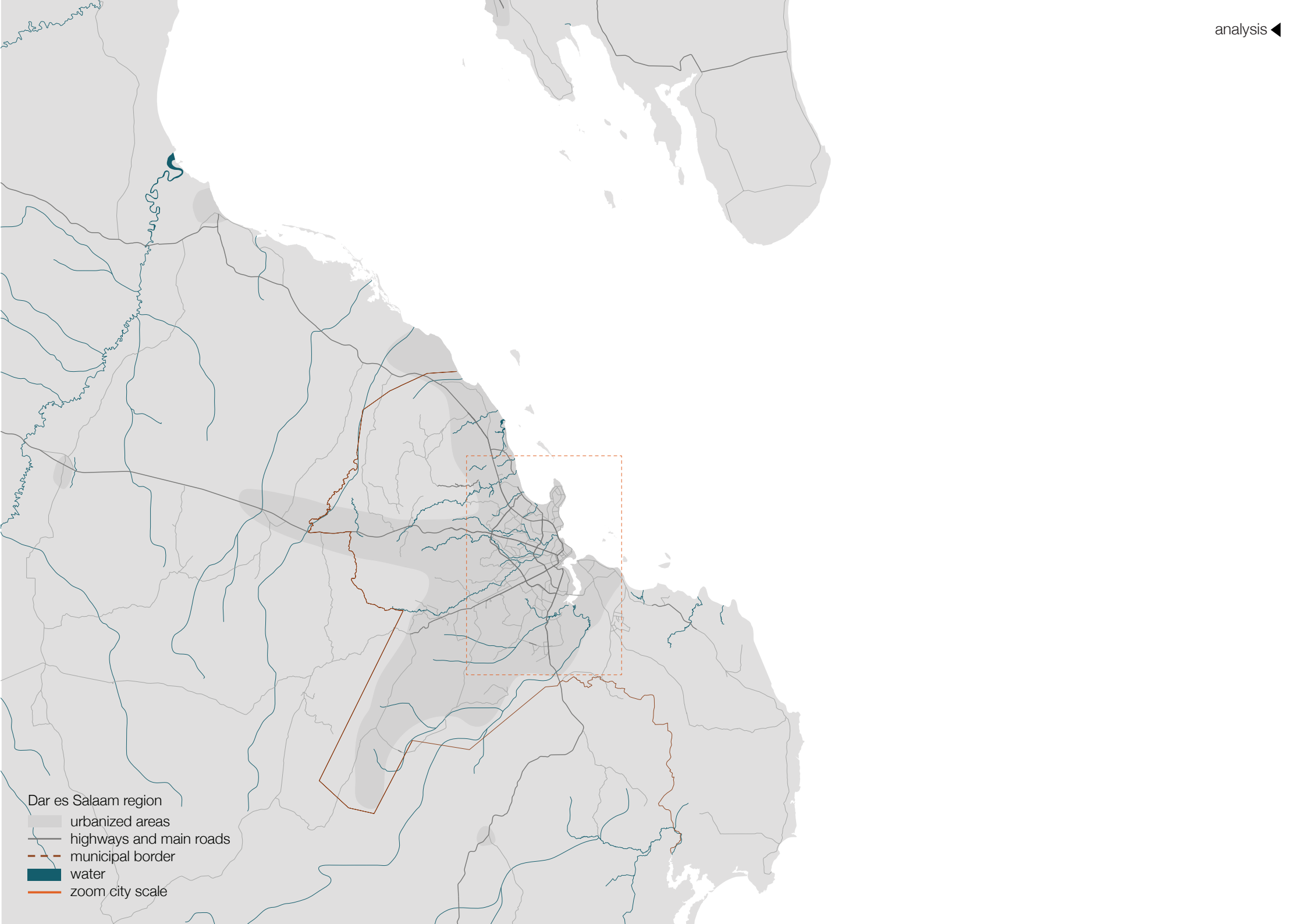
rapid urbanisation



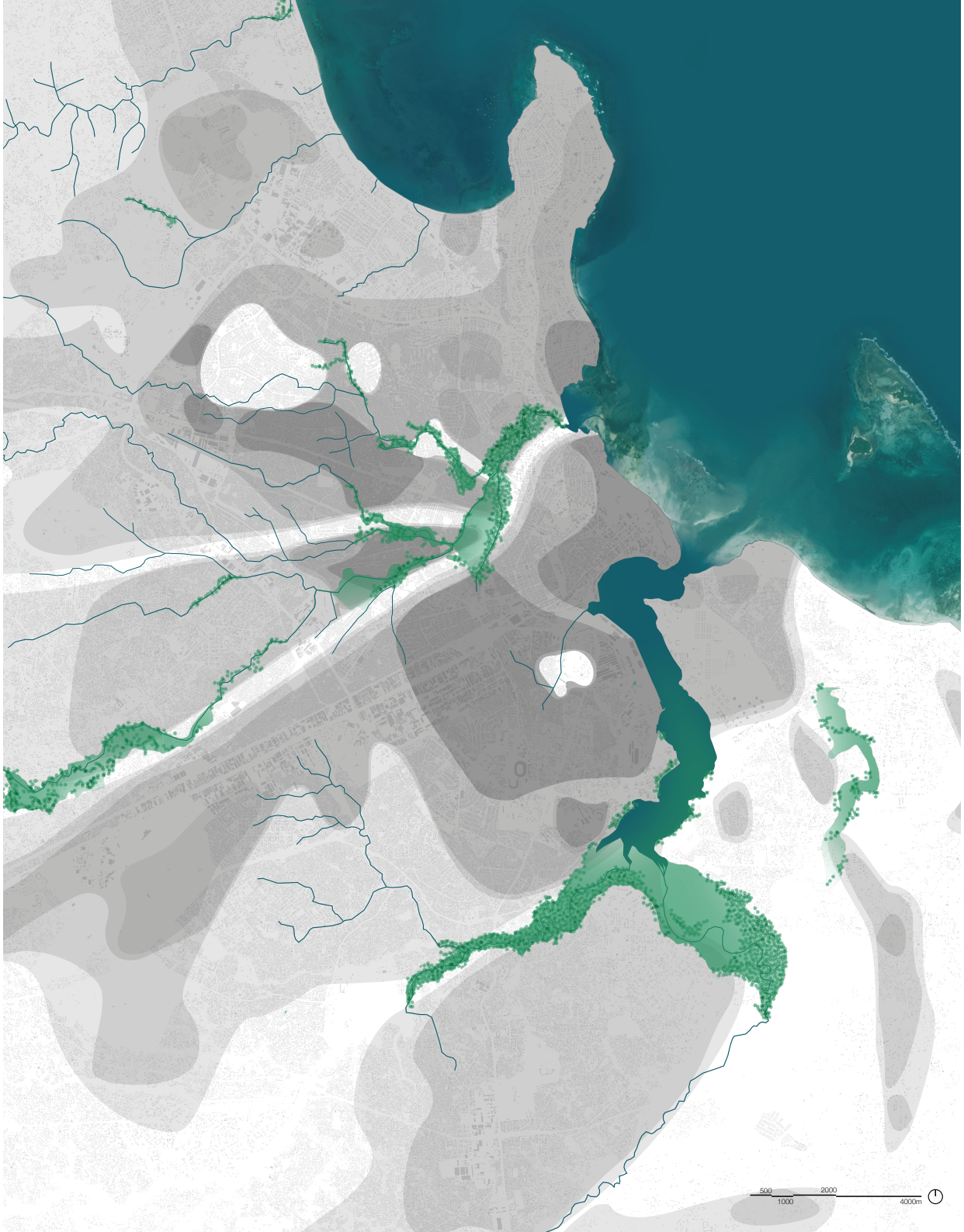
water



no coping capacity


Dar es Salaam region
urbanized areas
highways and main roads
municipal border
water
zoom city scale

▶ analysis
rapid urbanisation



Urban Growth
- blue structure
- green structure
- green vegetation
- 1997
- 1992
- 1978
- 1967
- 1945

▶ analysis
rapid urbanisation



Informal Settlement 1982
- blue structure
- green structure
- green vegetation
- informal housing

500 1000 2000 4000m

▶ analysis
rapid urbanisation



Informal Settlement 1992
- blue structure
- green structure
- green vegetation
- informal housing

500 1000 2000 4000m

▶ analysis
rapid urbanisation



Informal Settlement 1998
blue structure
green structure
green vegetation
informal housing

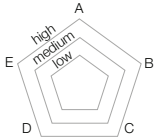
500 1000 2000 4000m

▶ analysis
rapid urbanisation

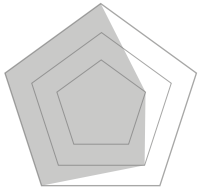


Informal Settlement 2002
- blue structure
- green structure
- green vegetation
- informal housing



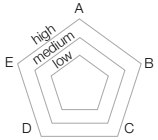


A - street infrastructure
B - green structure
C - sewage
D - fresh water
E - proximity

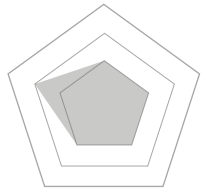


4 - city centre



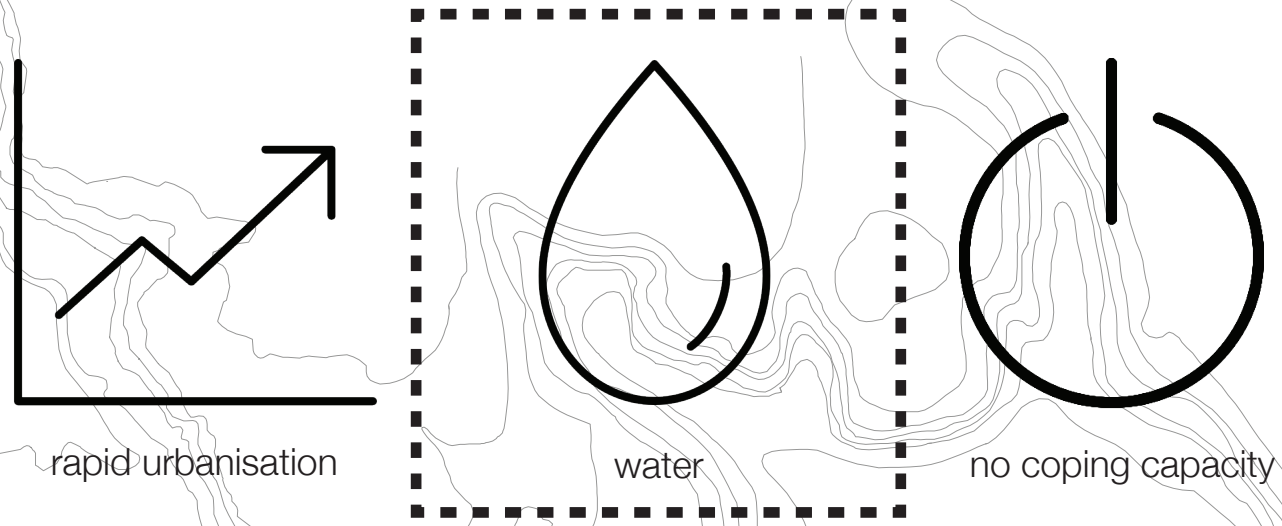


A - street infrastructure
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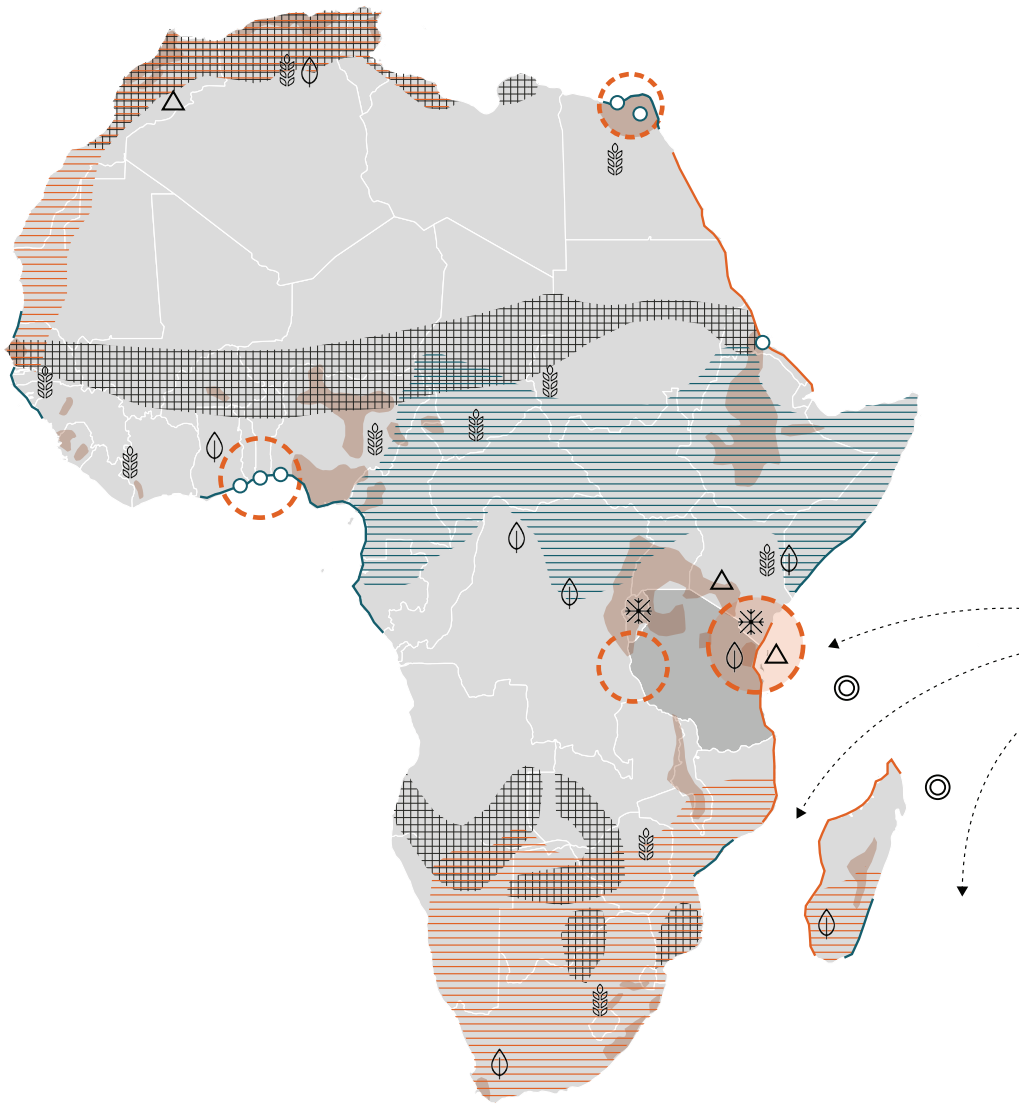


5 - informal settlement

▶ main problems

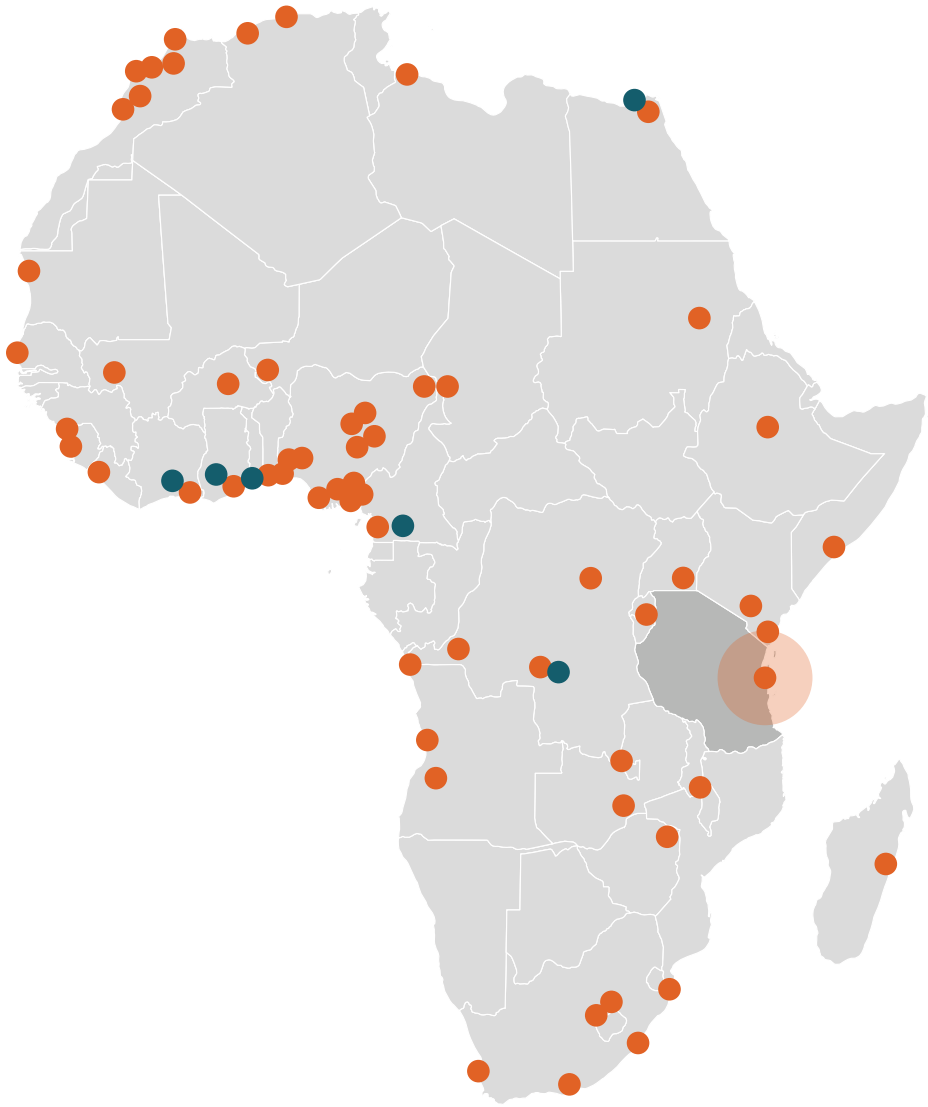




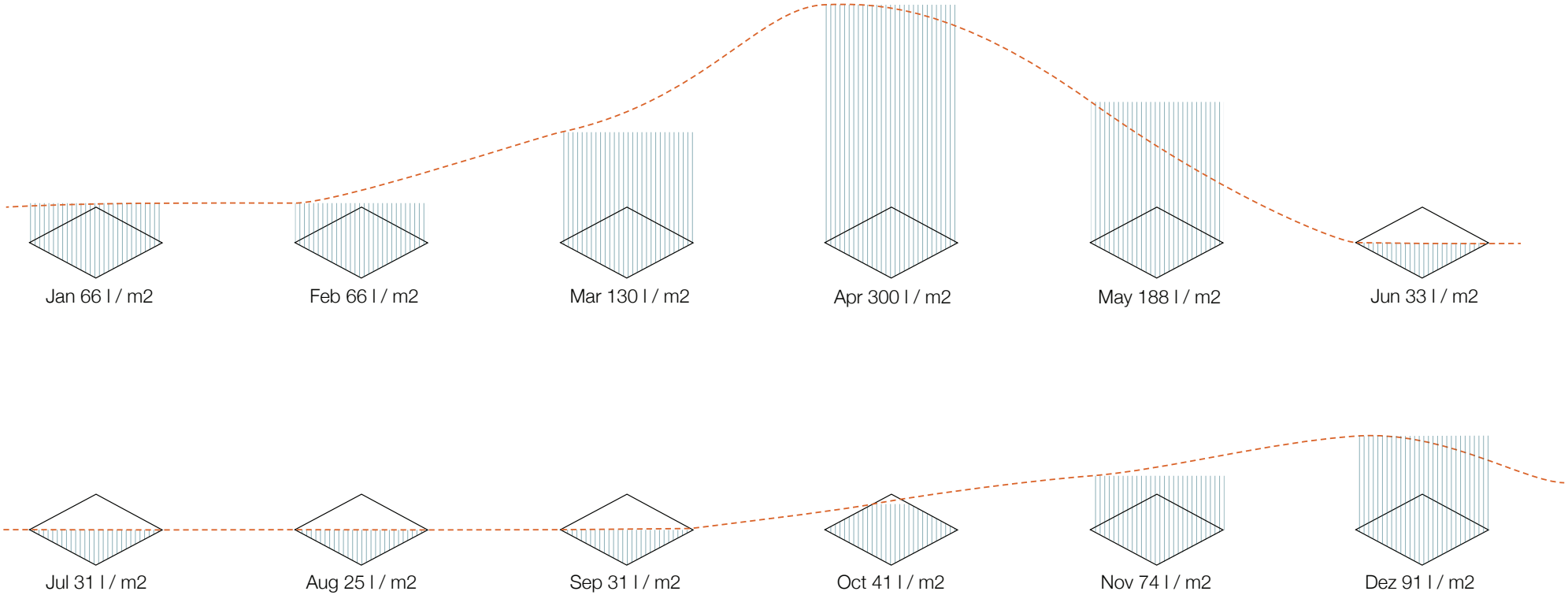


Climate Change Impacts

- changes in ecosystem
- melting of glaciers
- agricultural changes
- increasing cyclones
- impacts - mountain region
- climate change hotspots
- risk of desertification
- more precipitation
- less precipitation
- risk of desertification
- coral bleaching
- sea level rise - cities



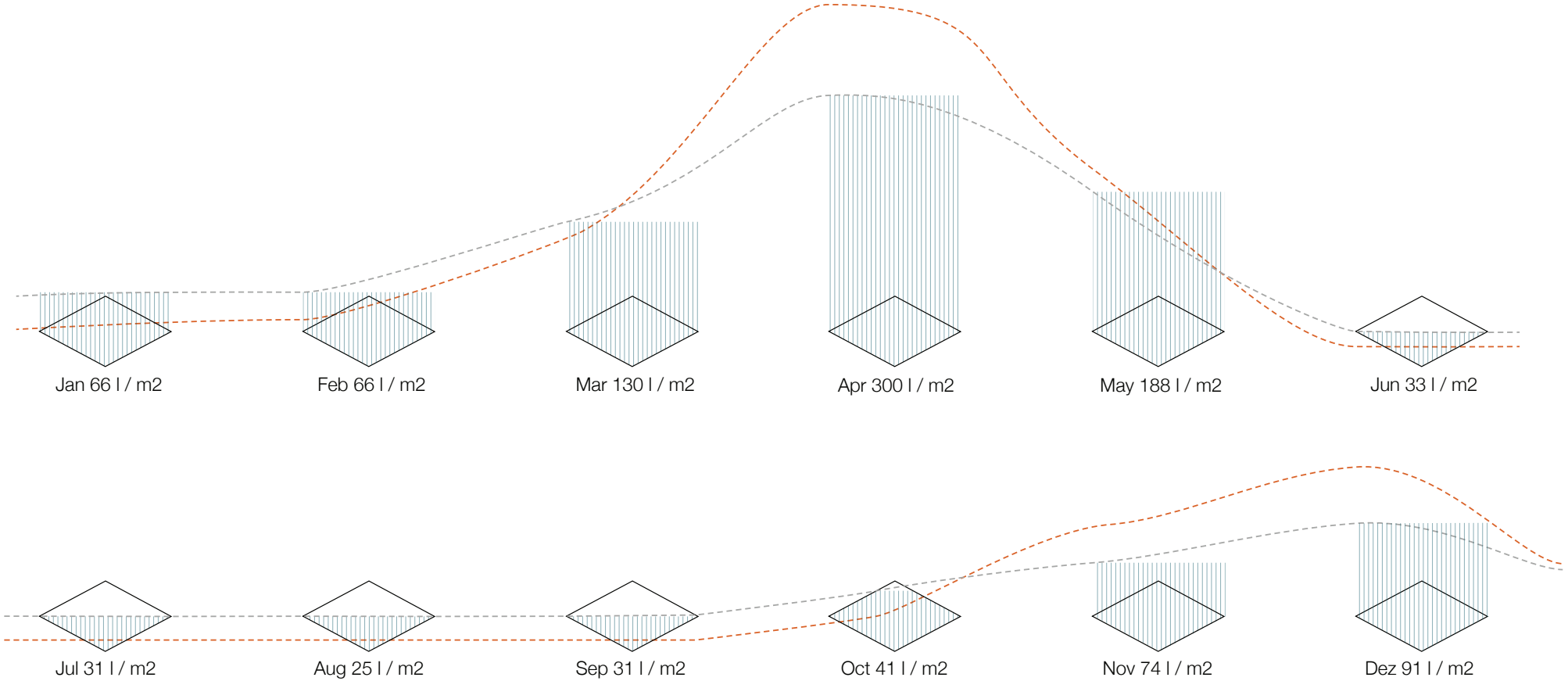
Hazards in African cities
- at least one hazard
- no hazard



Monthly rainfall Dar es Salaam

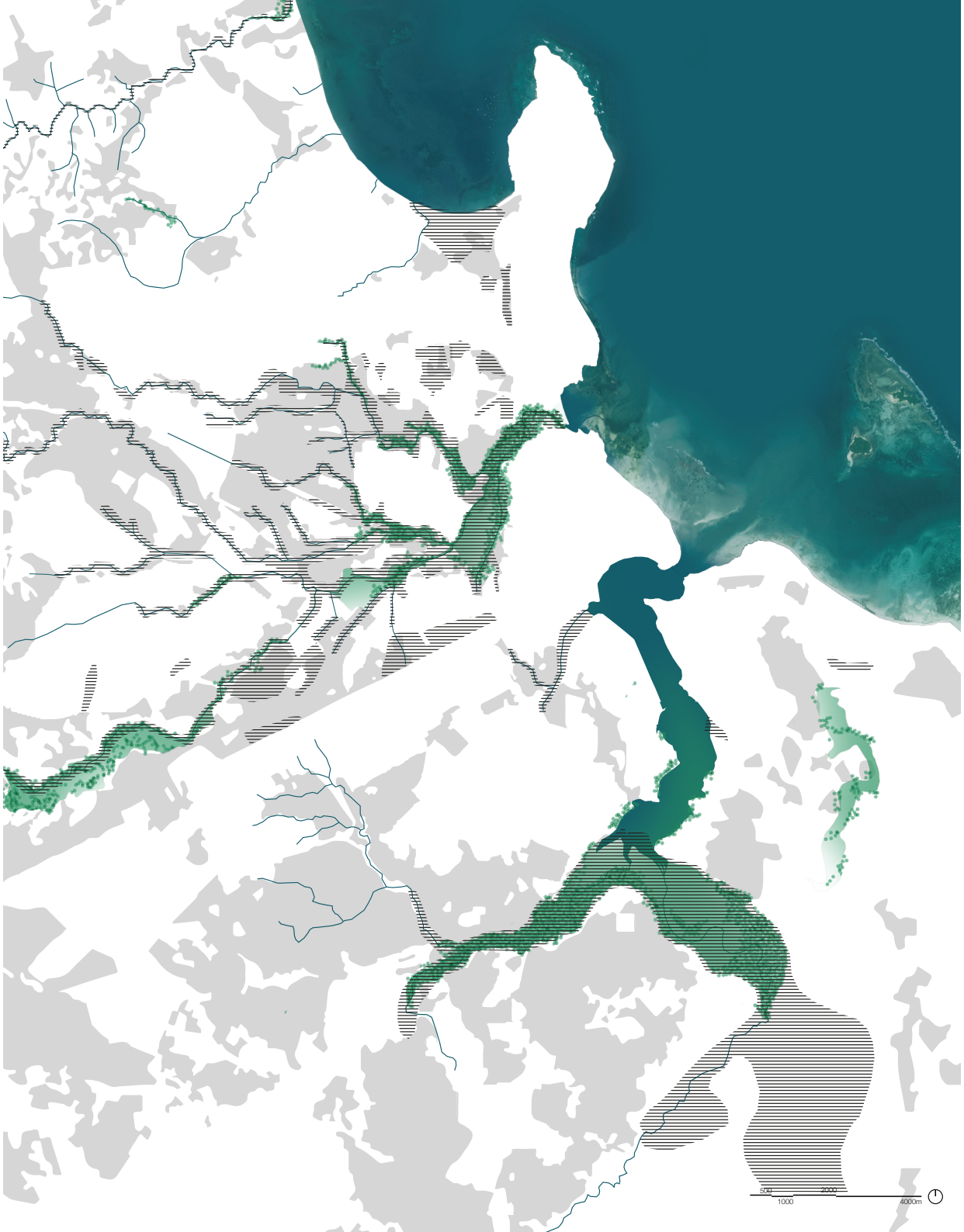
20 liter

rainfall/m2



Monthly rainfall Dar es Salaam
20 liter
rainfall/m2

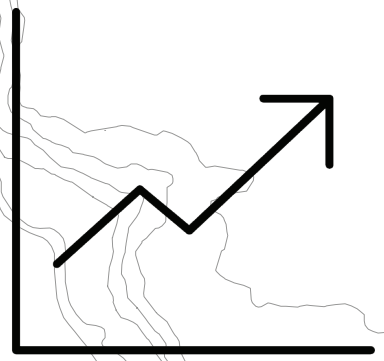
▶ analysis
water



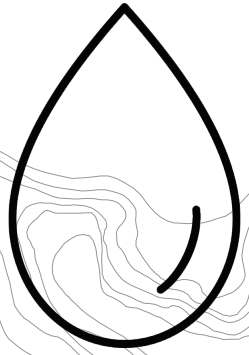
Flood Risk/Informal Settlement

- blue structure
- green structure
- green vegetation
- flood risk
- informal settlement

▶ main problems



rapid urbanisation

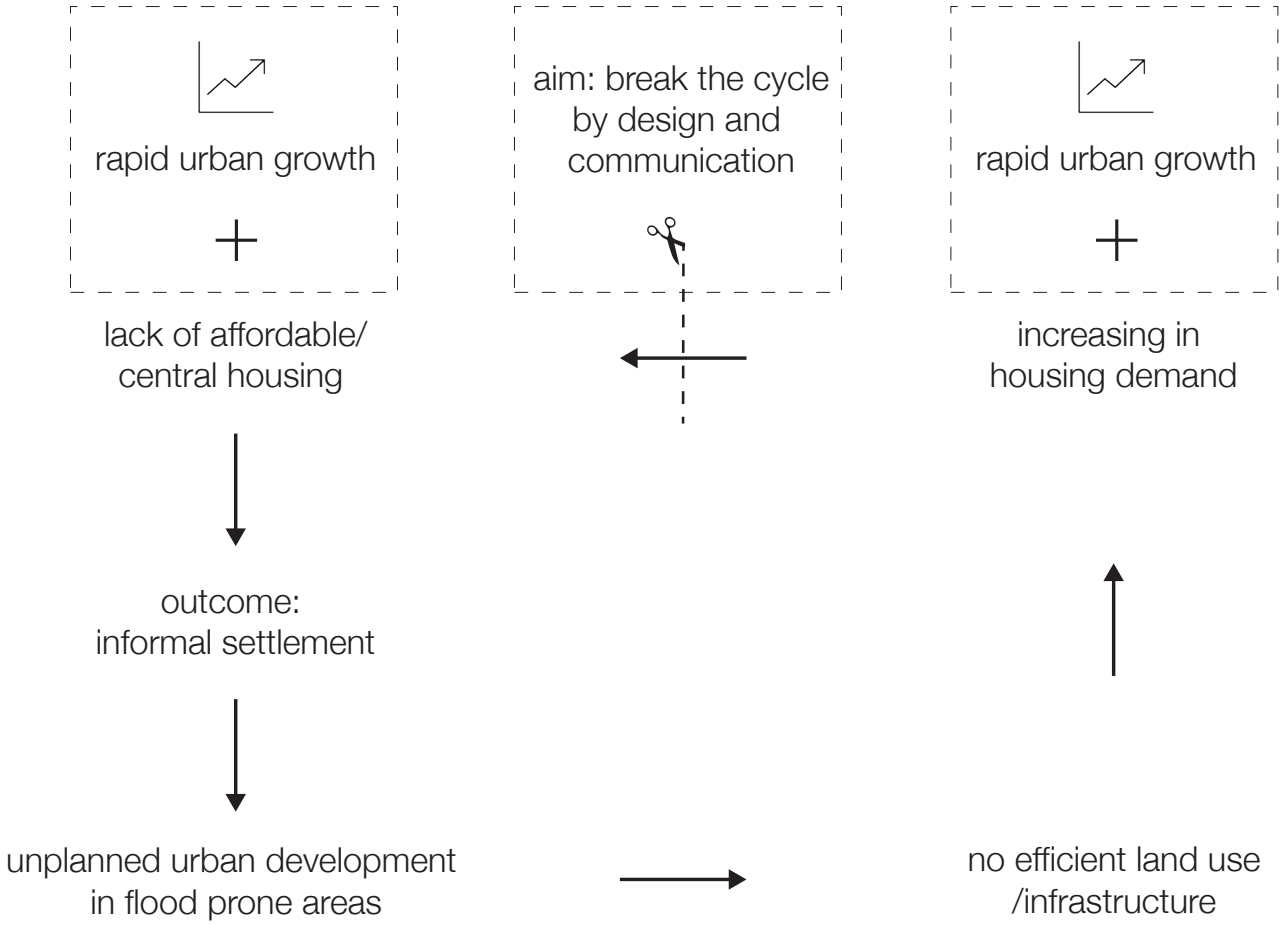


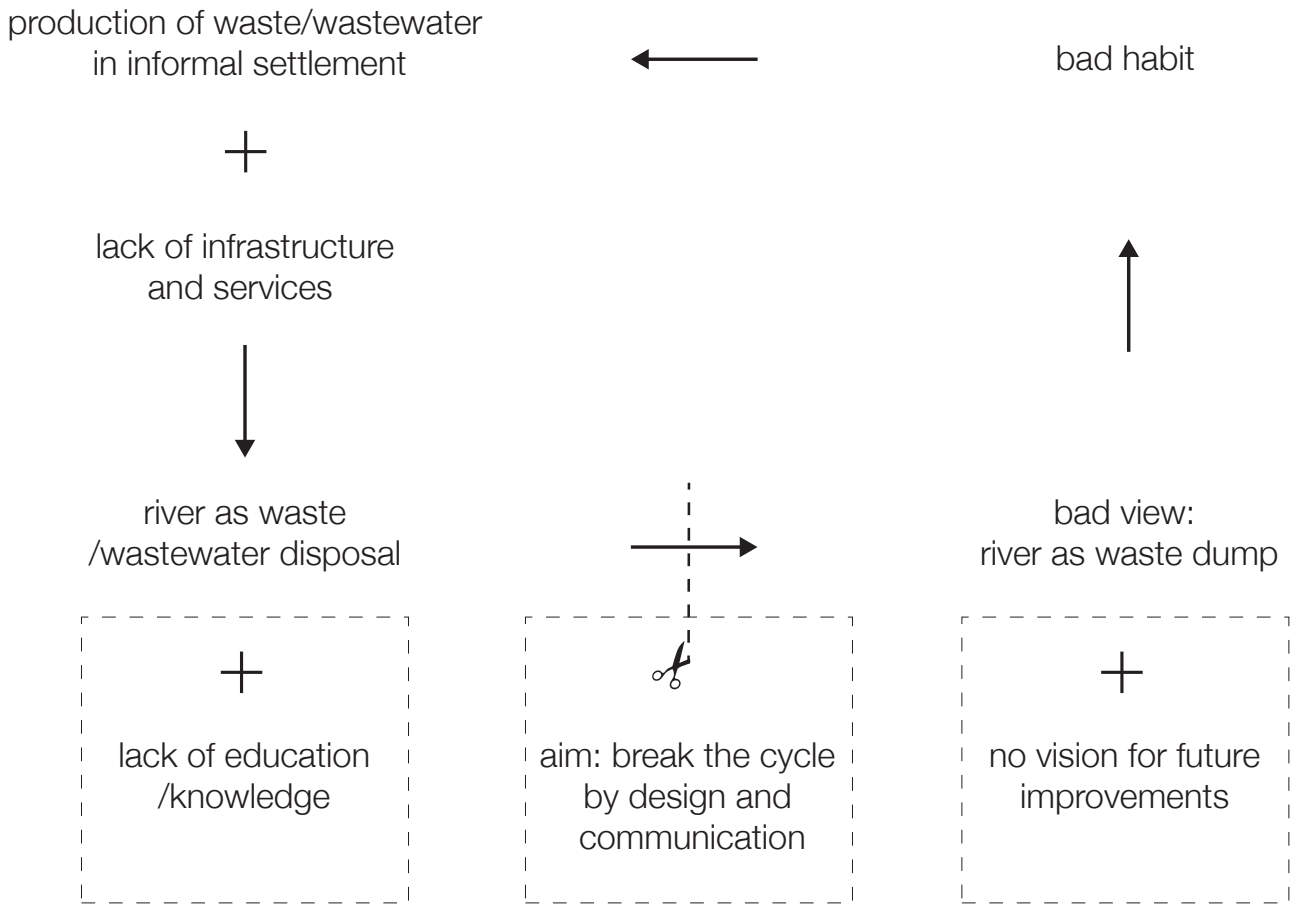
water



no coping capacity

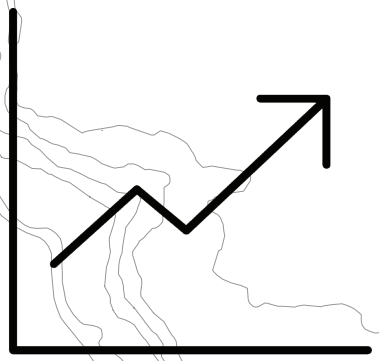



rapid urban growth
+
aim: break the cycle by design and communication
rapid urban growth
+
lack of affordable/ central housing
increasing in housing demand
outcome: informal settlement
unplanned urban development in flood prone areas
no efficient land use /infrastructure

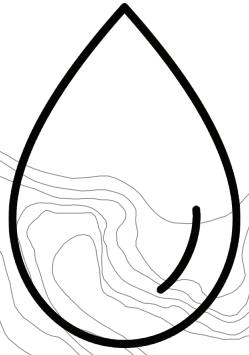

production of waste/wastewater
in informal settlement
+
lack of infrastructure
and services
river as waste
/wastewater disposal
+
lack of education
/knowledge
aim: break the cycle
by design and
communication
bad habit
bad view:
river as waste dump
+
no vision for future
improvements



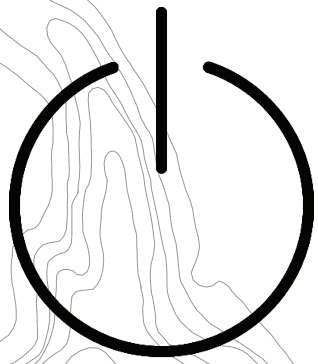
▶ main problems



rapid urbanisation

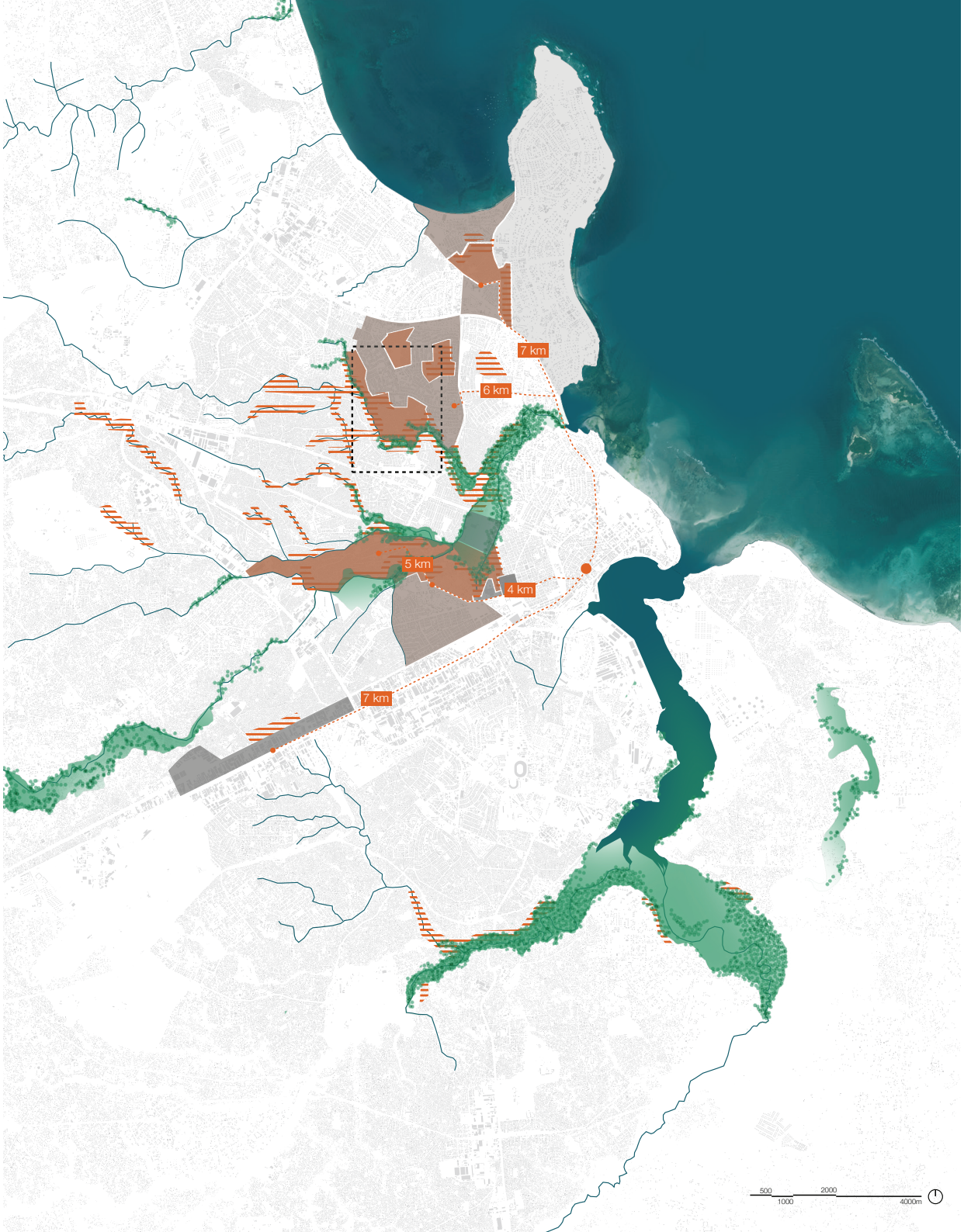


water



no coping capacity

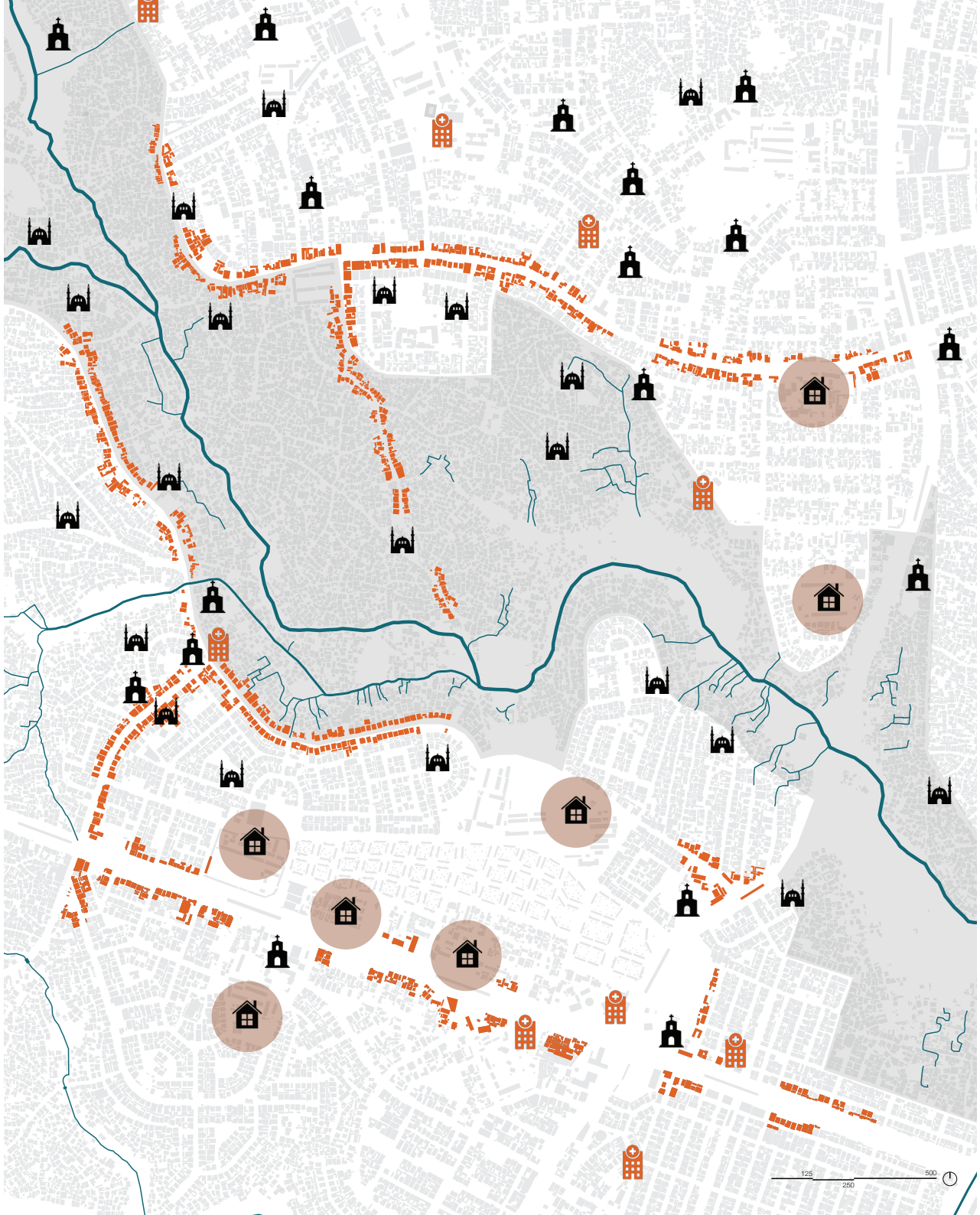
▶ location selection



Conclusion - design location

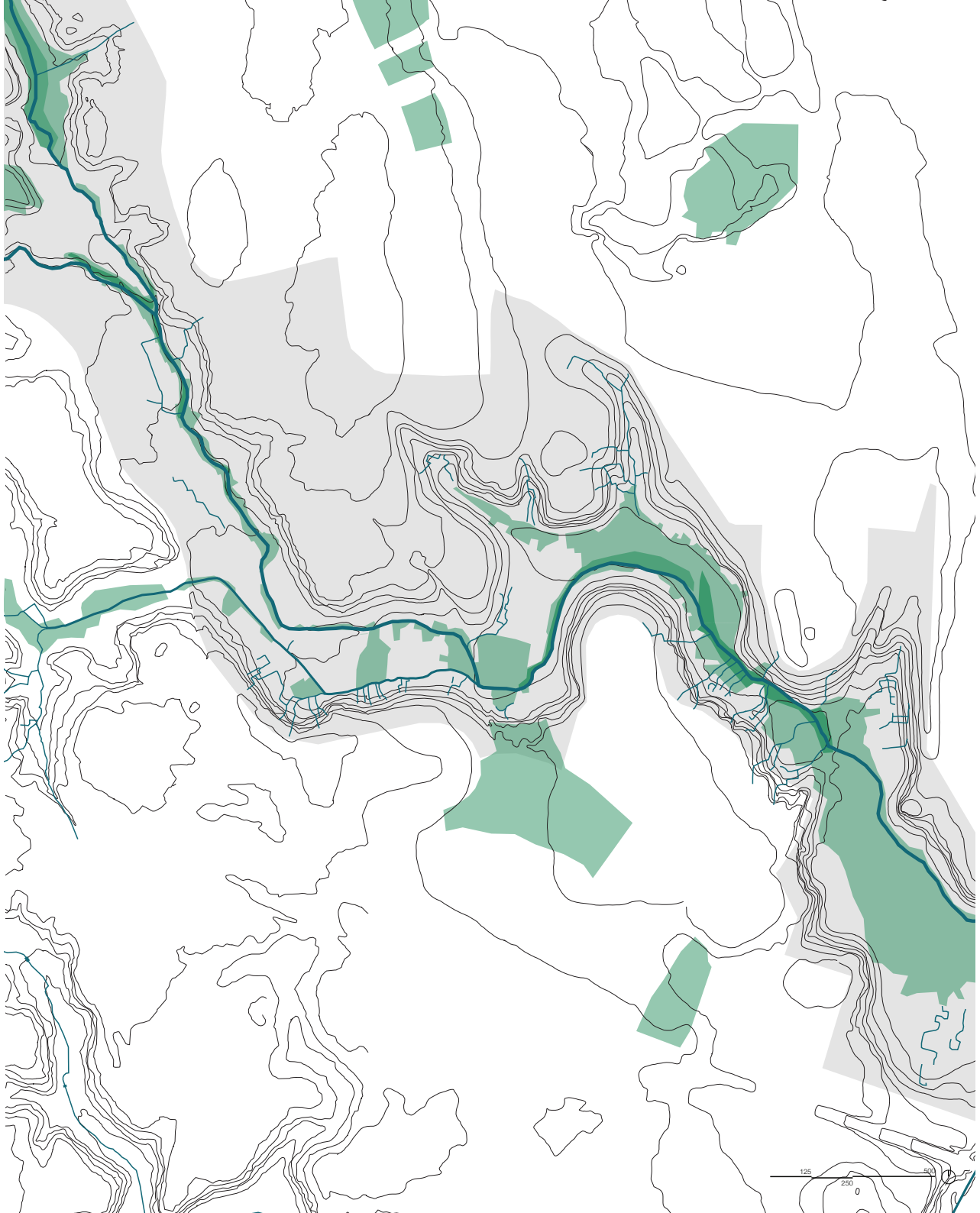
- blue structure
- green structure
- green vegetation
- informal settlement
- structured informal settlement
- city
- industry
- expat
- overlap informal settlement/ flood risk
- distance neighbourhood to city centre
- design location: Mwanan Yamala Makumbusho

▶ location analysis



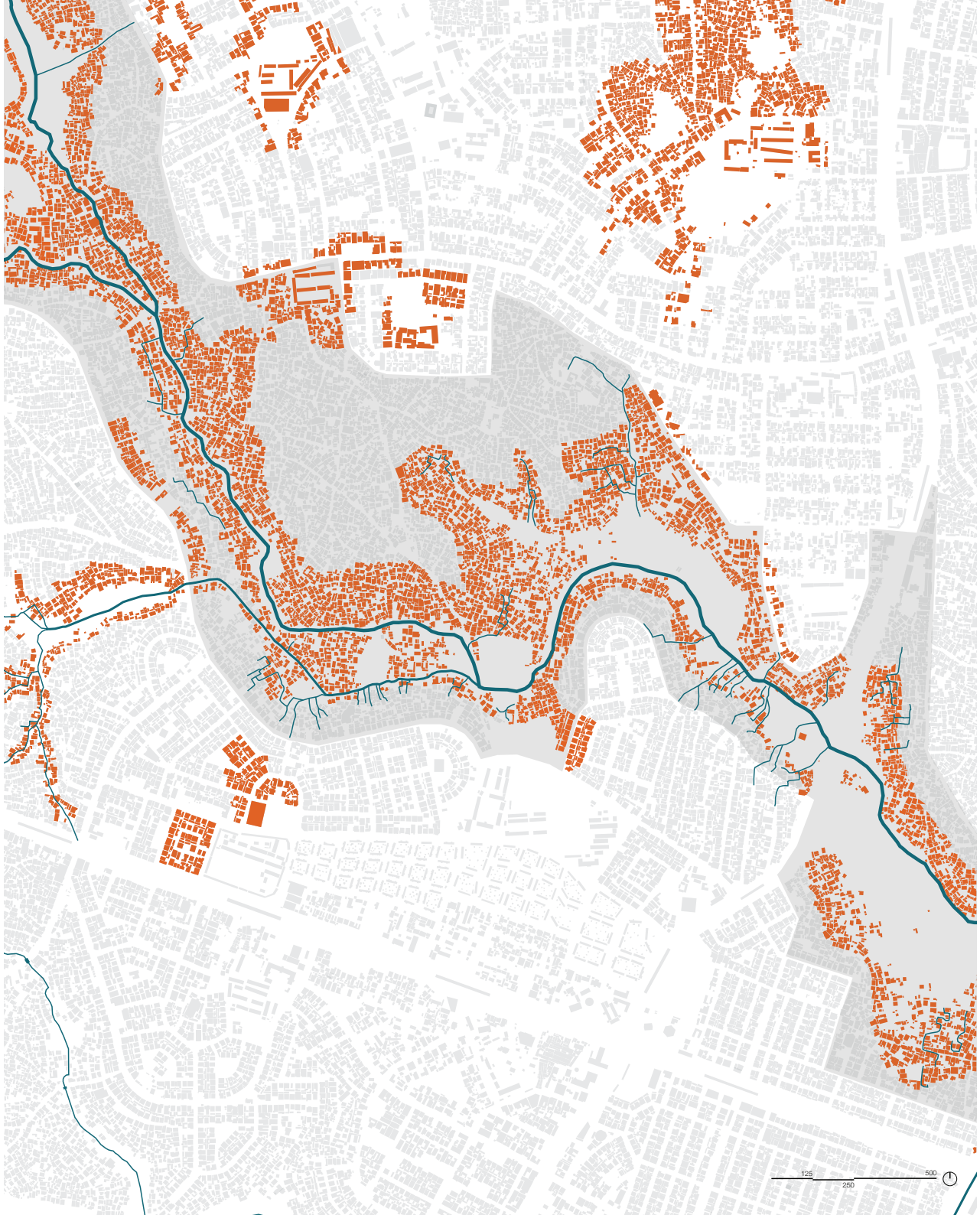
Functions
- hospital
- church
- mosque
- school
- 125m radius
- blue structure
- commercial streets
- informal settlement

▶ location analysis



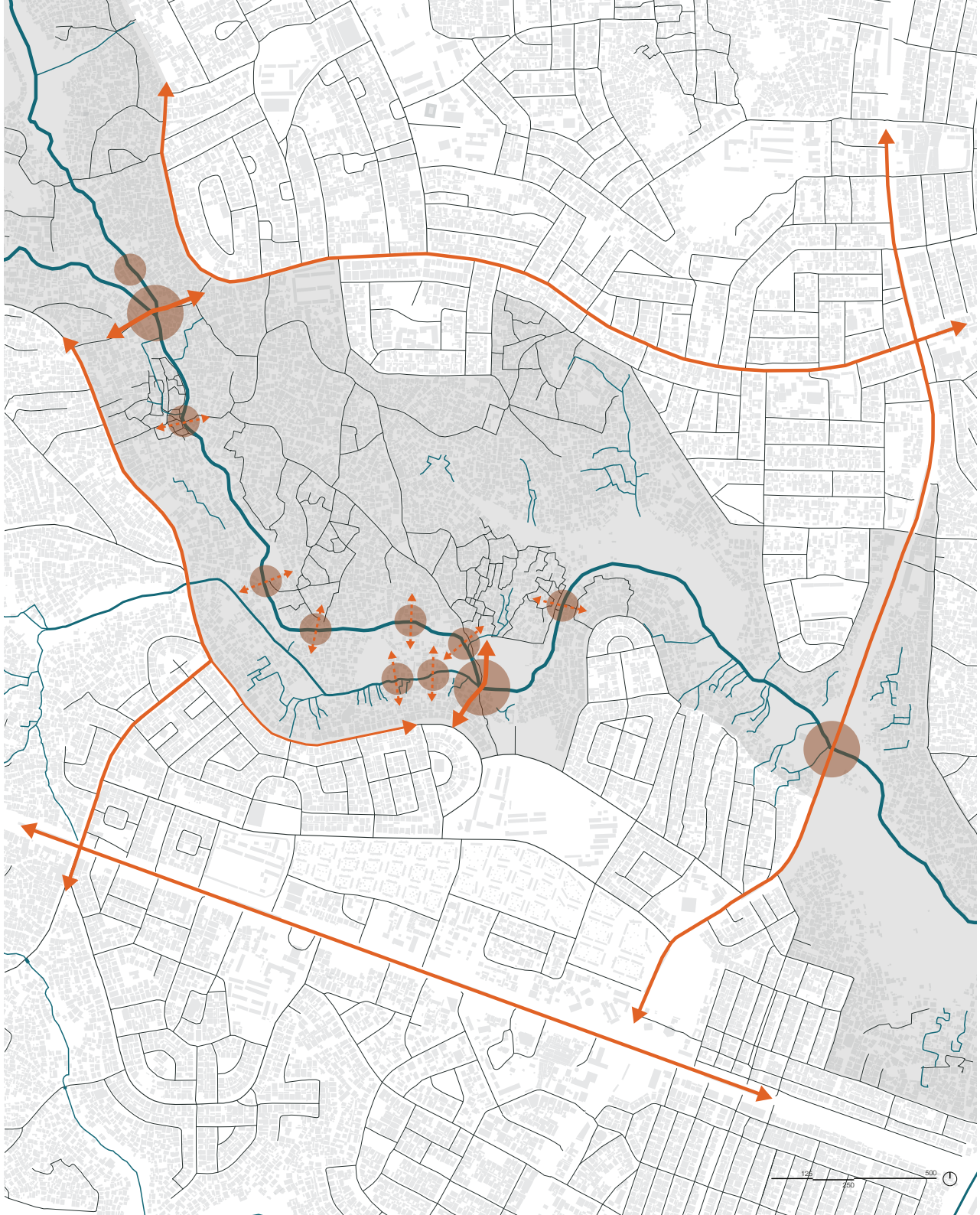
Elevation map
- blue structure
- green structure
- informal settlement
- 2m elevation line

▶ location analysis



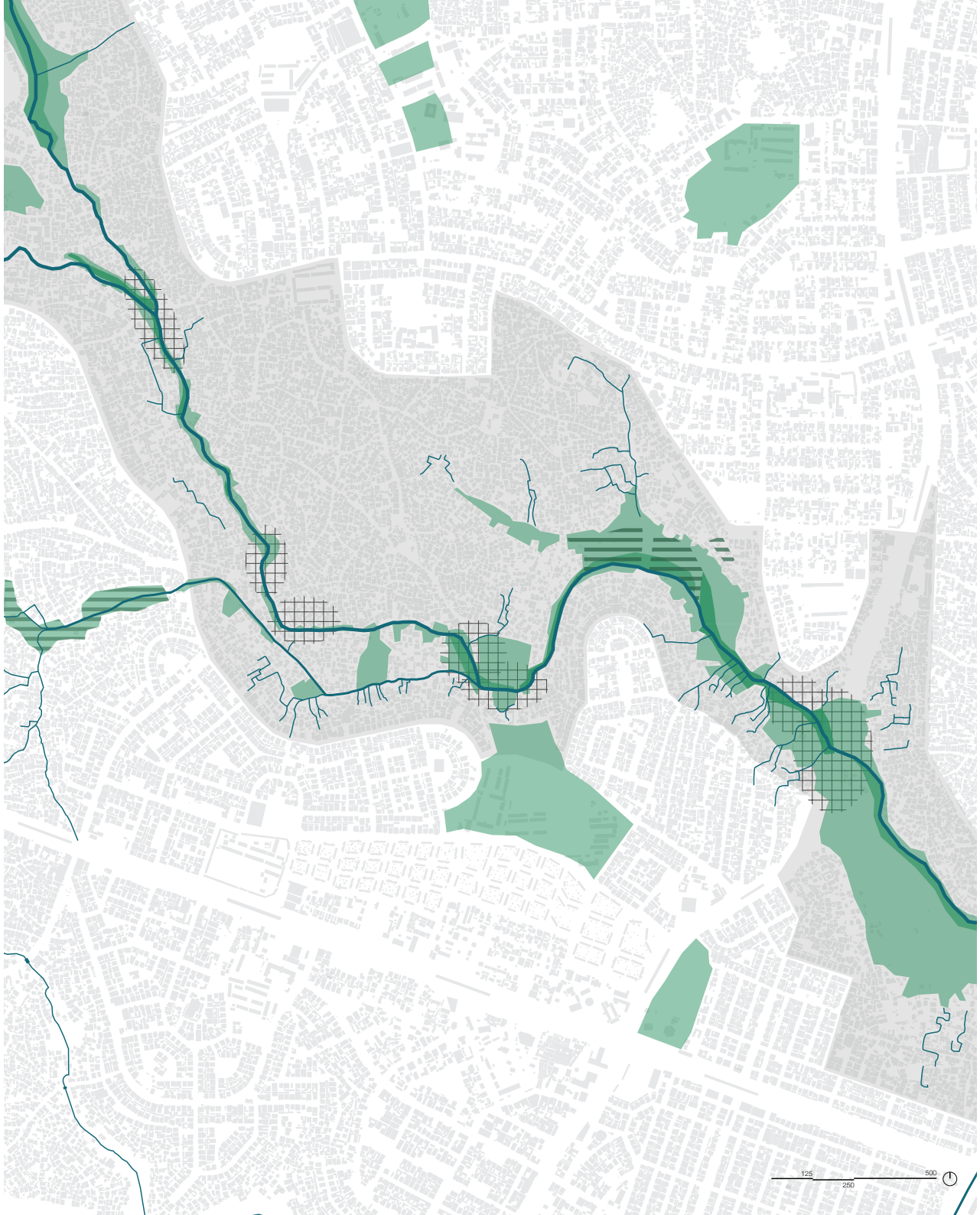
Flood risk
- blue structure
- informal settlemen
- flood risk

▶ location analysis



Connectivity
- bridges
- accessible by foot
- accessible by car
- main infrastructure
- streets
- informal settlement
- blue structure

▶ location analysis



Green Structure

- blue structure
- informal settlement
- green structure
- agriculture
- waste

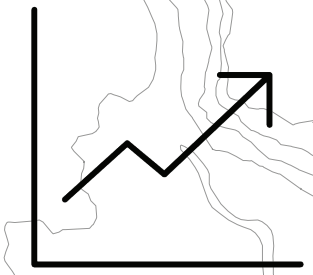



connectivity

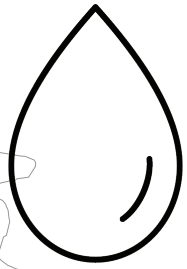



waste

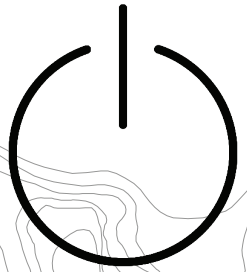
▶ main problems



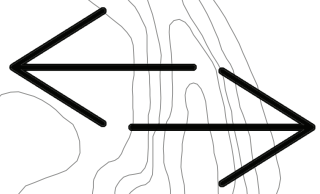
rapid urbanisation



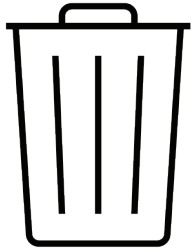
water



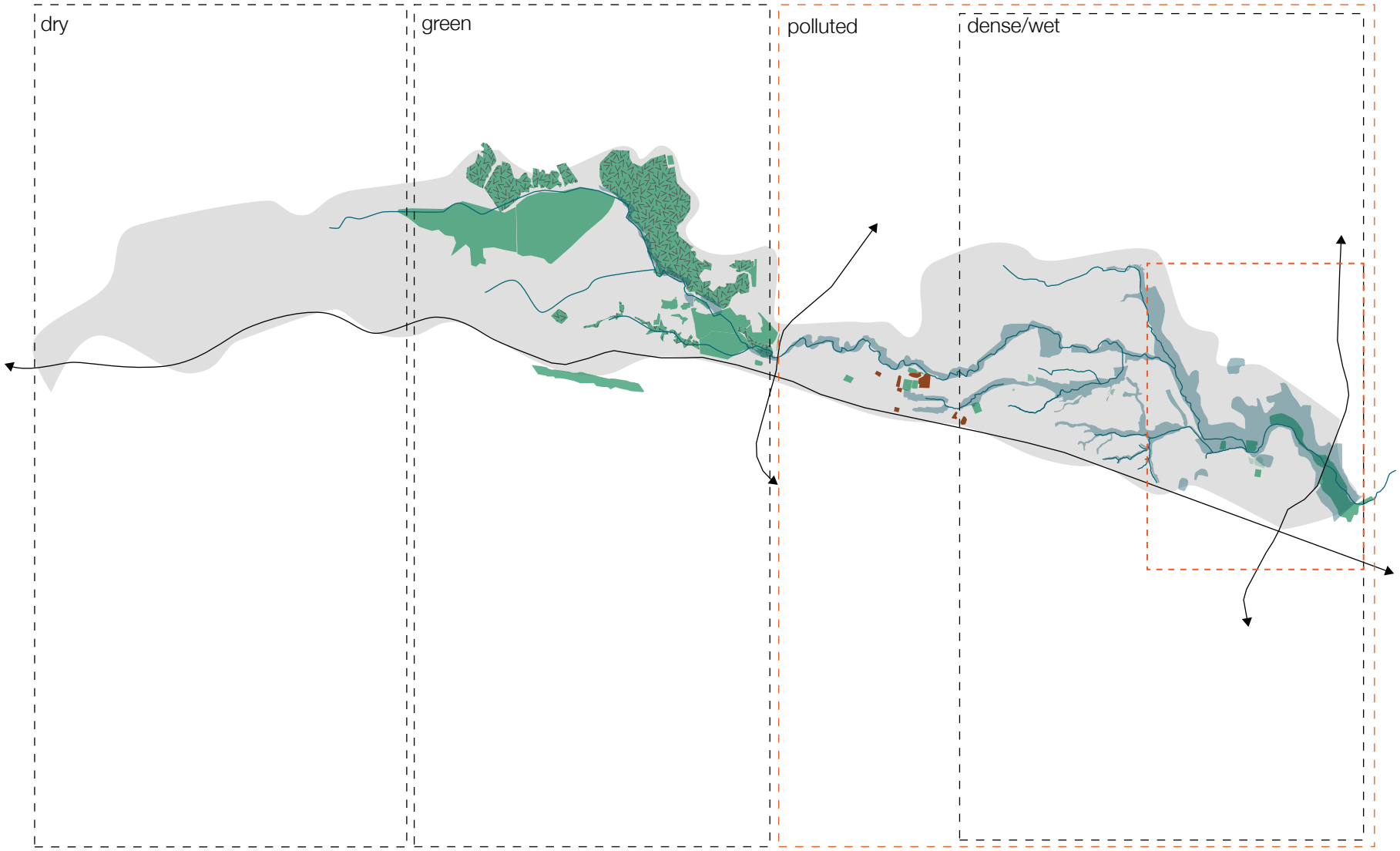
no coping capacity



connectivity



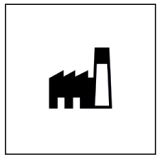
waste



approach:

reuse of rainwater	filtering industrial sewage	flood adaptation and mitigation
retention and purification of rainwater		

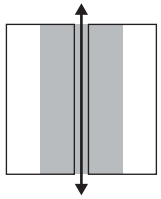
500 1000 1500 2500m



water treatment industry



no waste



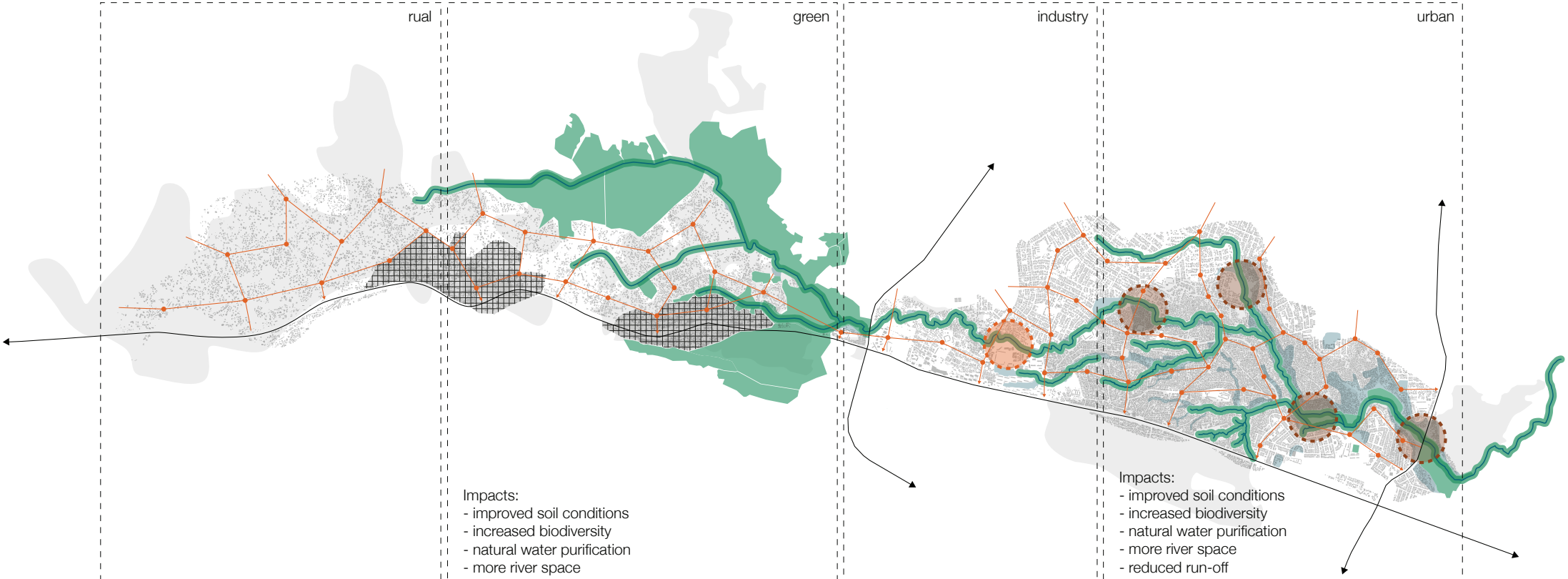
building stop in risk area



no new one story building



new renting models



Impacts:
- improved soil conditions
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

Interventions:
- restriction of urban sprawl
- keep infiltration capacity
- densification around sub-centre (courtyard system)
- maintain main infrastructure
- waste network

Problems addressed:

Impacts:
- improved soil conditions
- increased biodiversity
- natural water purification
- more river space
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

Interventions:
- keep infiltration capacity
- increase food production (courtyard system, chinampa system)
- relocation in 500m zone
- riverine buffer zone
- protection of green areas
- densification around sub-centre (courtyard system)
- maintain main infrastructure
- waste network

Problems addressed:

Impacts:
- industrial water purification
- more river space
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

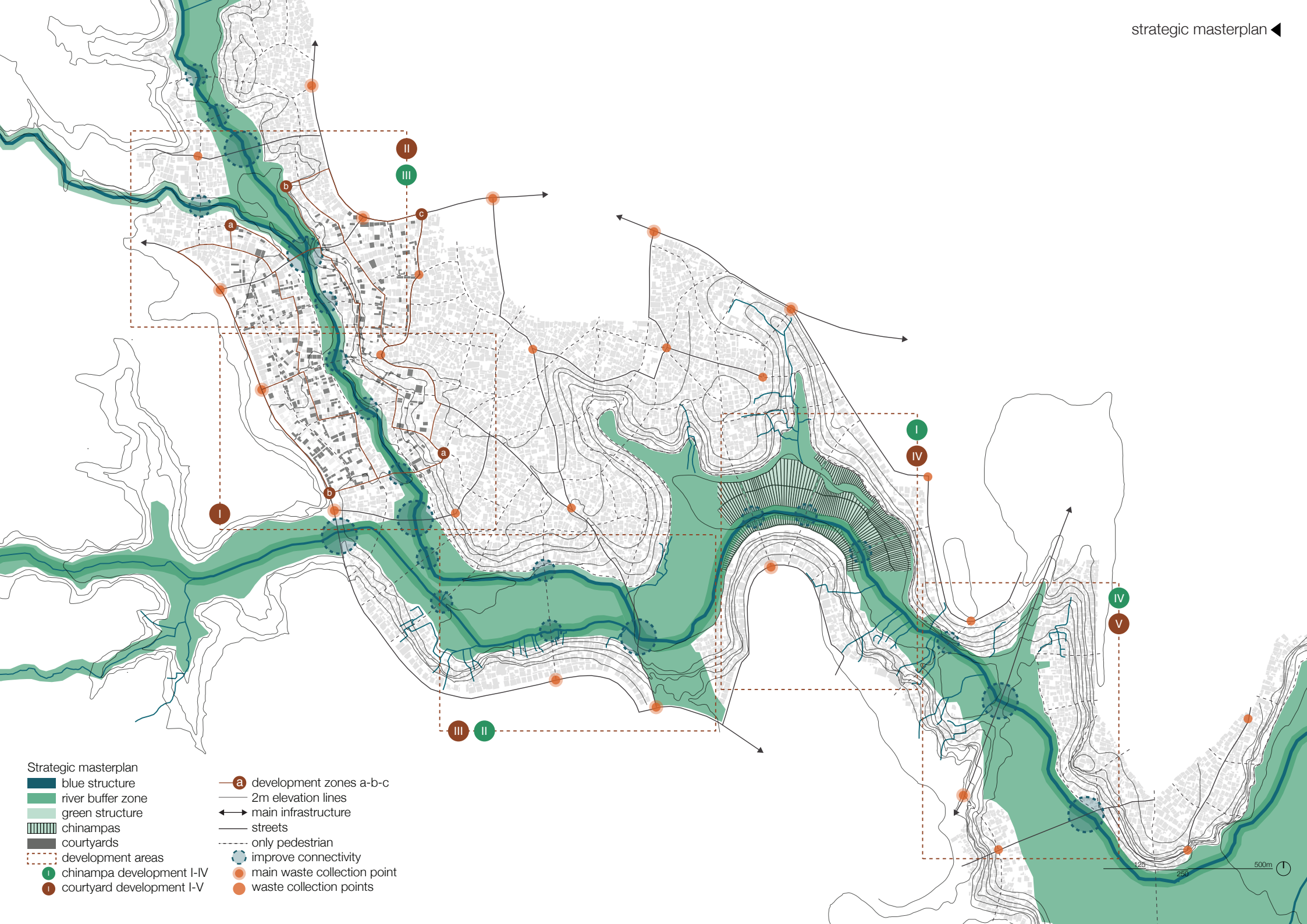
Interventions:
- relocation in 500m zone
- waste water treatment plant for industry
- riverine buffer zone
- maintain main infrastructure
- waste network

Problems addressed:

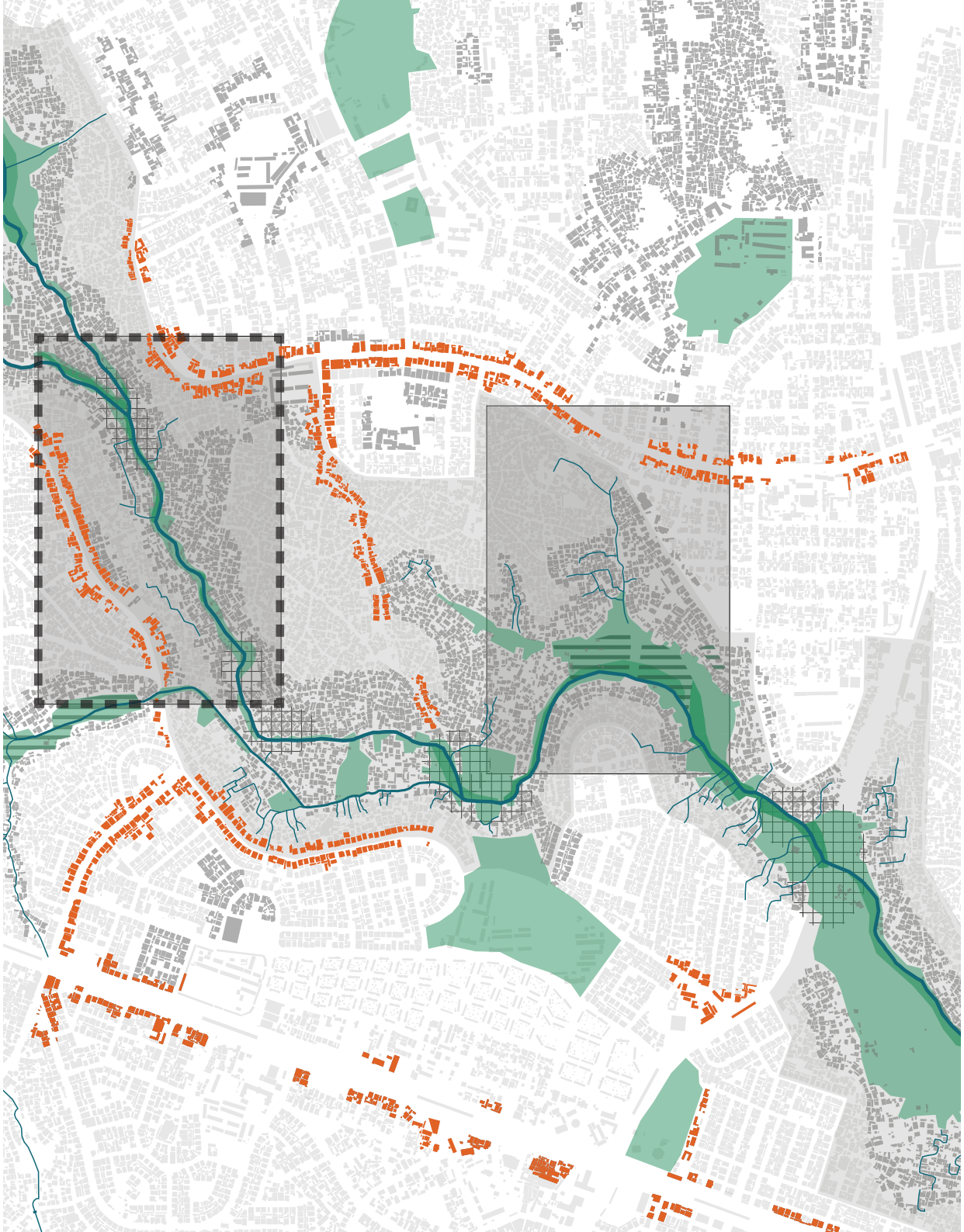
Impacts:
- improved soil conditions
- increased biodiversity
- natural water purification
- more river space
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

Interventions:
- increase food production (courtyard system, chinampa system)
- increase water retention capacity (courtyard system, chinampa system)
- relocation in 500m zone
- riverine buffer zone
- densification (courtyard system)
- conflict/risk zone - awareness campaign, early warning system, evacuation plan
- maintain main infrastructure
- waste network

Problems addressed:

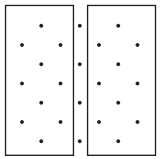

Strategic masterplan
blue structure
river buffer zone
green structure
chinampas
courtyards
development areas
chinampa development I-IV
courtyard development I-V
development zones a-b-c
2m elevation lines
main infrastructure
streets
only pedestrian
improve connectivity
main waste collection point
waste collection points
125
250
500m

▶ courtyard

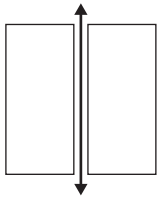


Individual design location

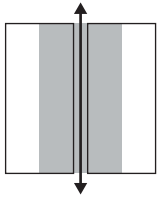
- blue structure
- agriculture
- green structure
- informal settlement
- flood risk area
- waste
- commercial streets
- individual design location



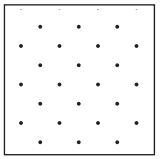
site consist of two neighbourhoods:
tandale/makumbusho



river in between called Ng‘ombe



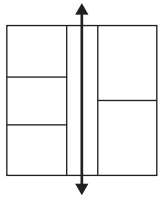
about 50% is flood risk area



site is about 500 000m^2

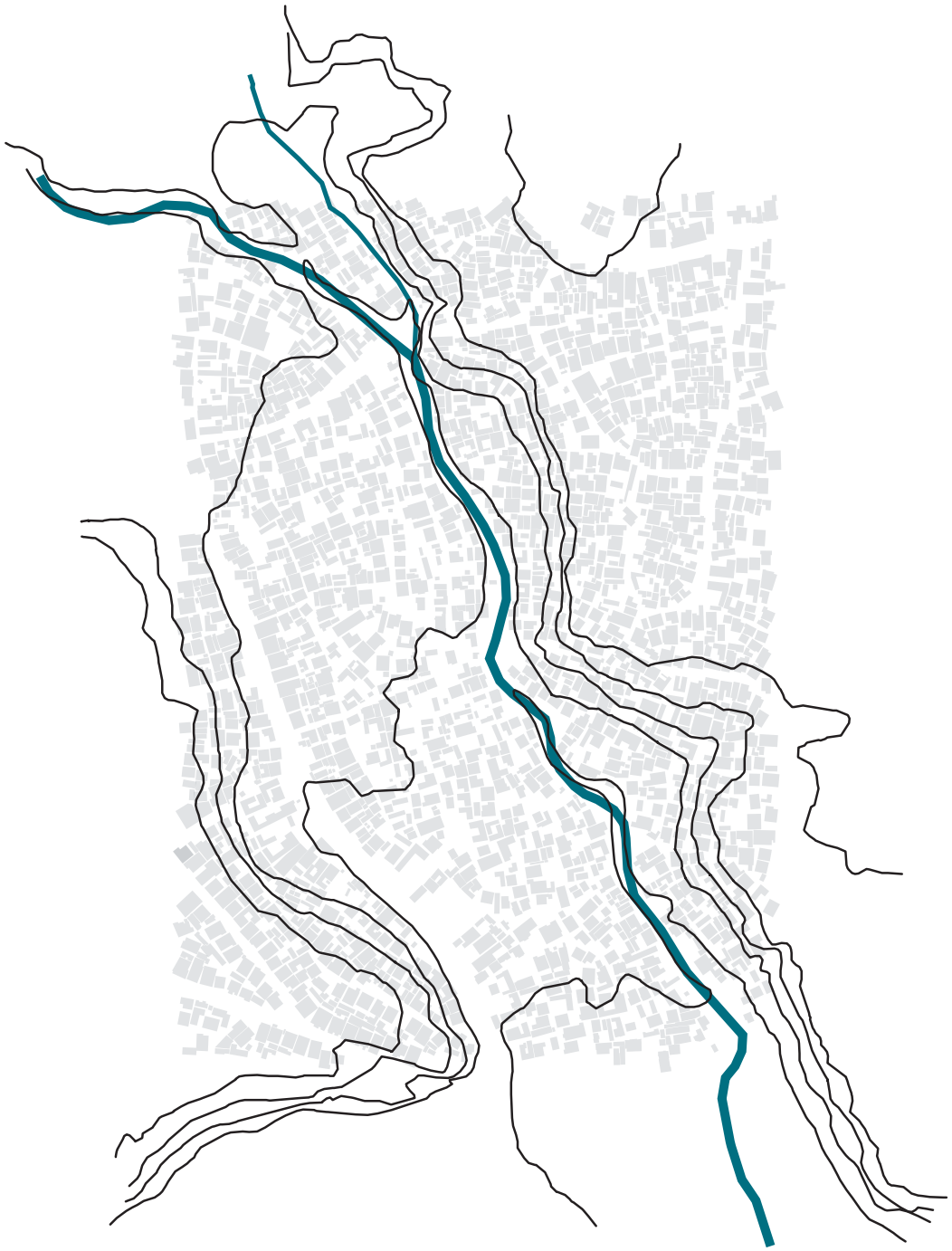


in one swahili house
live 4-5 families



typical swahili floor plan with
common hall way

▶ site analysis

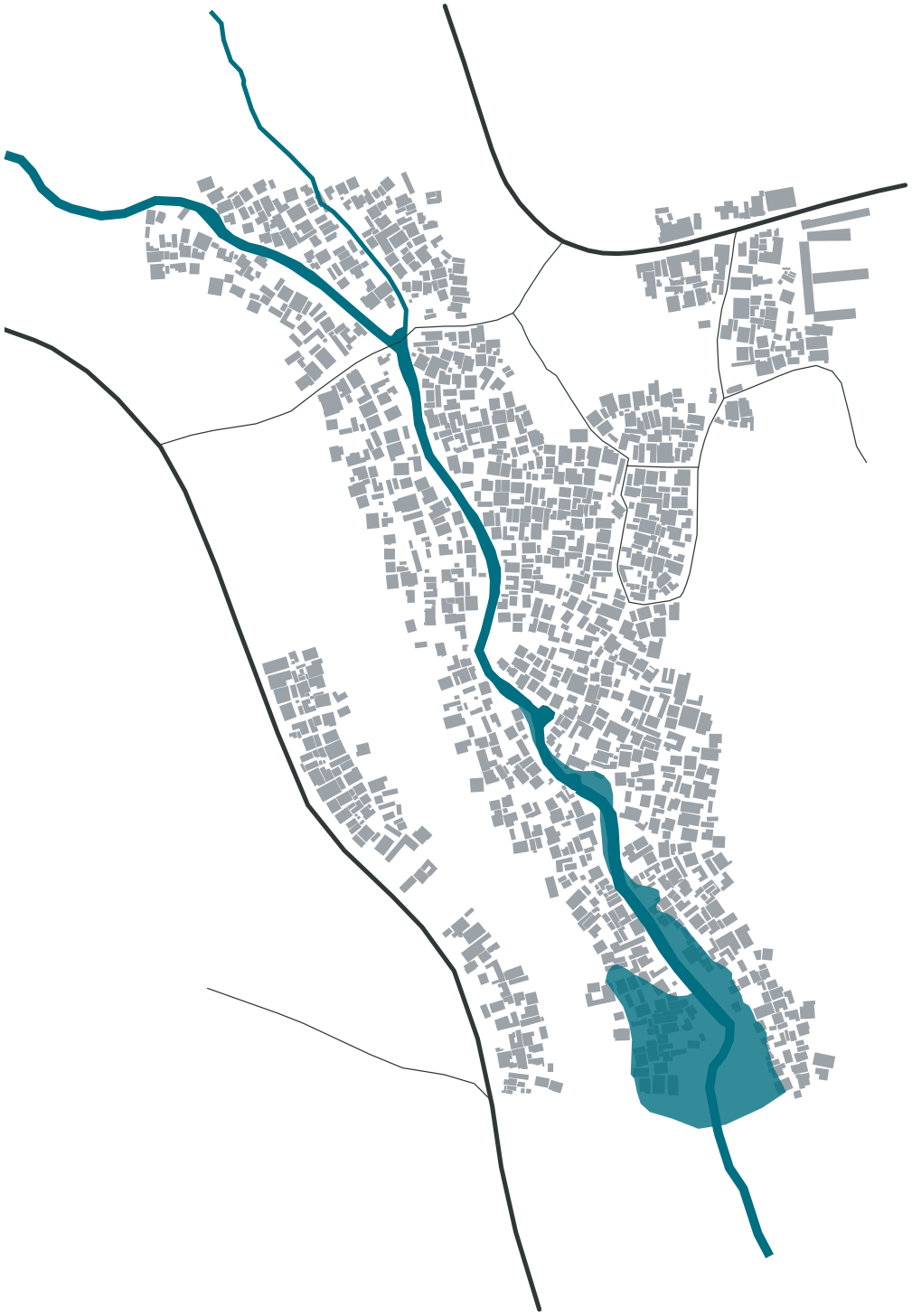


Elevation map
blue structure
2m elevation line



Green structure
- blue structure
- green structure
- flood risk

▶ site analysis



Low - high flood level
blue structure
main roads
car roads
flood risk

▶ site analysis



Low - high flood level
blue structure
main roads
car roads
flood risk

▶ site analysis



Low - high flood level
blue structure
main roads
car roads
flood risk

▶ site analysis



Low - high flood level
blue structure
main roads
car roads
flood risk

▶ site analysis



Infrastructure
- blue structure
- main roads
- car roads
- only pedestrian
- existing grid
- 100m radius
- connected
- missing connection

▶ site analysis



Infrastructure
- blue structure
- main roads
- car roads
- only pedestrian
- existing grid
- 100m radius
- connected
- missing connection

▶ site analysis



Infrastructure
- blue structure
- main roads
- car roads
- only pedestrian
- existing grid
- 100m radius
- connected
- missing connection

▶ site analysis



Vacant land 1:15000

- blue structure
- green structure
- vacant land

▶ site analysis



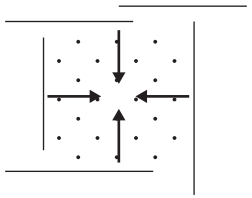
Vacant land 1:15000

- blue structure
- green structure
- vacant land

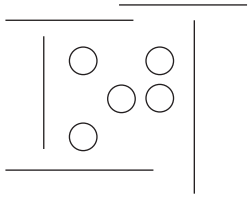




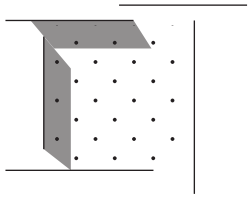
▶ why courtyard?



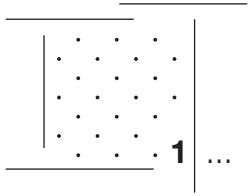
arabic/muslim courtyard culture



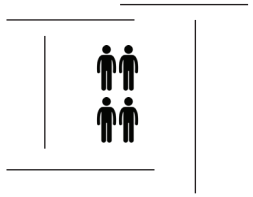
small scale intervention



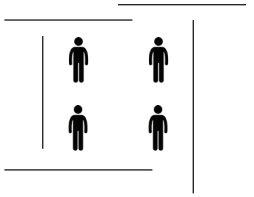
good climate - shade/green space



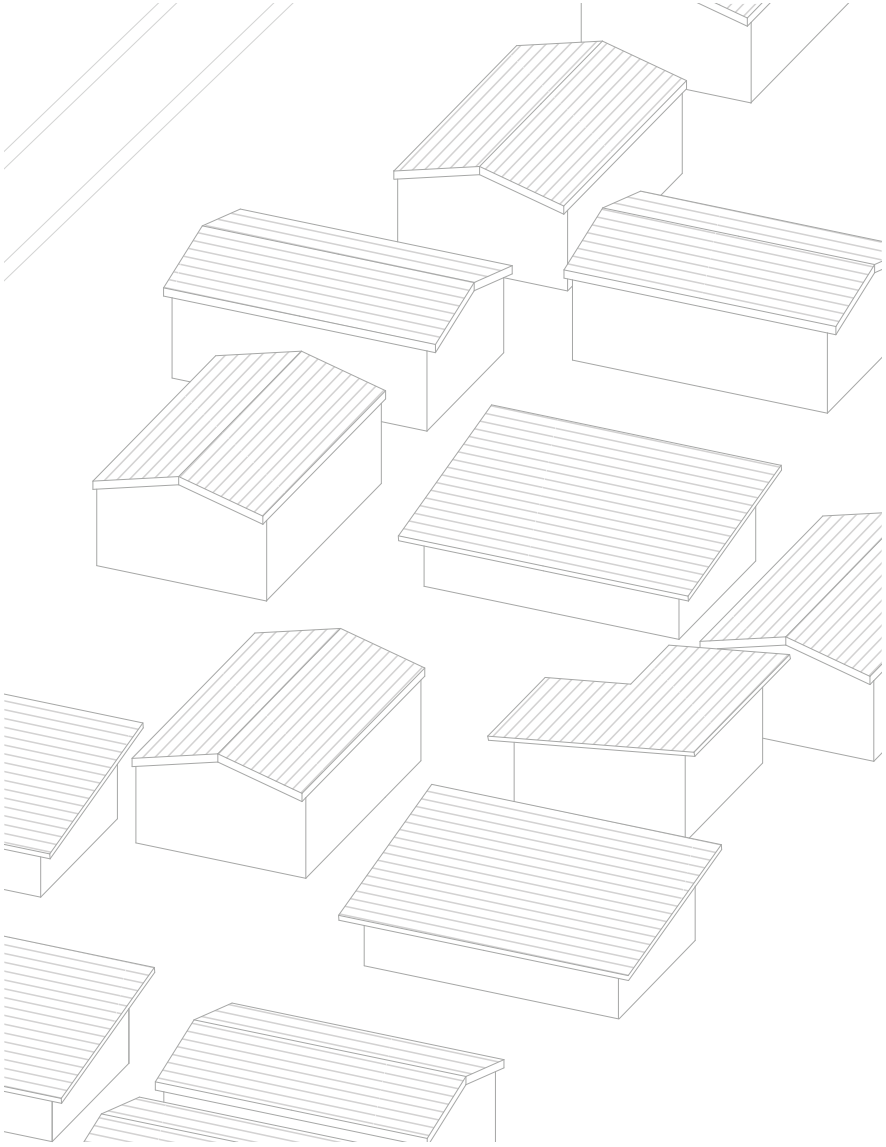
implementation by units



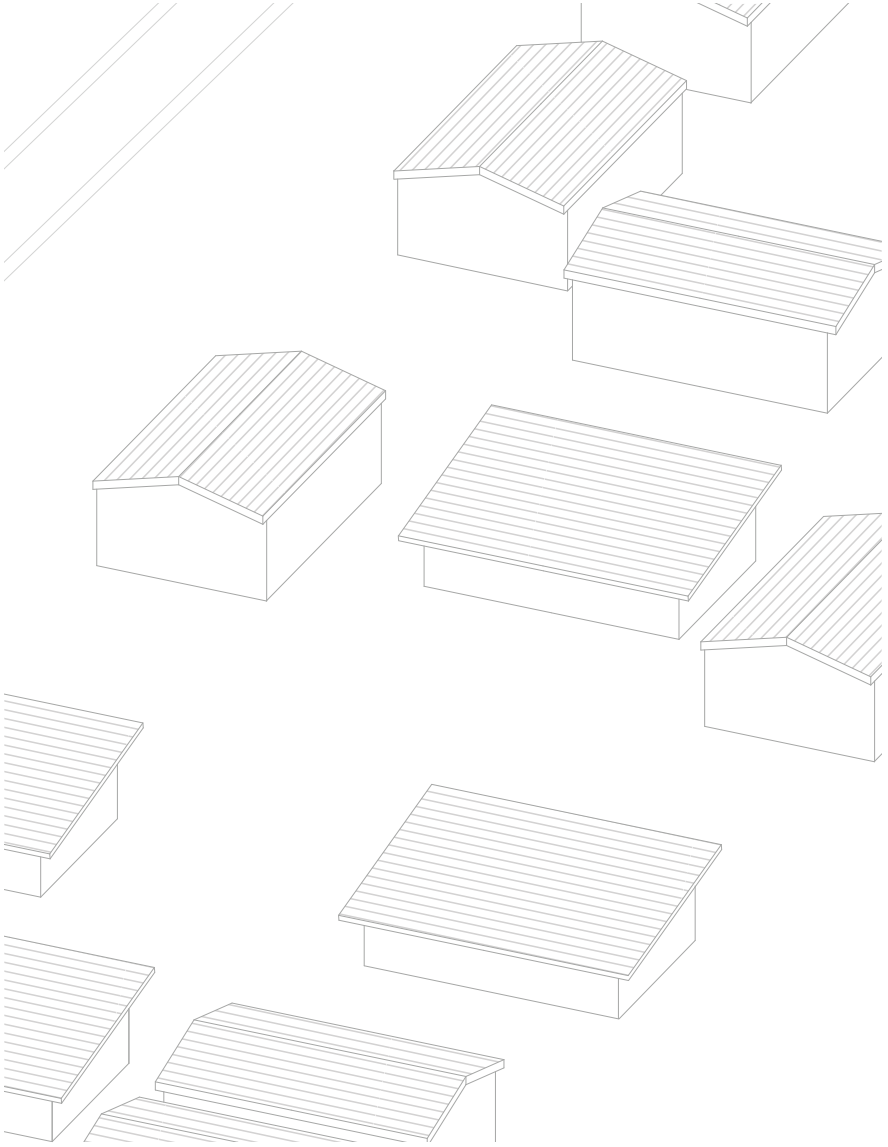
don‘t have to move



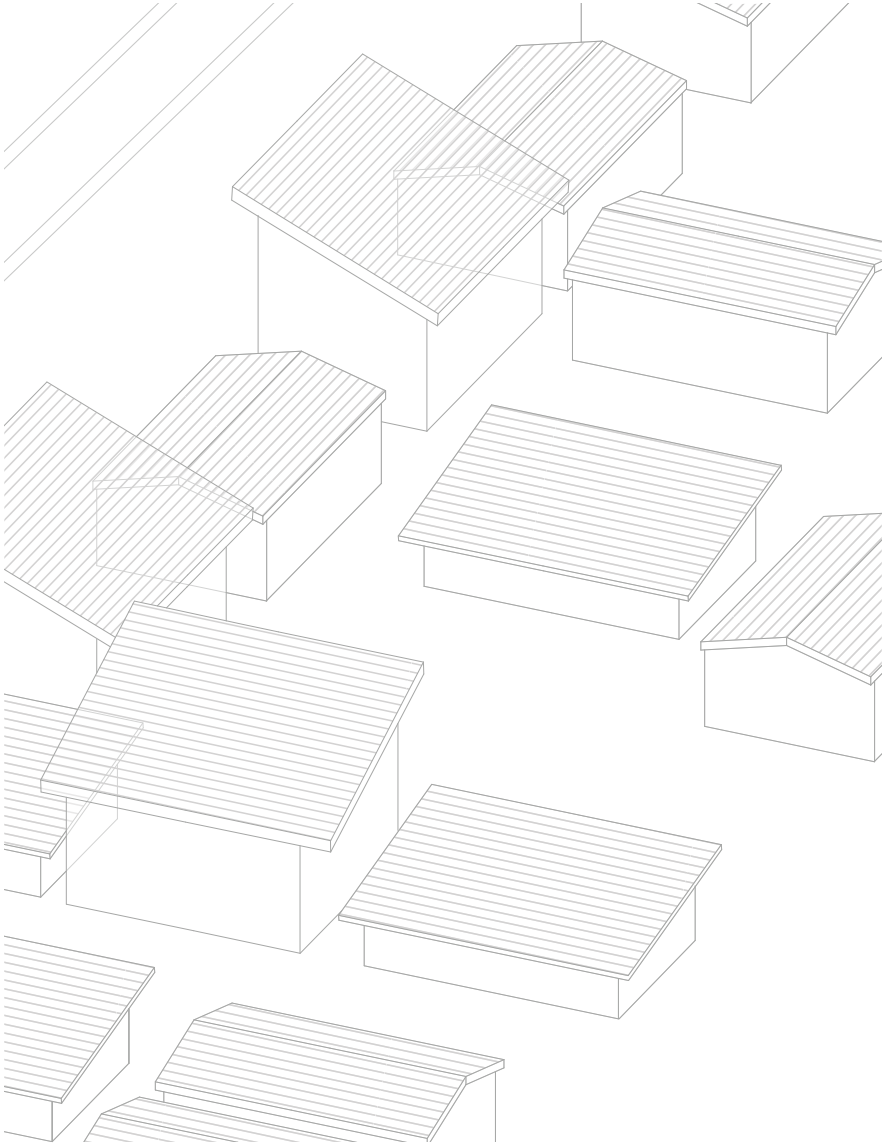
community based units



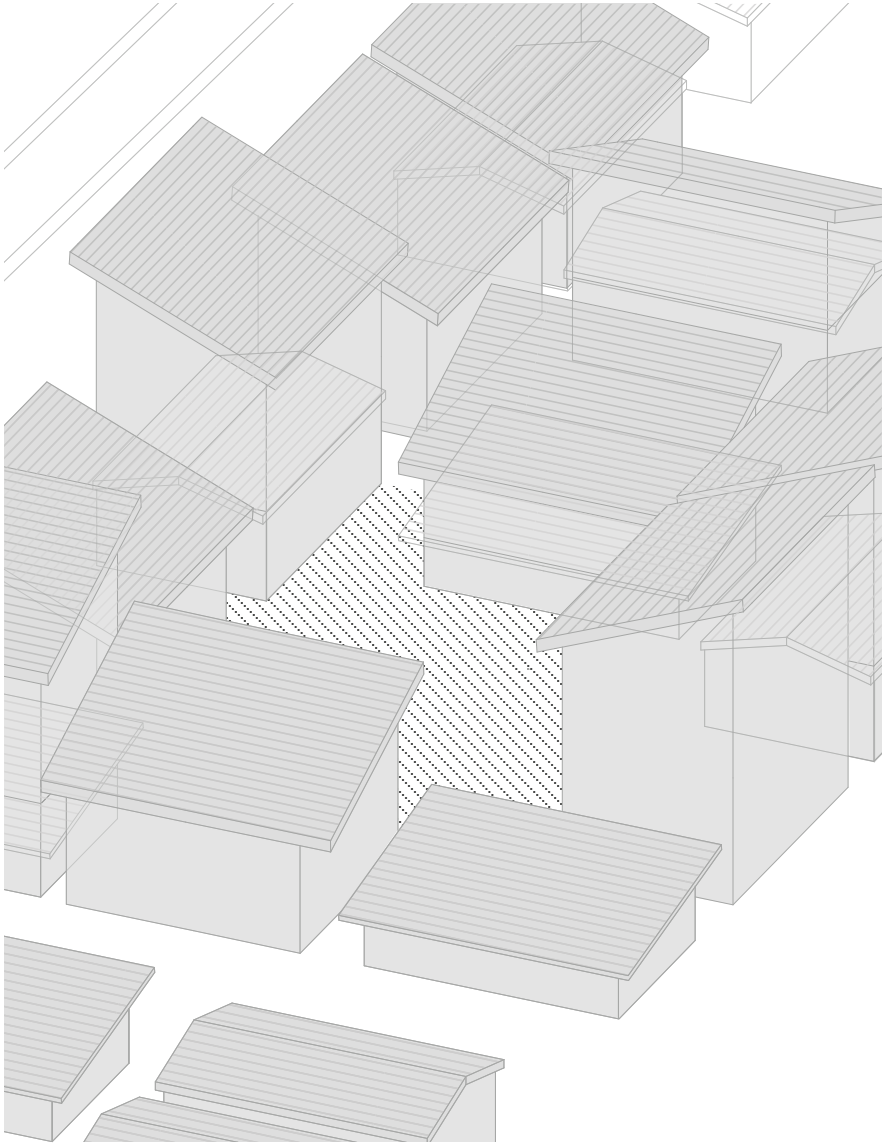
current situation -



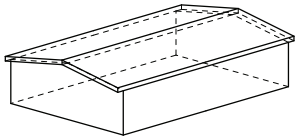
current situation - removing -



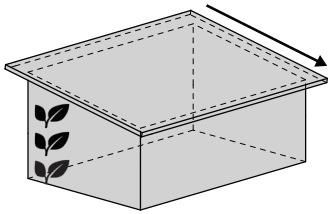
current situation - removing - filling -



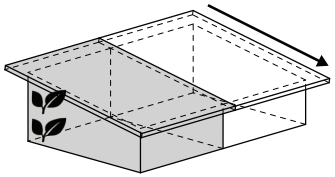
current situation - removing - filling - densifying



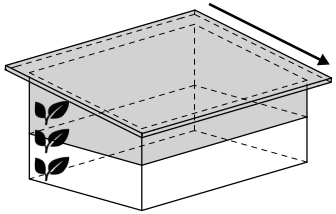
25% strategic removal of
old houses/reducing built surface



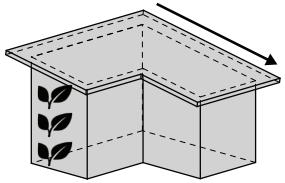
20% new housing /guiding and
manageing run-off rain water /using
facade for aquaponics



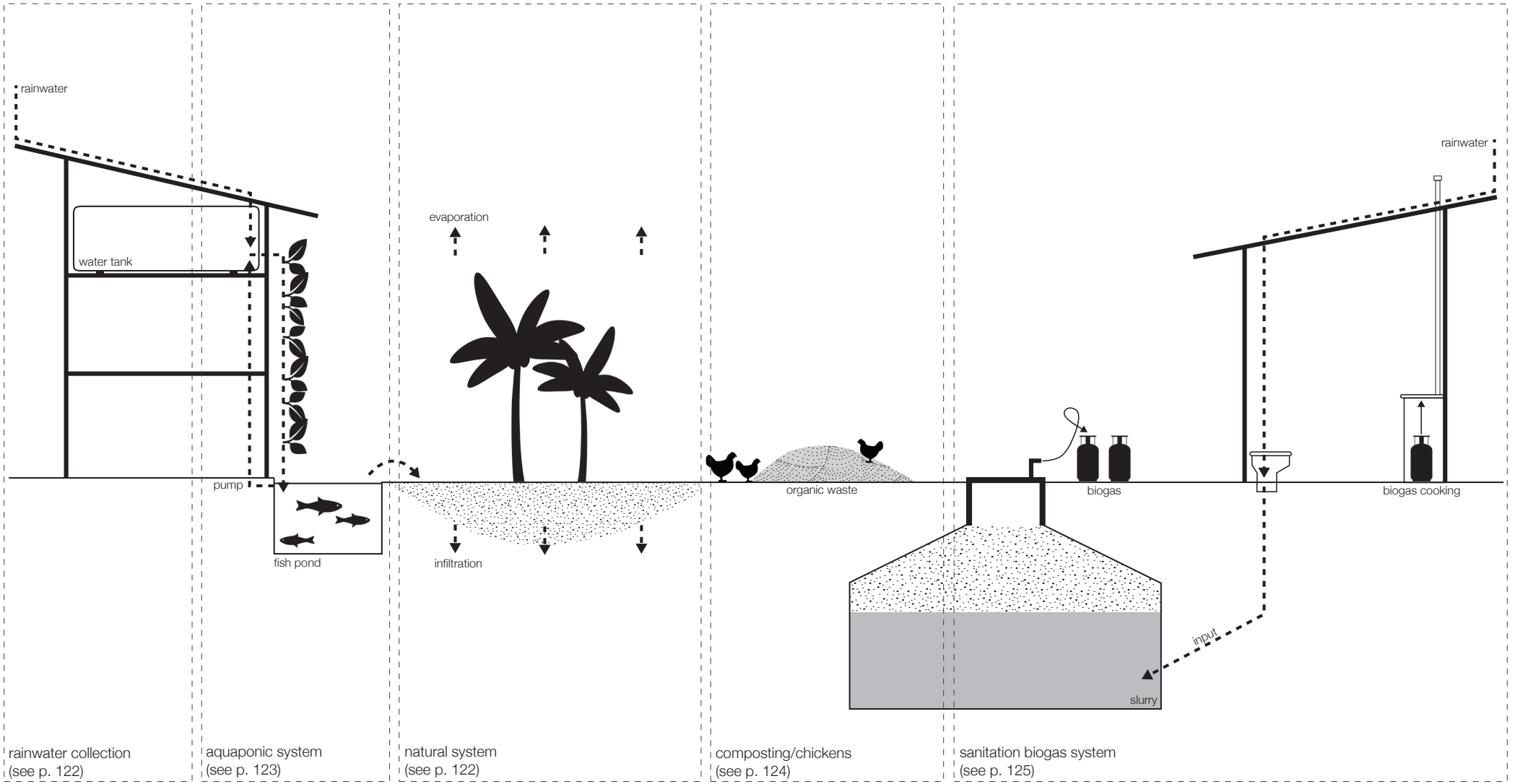
strategic housing expansion /guiding
and manageing run-off rain water
/using facade for aquaponics



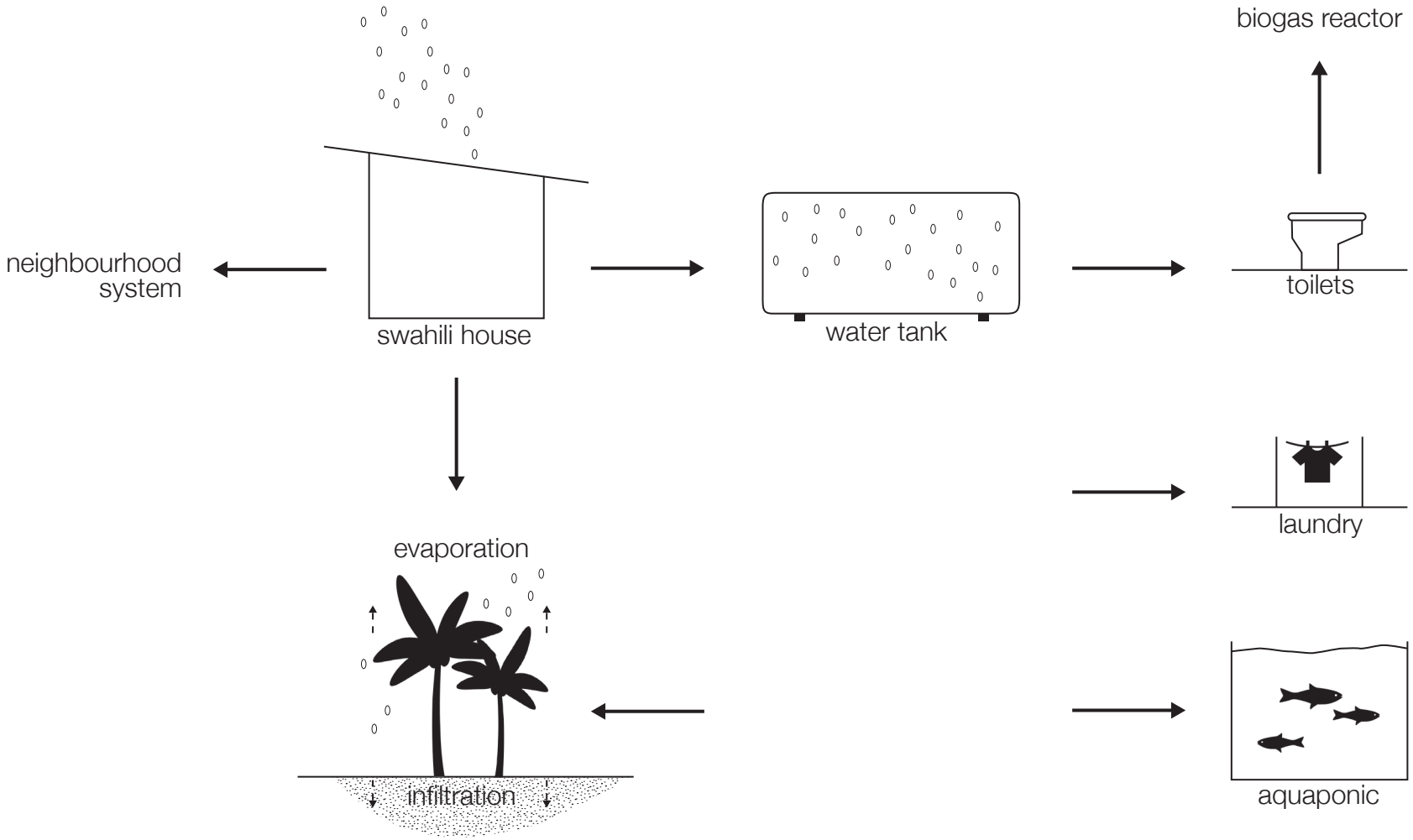
densifying in height
/reducing built surface /guiding and
manageing run-off rain water /using
facade for aquaponics



enhancing courtyard
structure /guiding and manageing
run-off rain water /using facade for
aquaponics


rainwater
water tank
pump
fish pond
evaporation
infiltration
organic waste
biogas
rainwater
biogas cooking
input
slurry
rainwater collection
(see p. 122)
aquaponic system
(see p. 123)
natural system
(see p. 122)
composting/chickens
(see p. 124)
sanitation biogas system
(see p. 125)

▶ rainwater

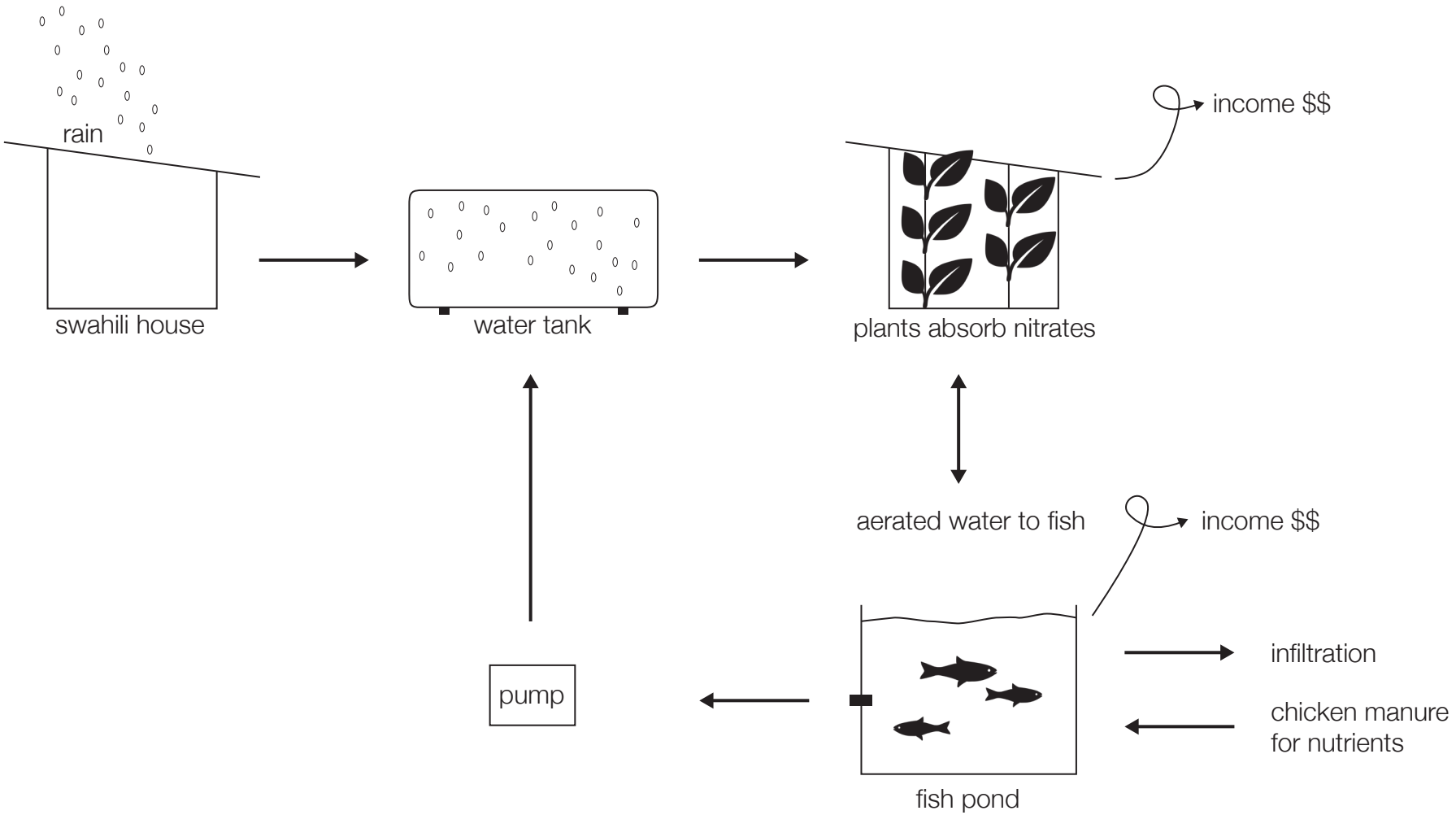

biogas reactor
neighbourhood system
swahili house
water tank
toilets
laundry
evaporation
infiltration
aquaponic

▶ rainwater calculation

	rain water	green space
∅ courtyard	25% deep infiltration 25% shallow infiltartion 40% evaporation 10% run off	380 m²

	rain water	urban space
∅ courtyard	5% deep infiltration 10% shallow infiltartion 30% evaporation 55% run off	2000 m²

	55% run off water	urban space
∅ courtyard	5% toilet 15% aquaponic 20% fish pond 5% laundry	2000 m²

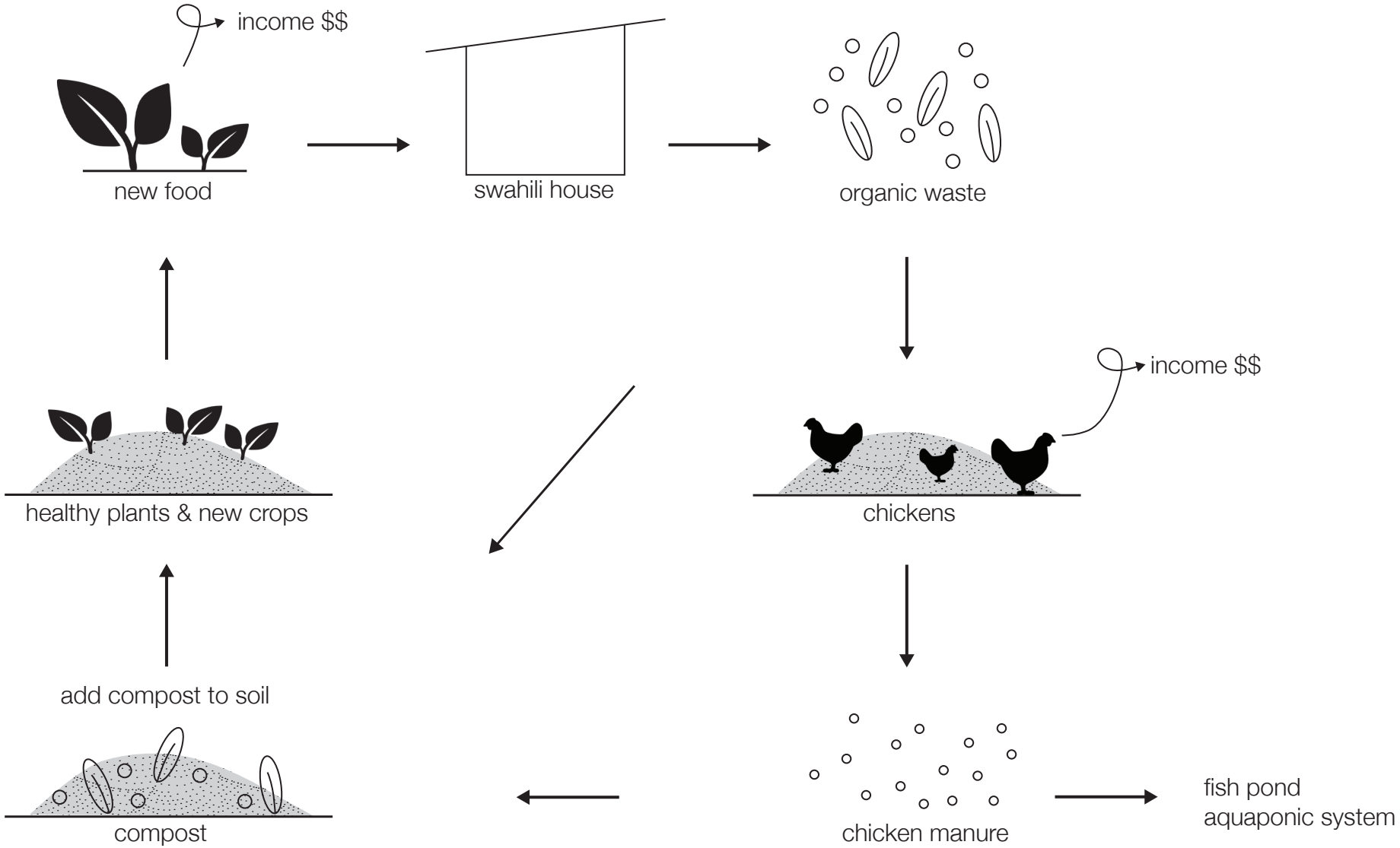

rain
swahili house
water tank
plants absorb nitrates
income $$
aerated water to fish
income $$
pump
infiltration
chicken manure
for nutrients
fish pond

	3.8 kg	1 m²	1 year
∅ courtyard	957.5 kg	250 m²	1 year
max. capacity	18.4 kg	250 m²	1 week
	2.6 kg	250 m²	1 day

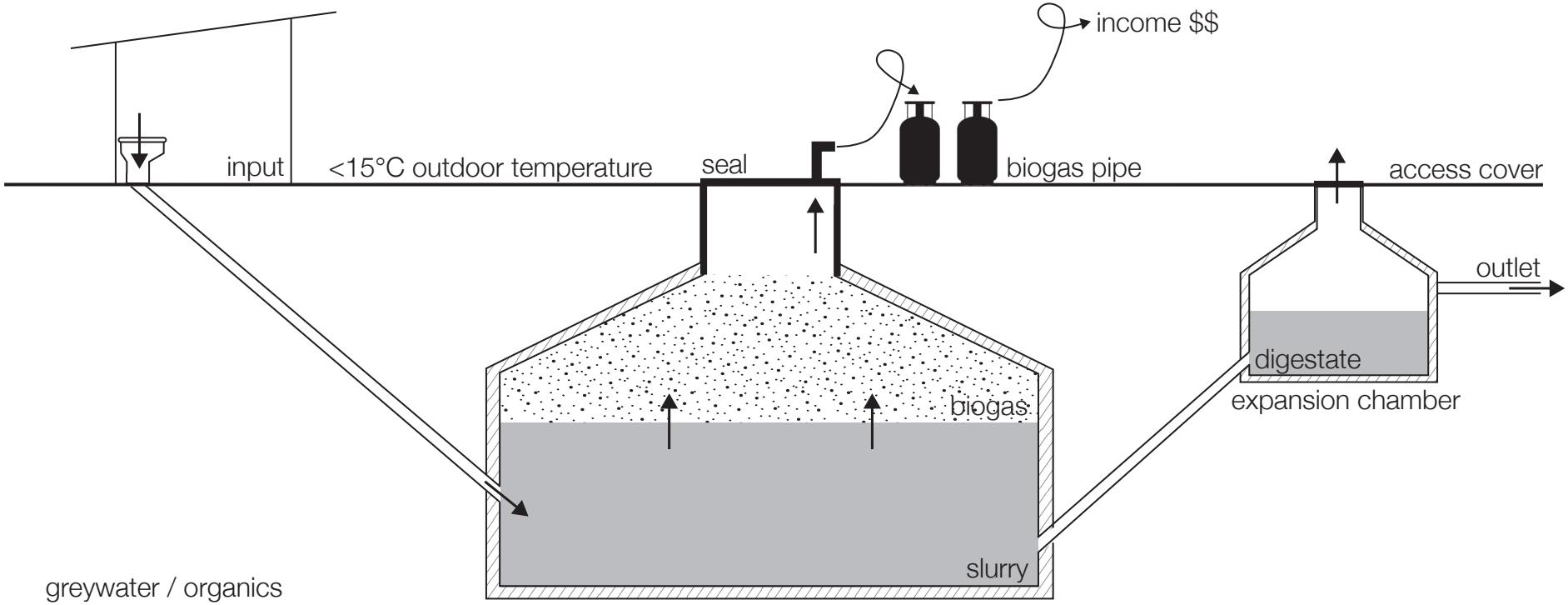
	10.2 kg	1 m²	1 year
∅ courtyard	2550 kg	250 m²	1 year
max. capacity	49 kg	250 m²	1 week
	7 kg	250 m²	1 day

	50 kg	1 m³	1 year
∅ courtyard	5000 kg	100 m³	1 year
max. capacity	96.2 kg	100 m³	1 week
	13.7 kg	100 m³	1 day

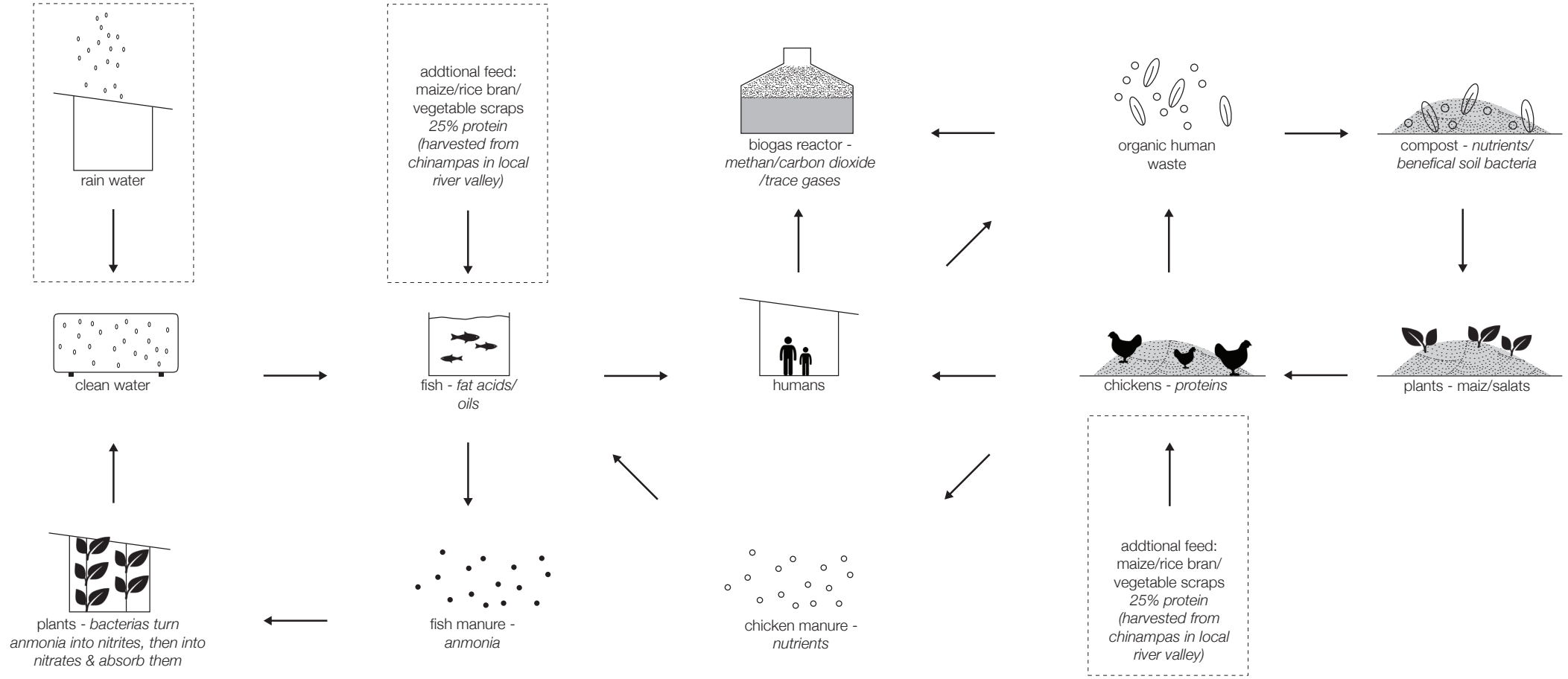
▶ compost/chicken



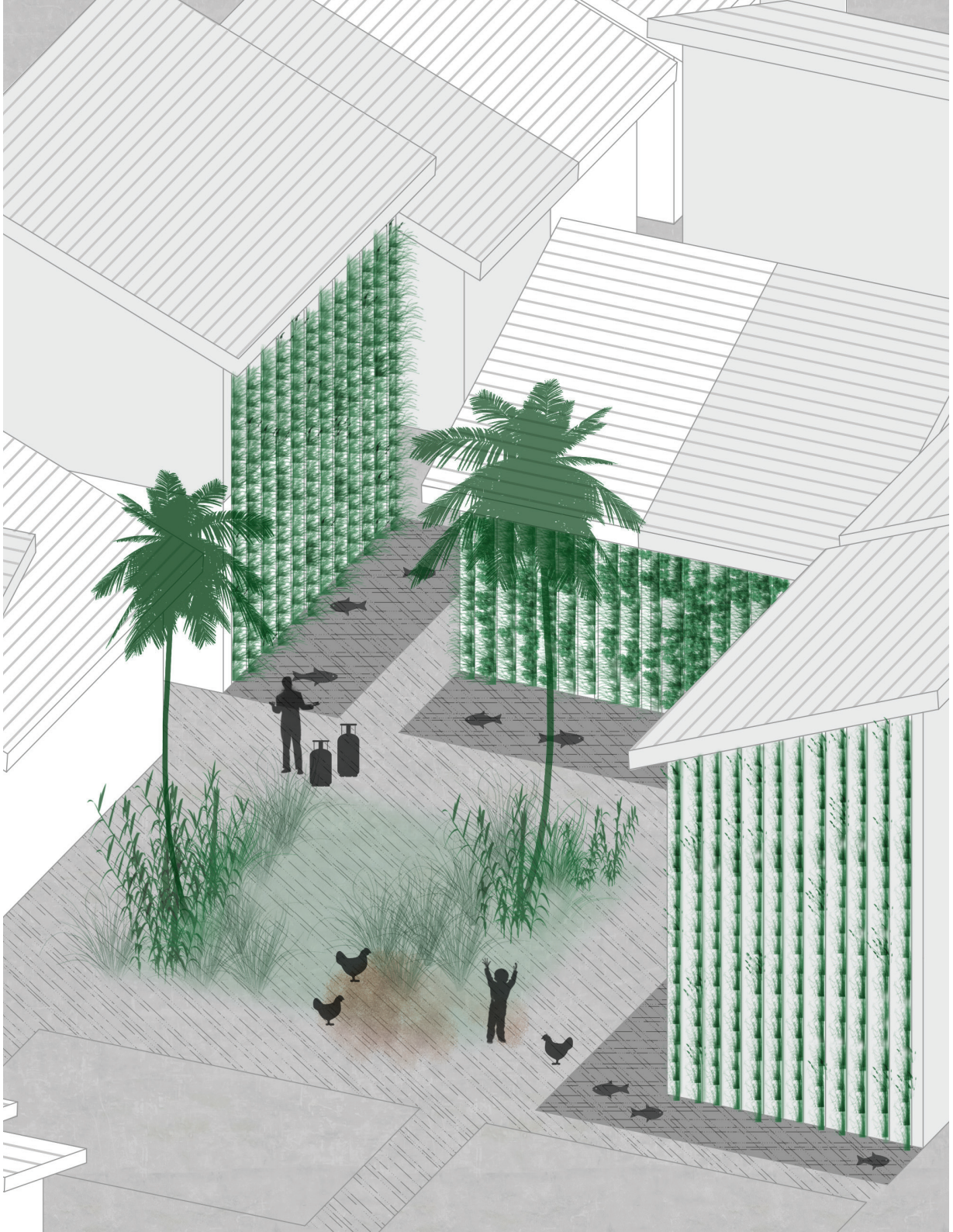
▶ biogas reactor



▶ agriculture cycle

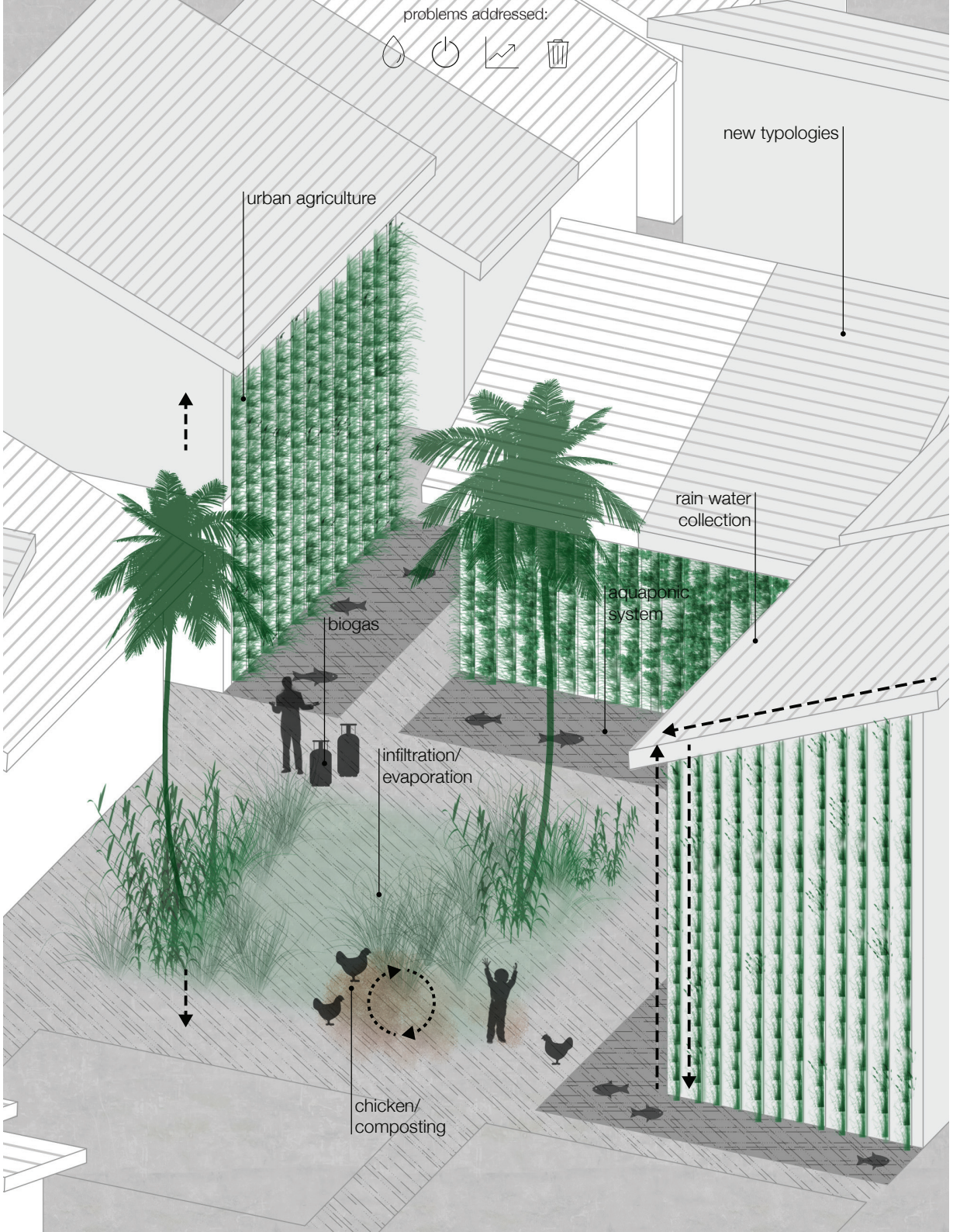


▶ relation courtyard



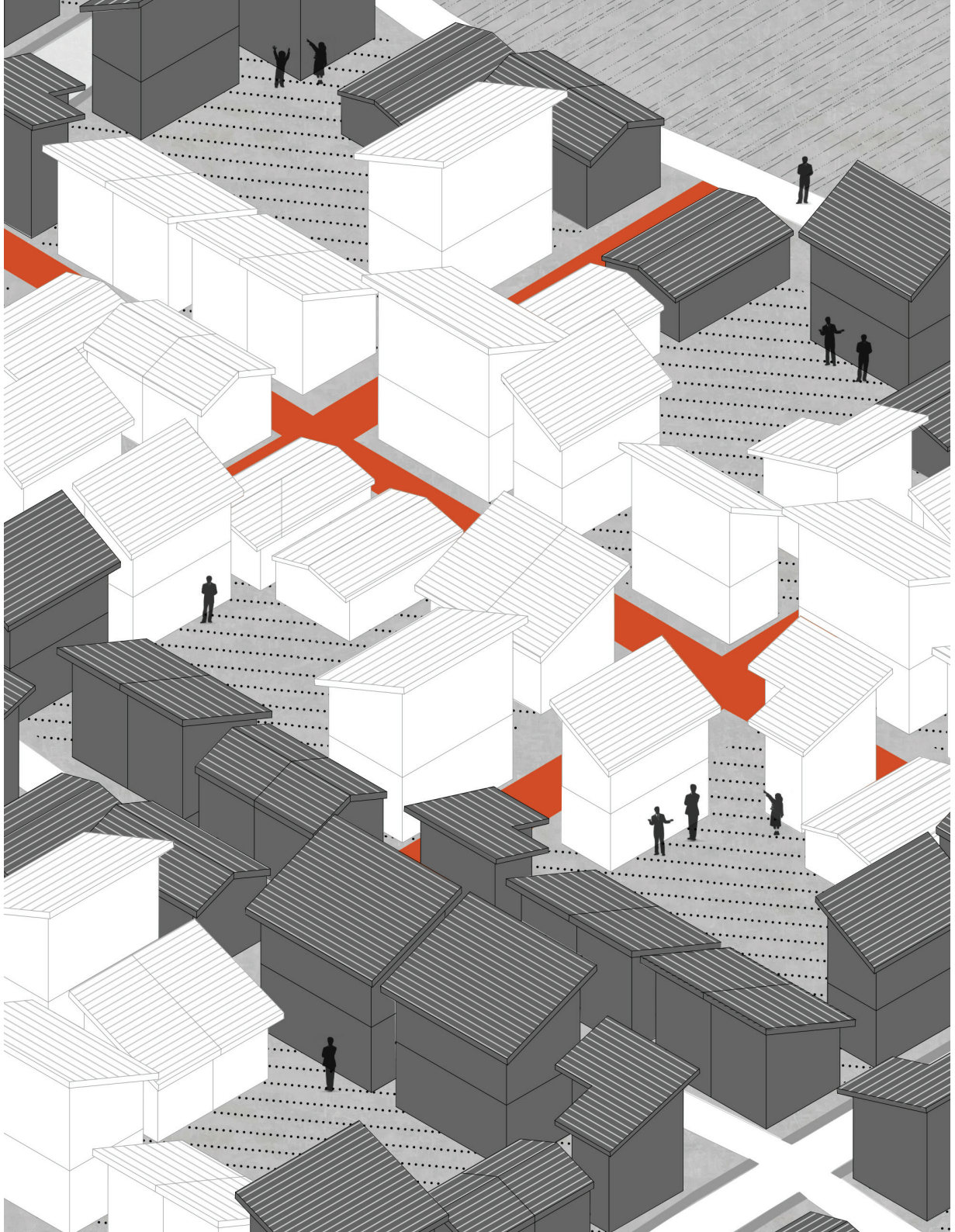
Courtyard scheme
- - ▶ water flow
·····▶ waste flow

▶ relation courtyard



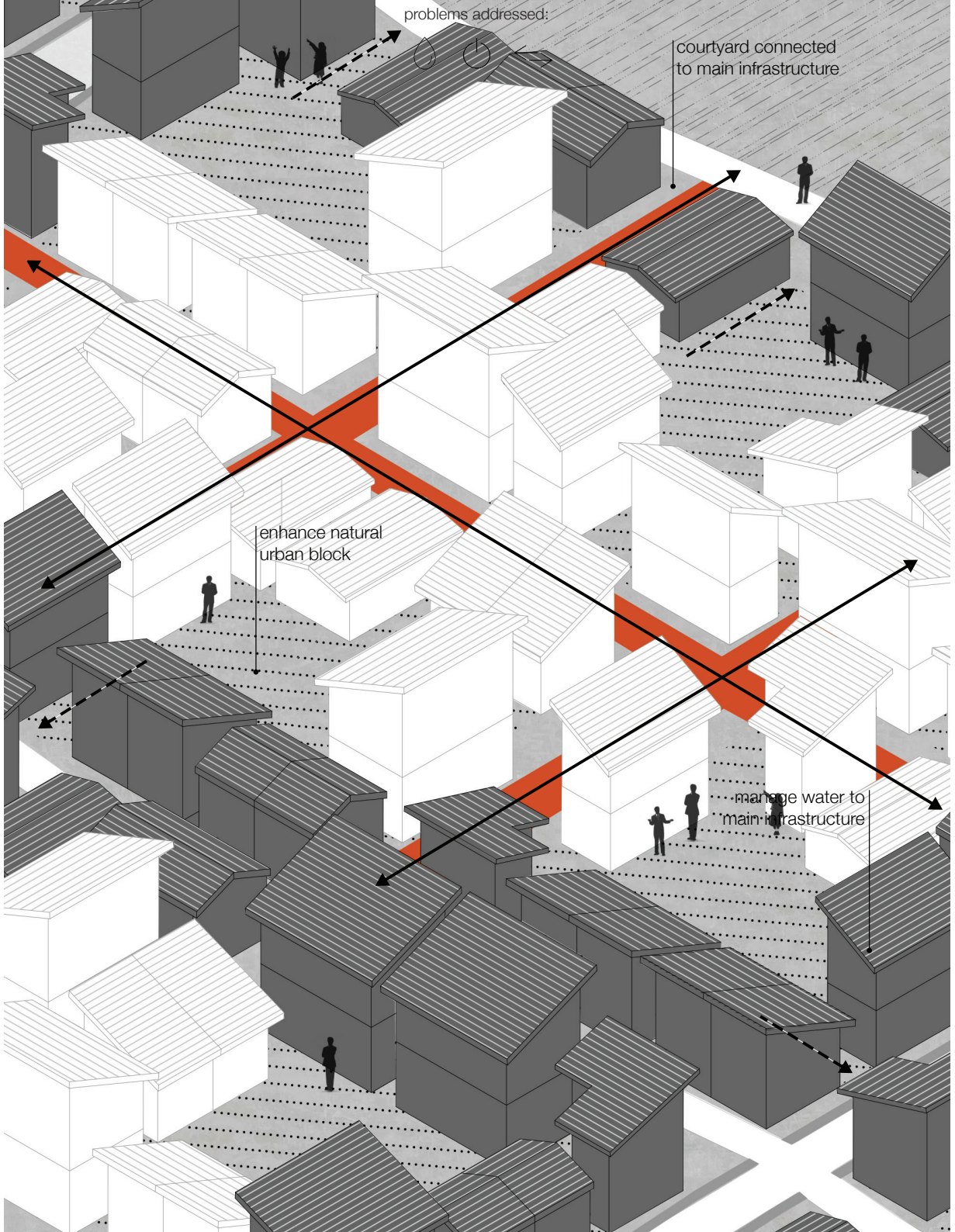
Courtyard scheme
- - - ▶ water flow
·····▶ waste flow

▶ relation urban block



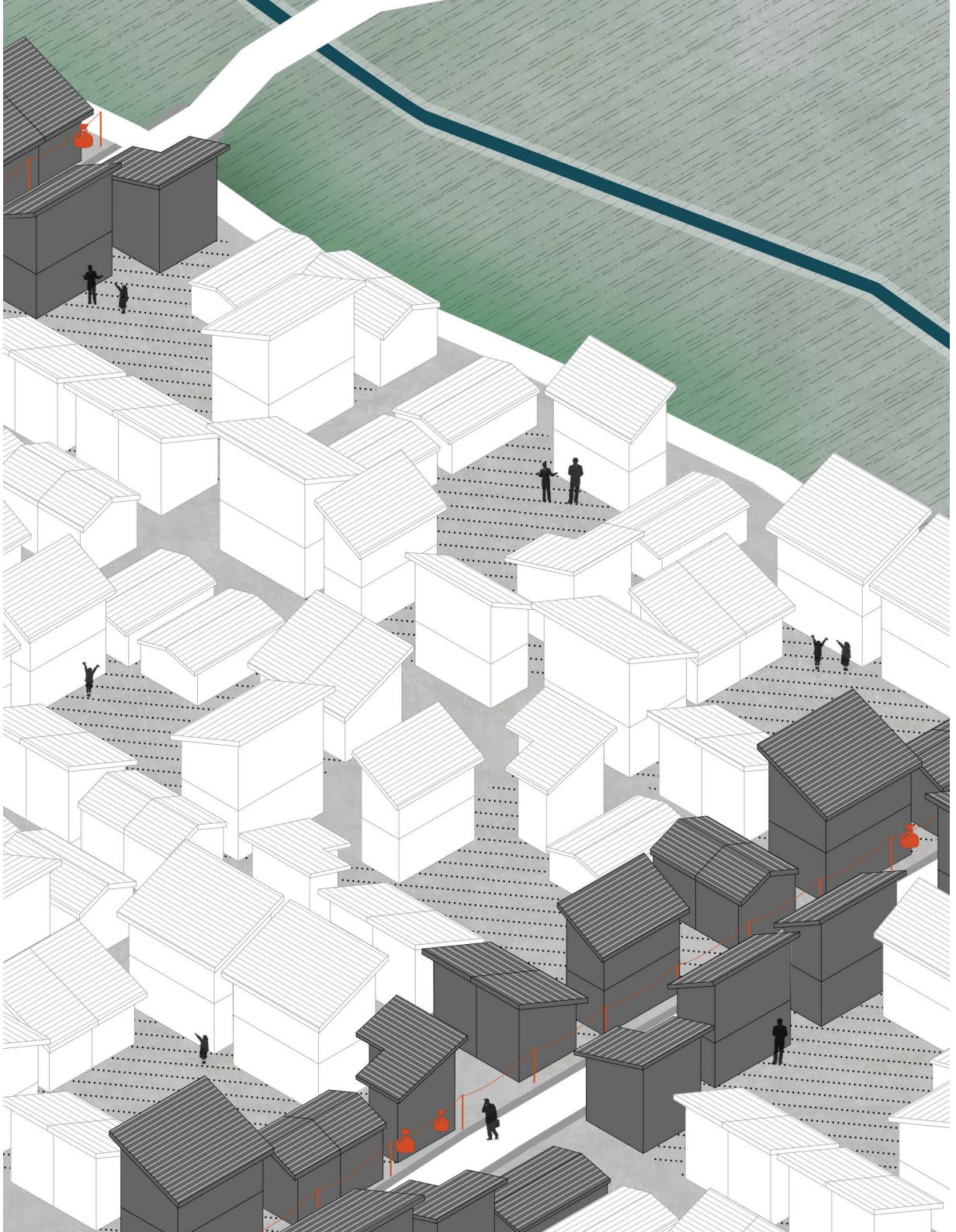
Urban block scheme
→ main access
- - → water flow

▶ relation urban block



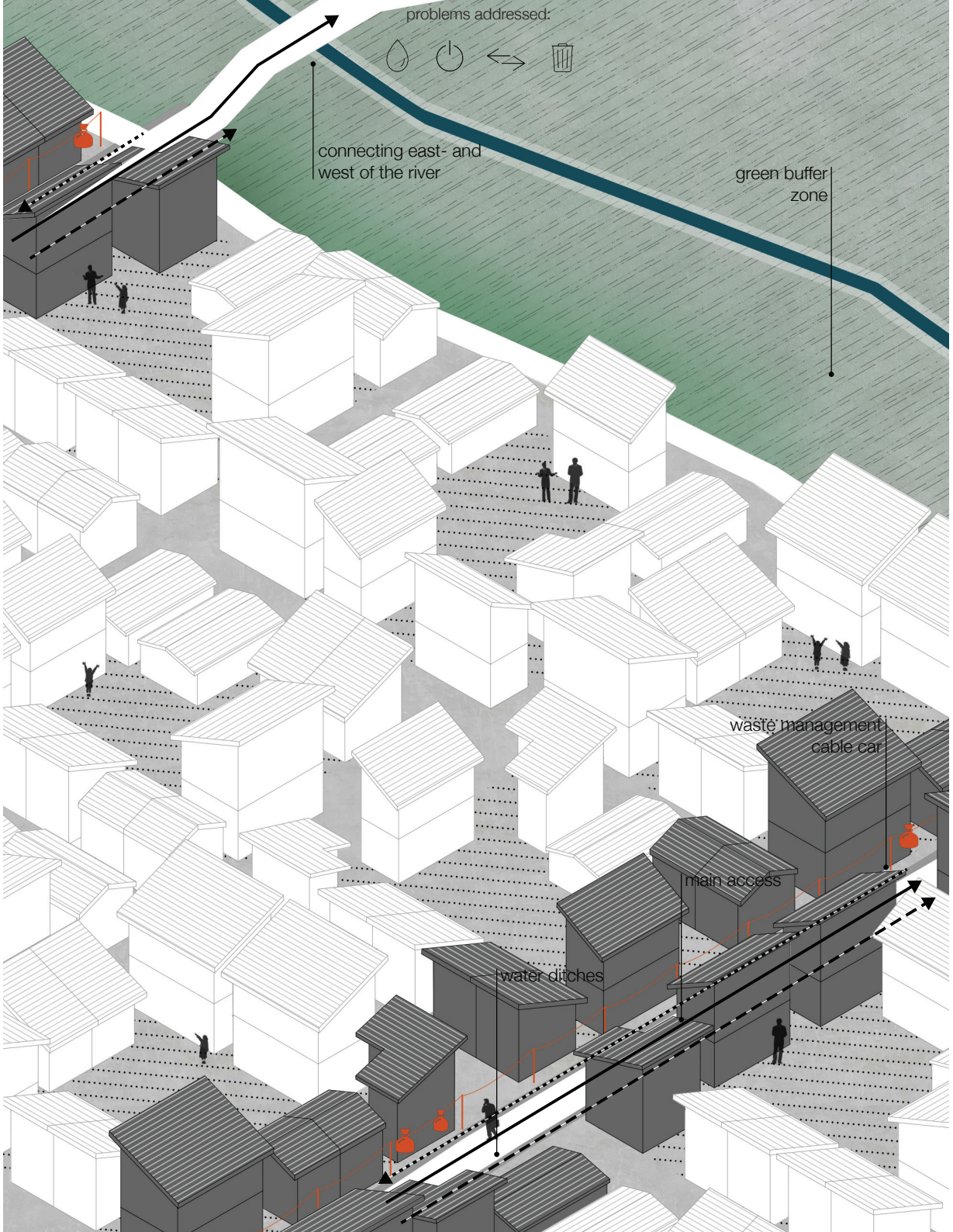
Urban block scheme
→ main access
- - → water flow

▶ relation neighbourhood



Neighbourhood scheme
——▶ main access
- - -▶ water flow
·····▶ waste flow

▶ relation neighbourhood



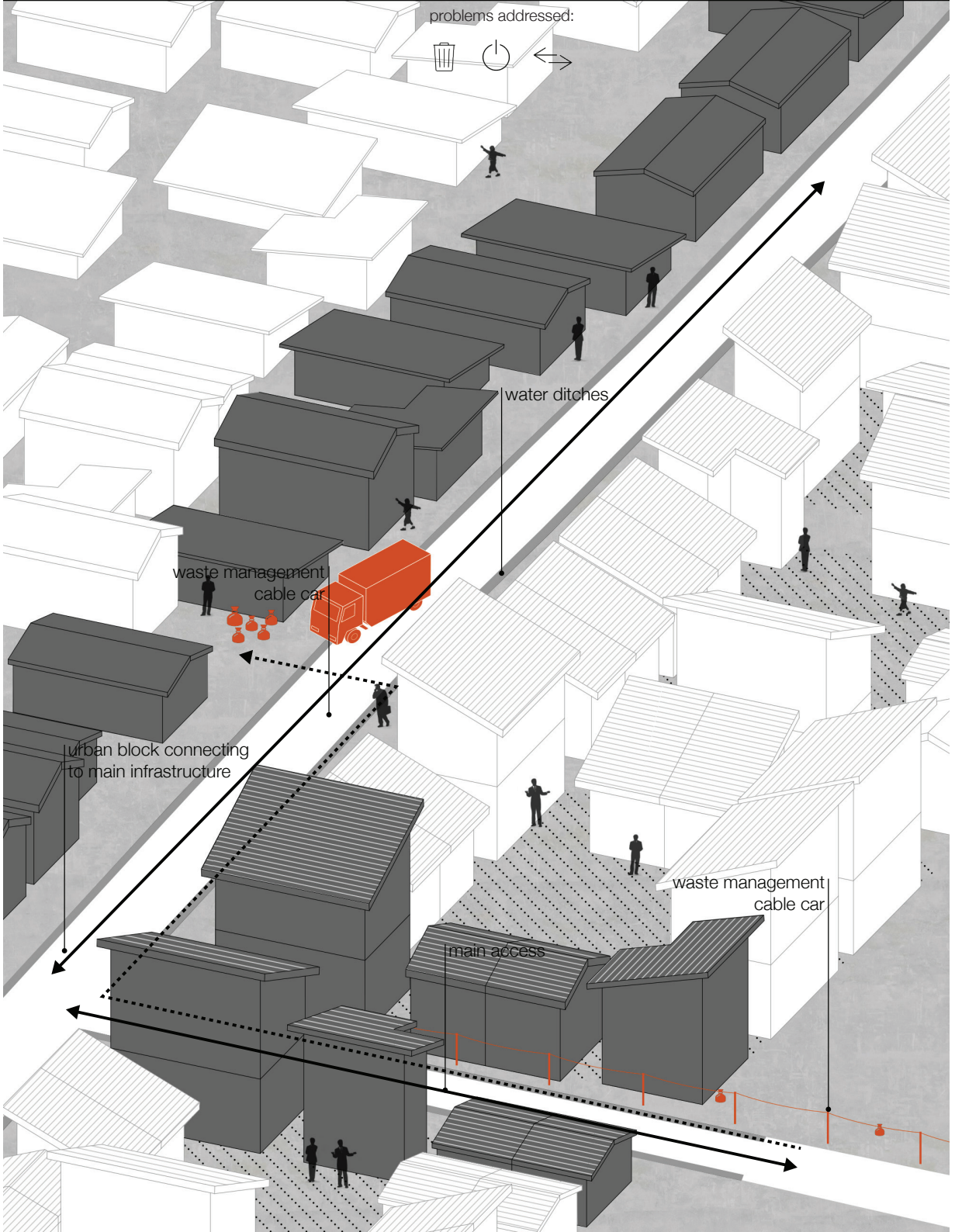
Neighbourhood scheme
main access
water flow
waste flow

▶ relation city



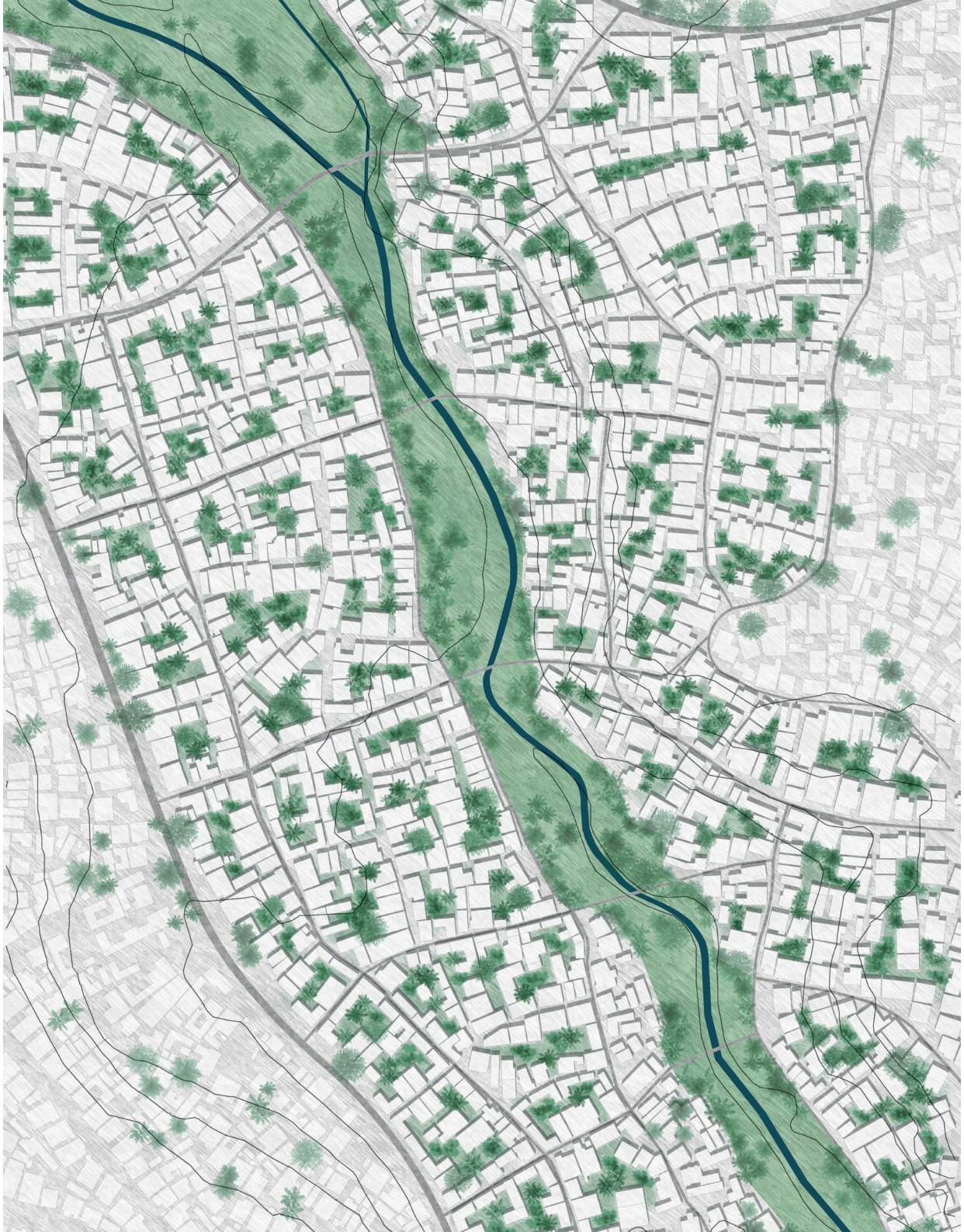
City scheme
main access
waste flow

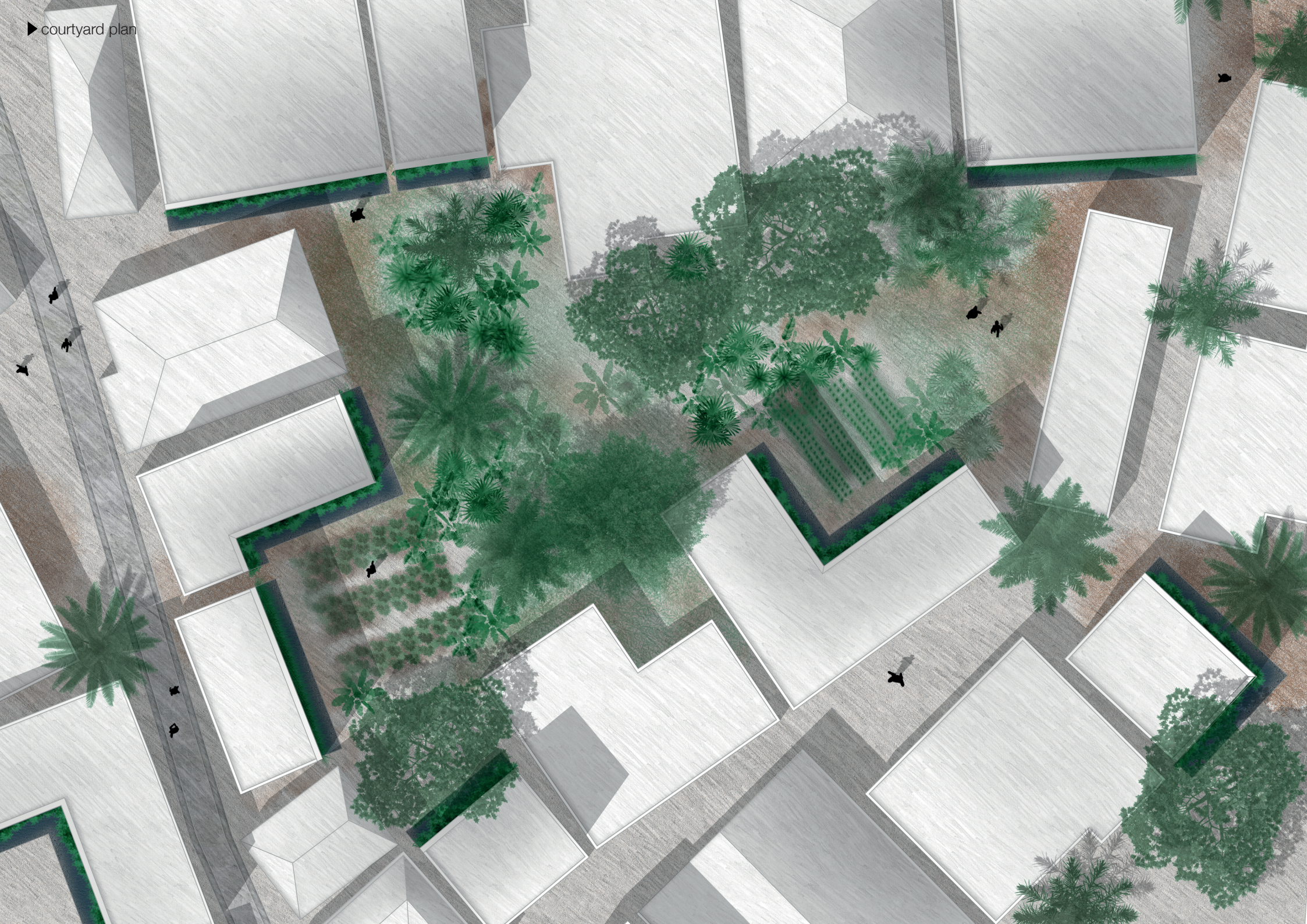
▶ relation city



City scheme
main access
waste flow

▶ site plan

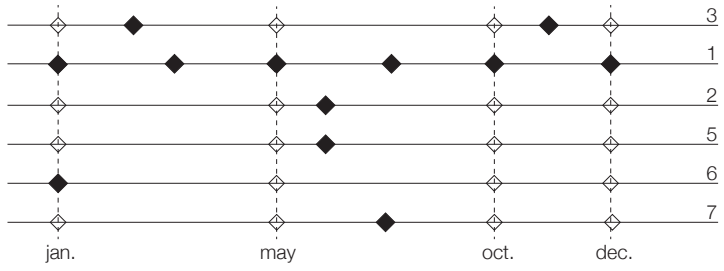



courtyard plan

▶ plant selection/harvest

Courtyard trees:
1 cocos nucifera / 2 carica papaya / 3 musa sapientum / 4 encephalartos hildebrandtii / 5 tamarindus indica / 6 mangifera indica / 7 ficus sycomorus







▶ cross section west side





▶ cross section east side

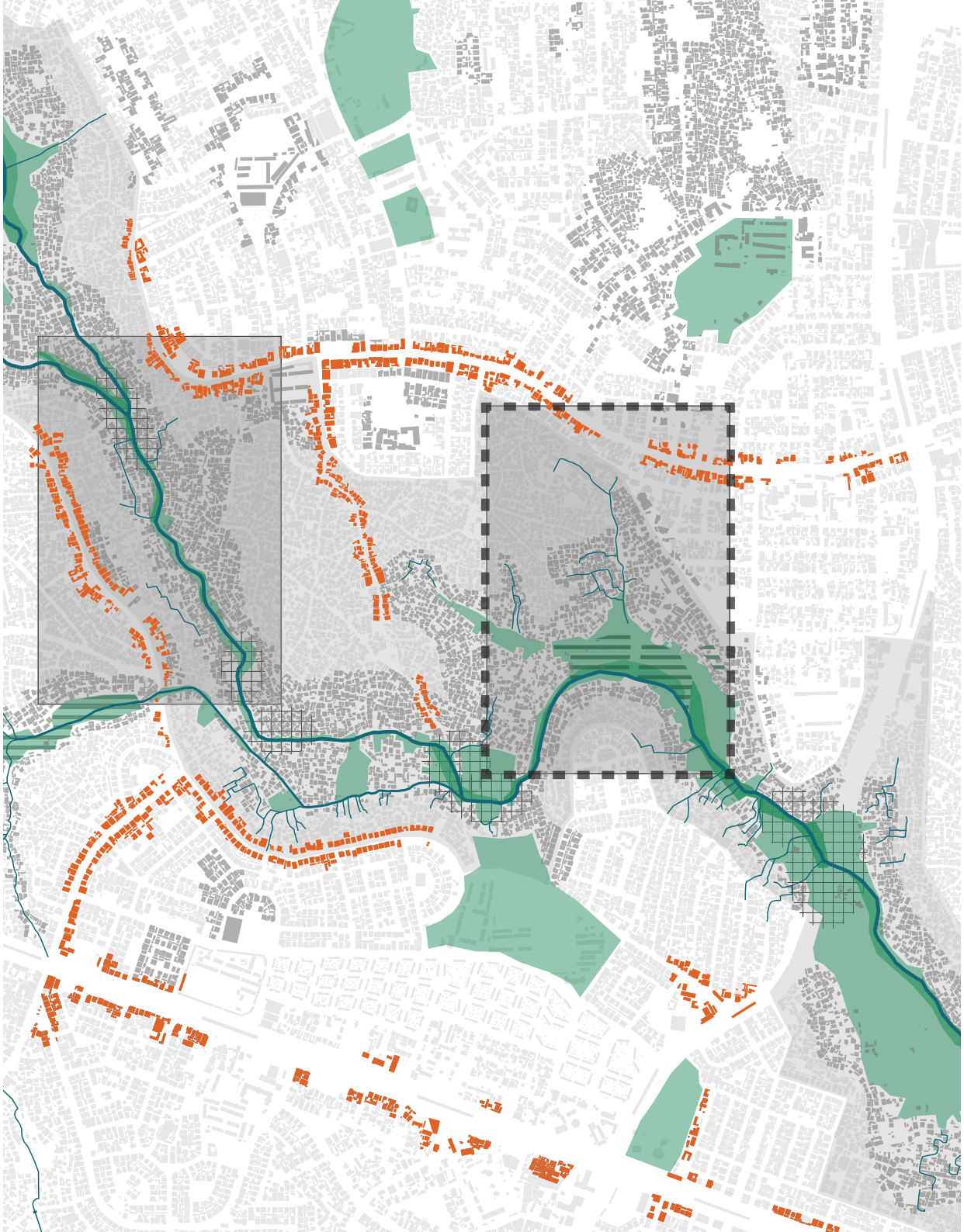






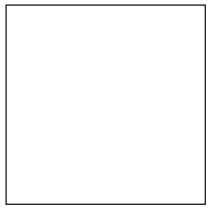


▶ chinampa



Individual design location

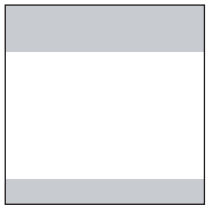
- blue structure
- agriculture
- green structure
- informal settlement
- flood risk area
- waste
- commercial streets
- individual design location



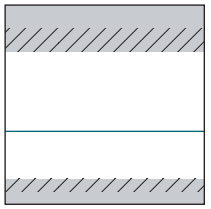
total area: 500.000m^2



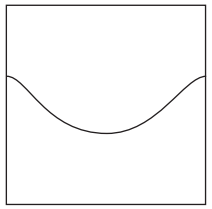
river valley:105.000m^2



built up area: 35%



flood risk buildings: 50%



total height difference: 12m

▶ site analysis

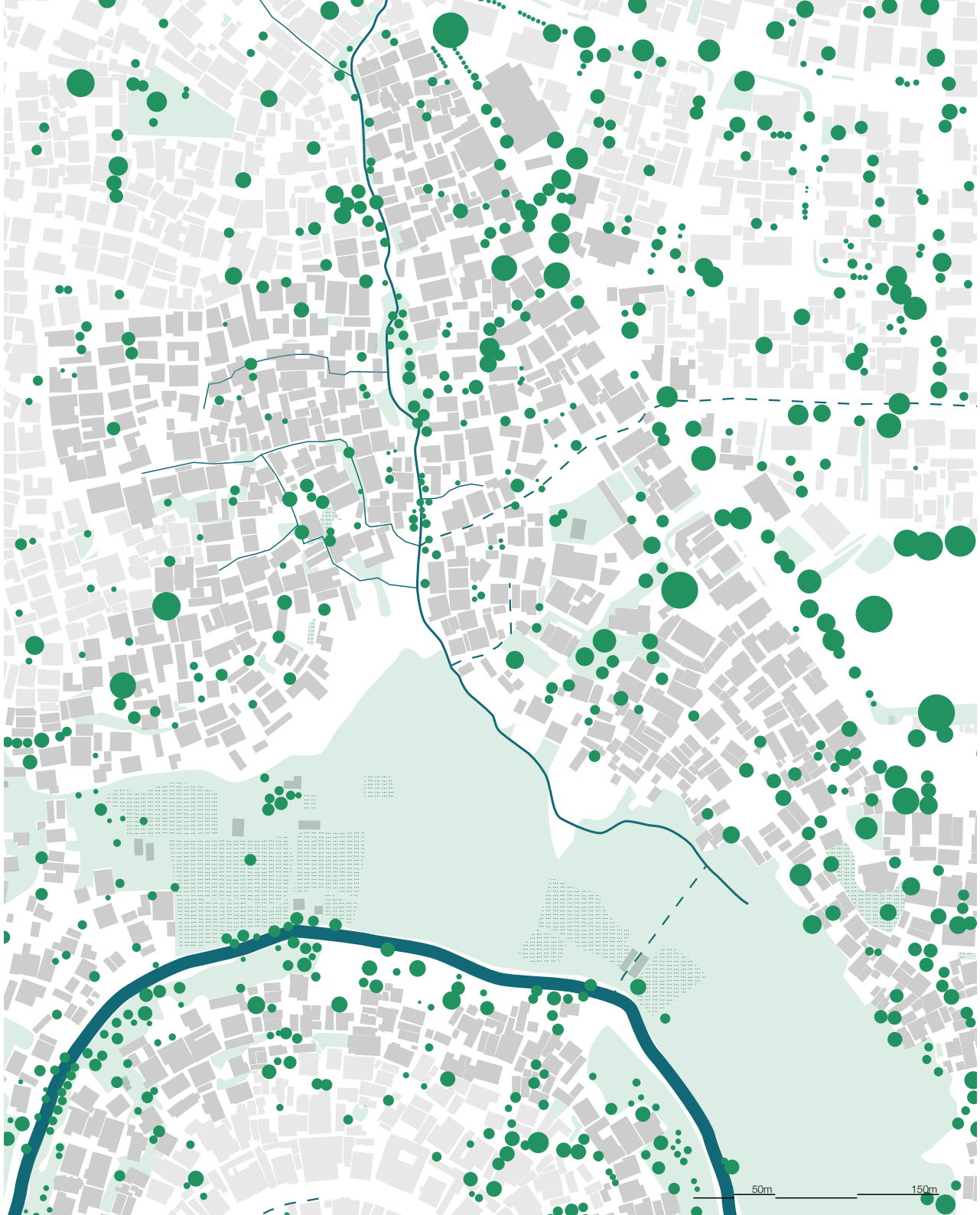


elevations

buildings

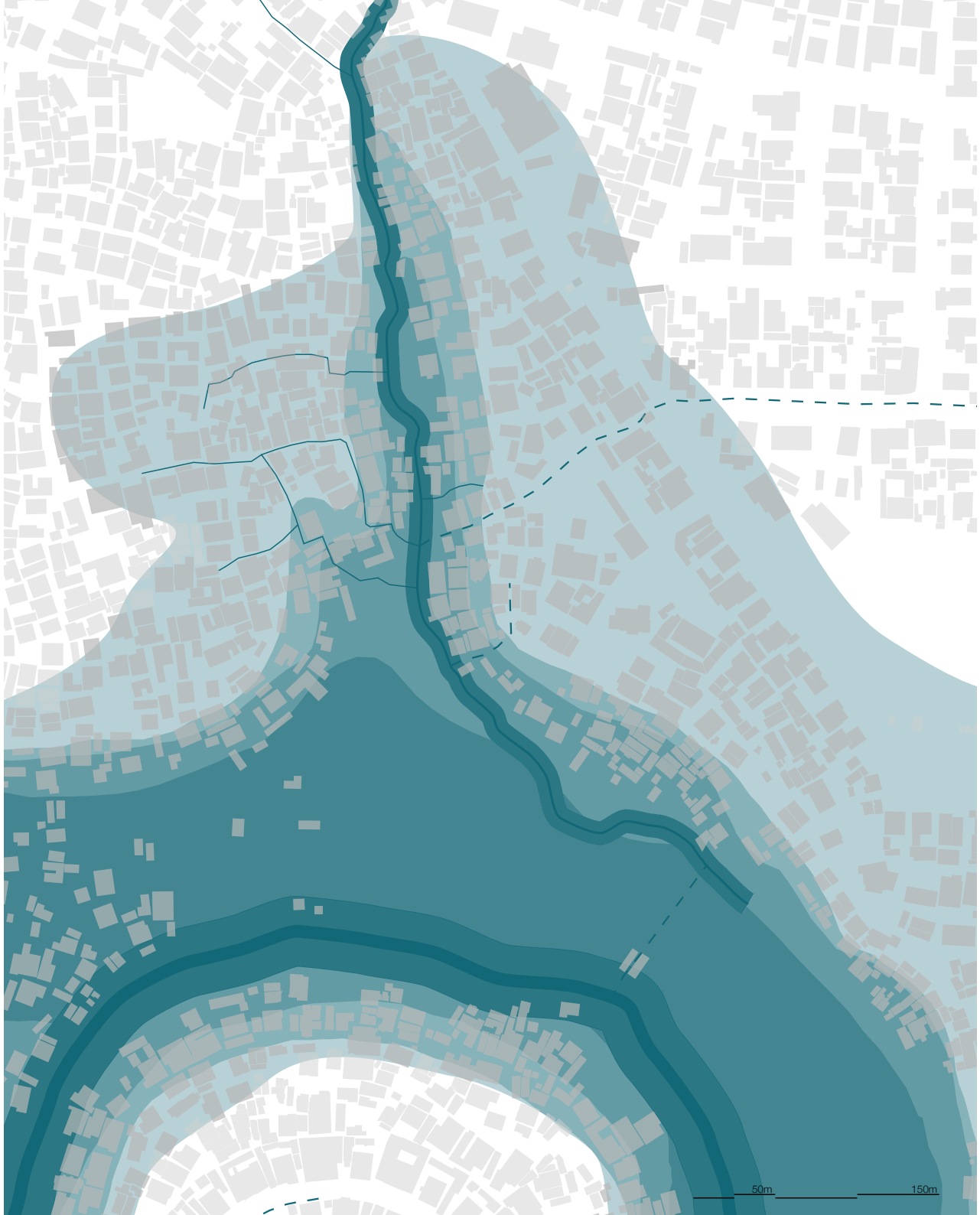
2m elevation line

▶ site analysis



green
buildings
buildings at risk
river/creek
drainage
grass/bushes
agriculture
tree

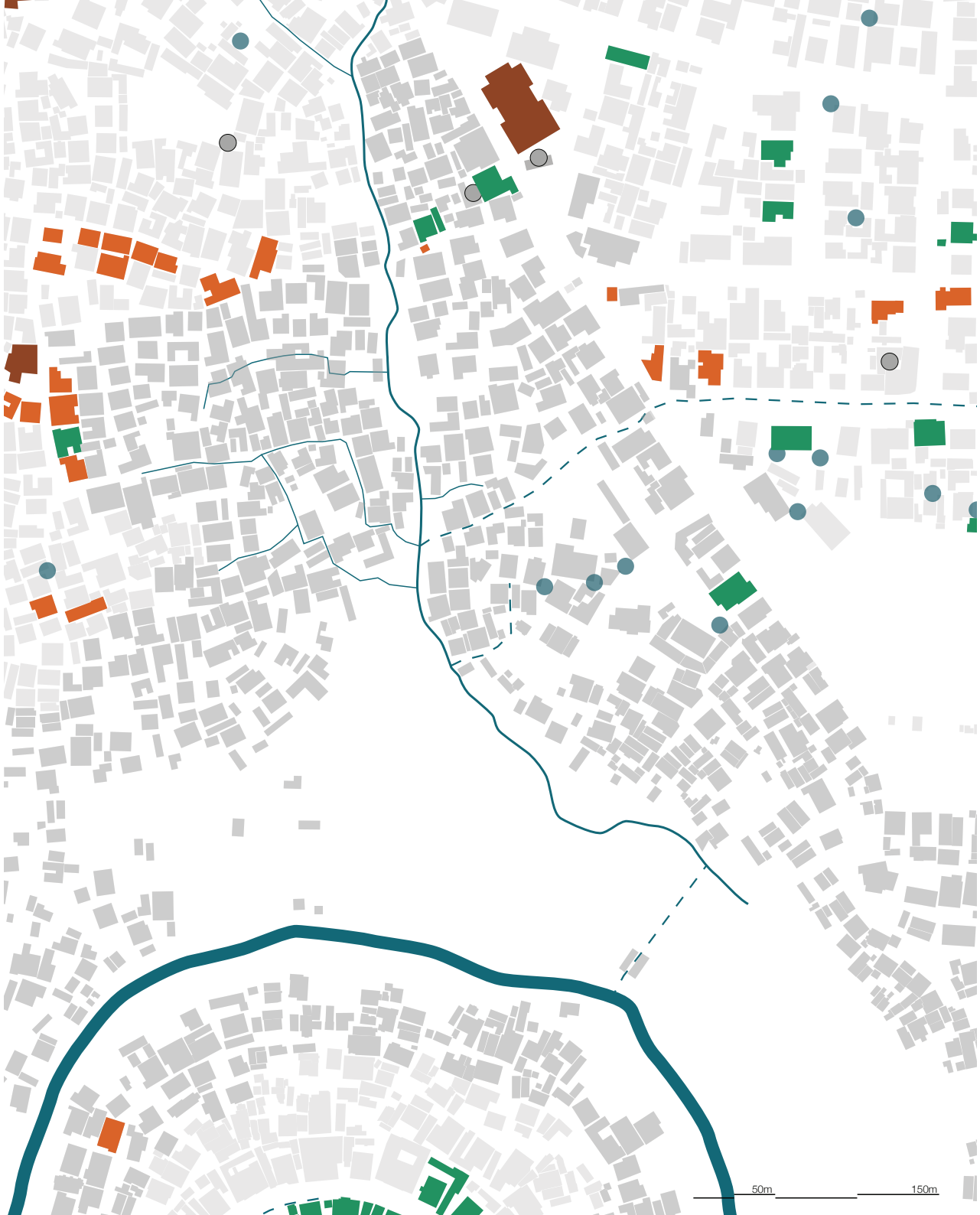
▶ site analysis



flood risk

- buildings
- buildings at risk
- river/creek
- immediate flooding
- low flooding
- moderate flooding
- high flooding
- extreme flooding

▶ site analysis

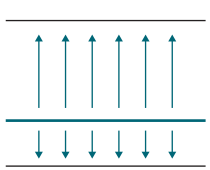


▶ site analysis

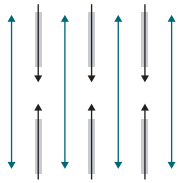


connectivity

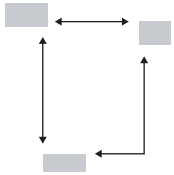
- water surface
- main road
- local road
- pedestrian path
- water crossing
- dead end



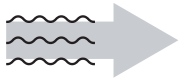
space for water



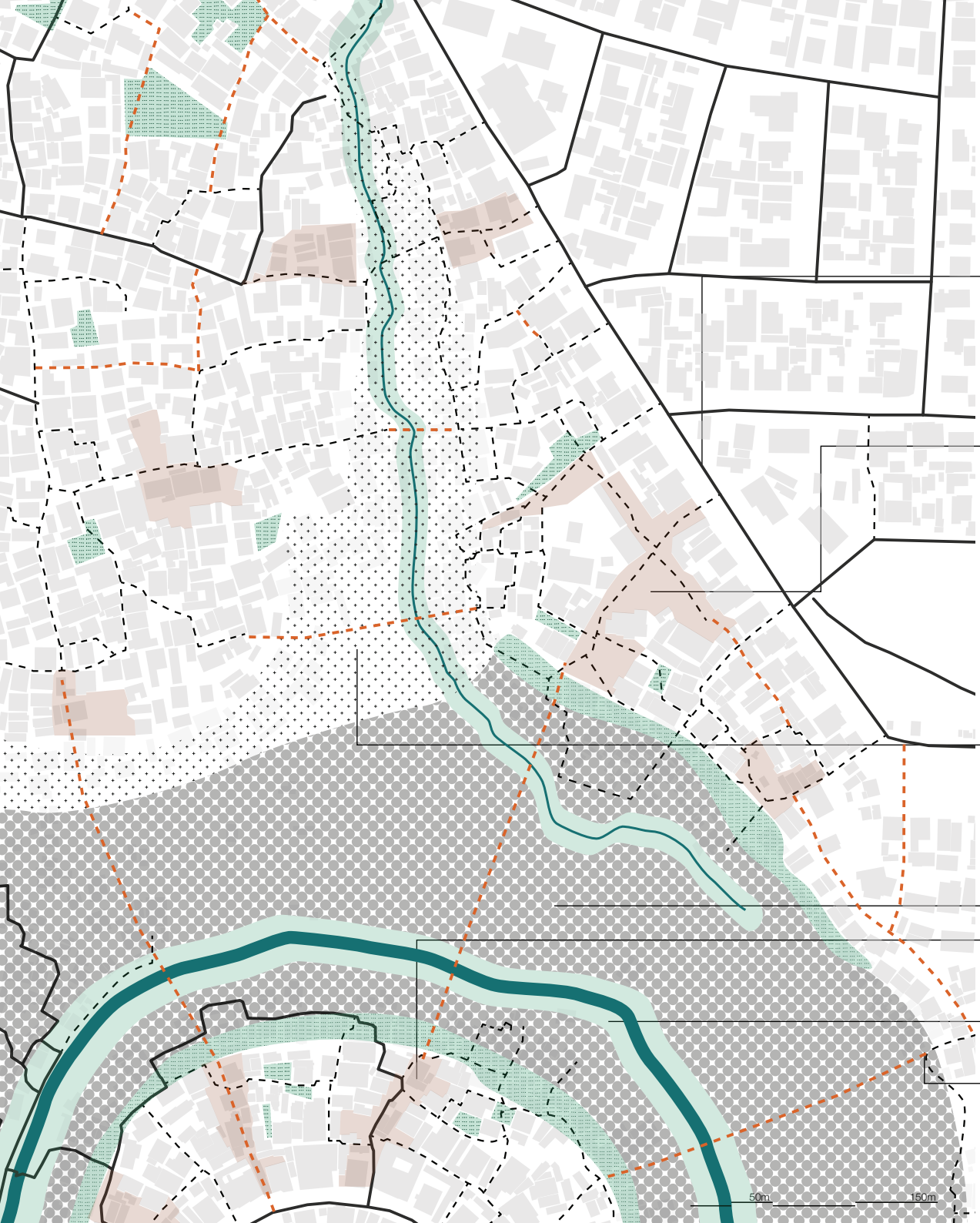
combine water & human adaptation

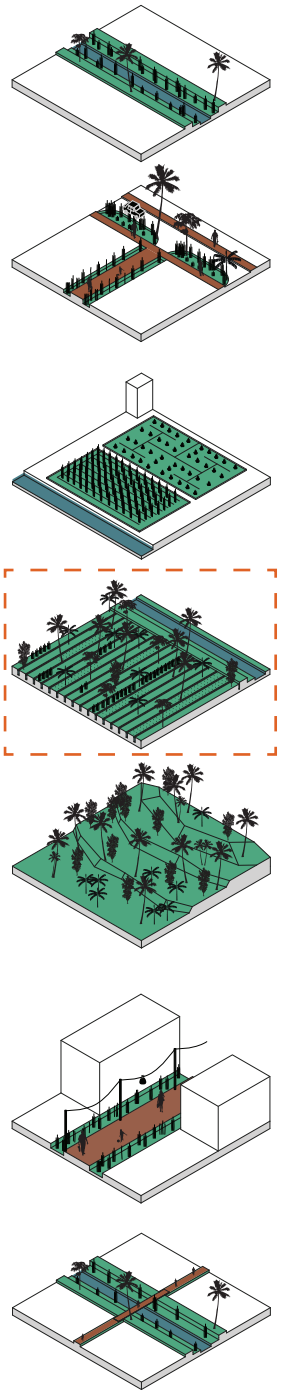


connect economic clusters

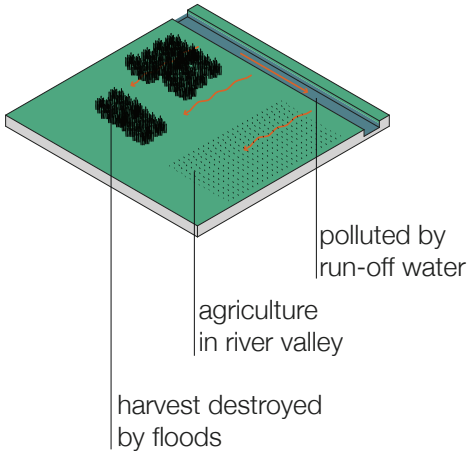


steer movement of water

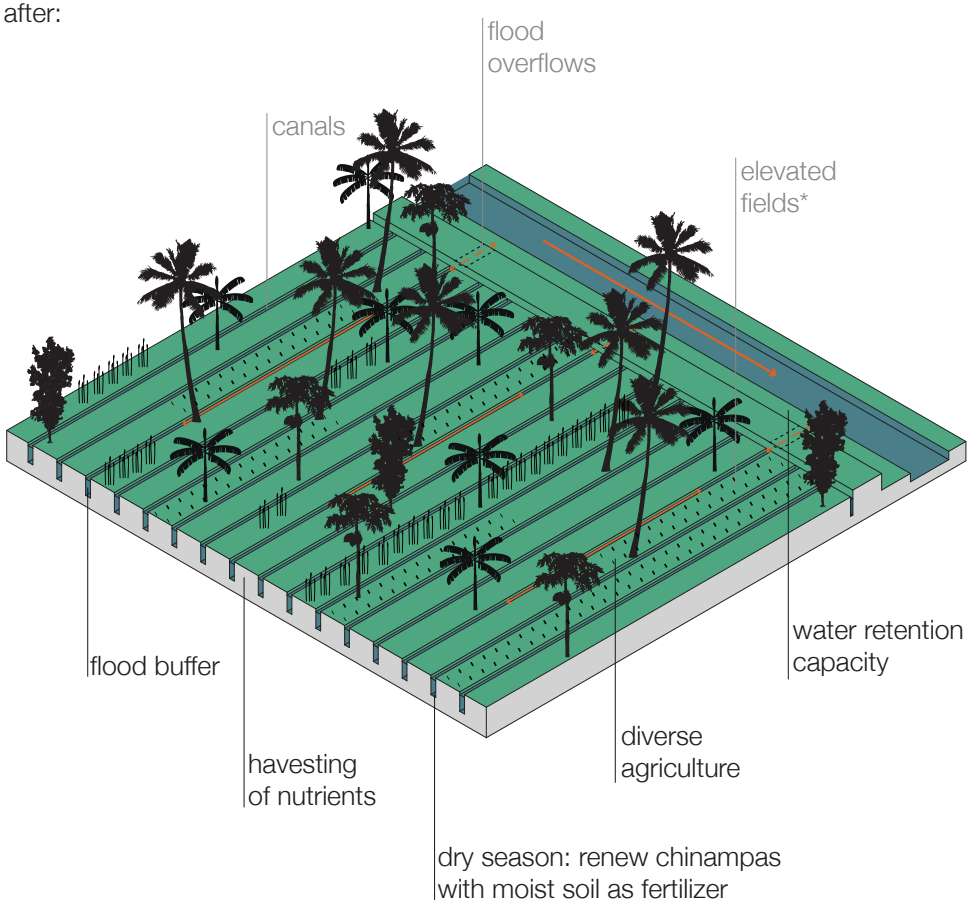

50m
150m



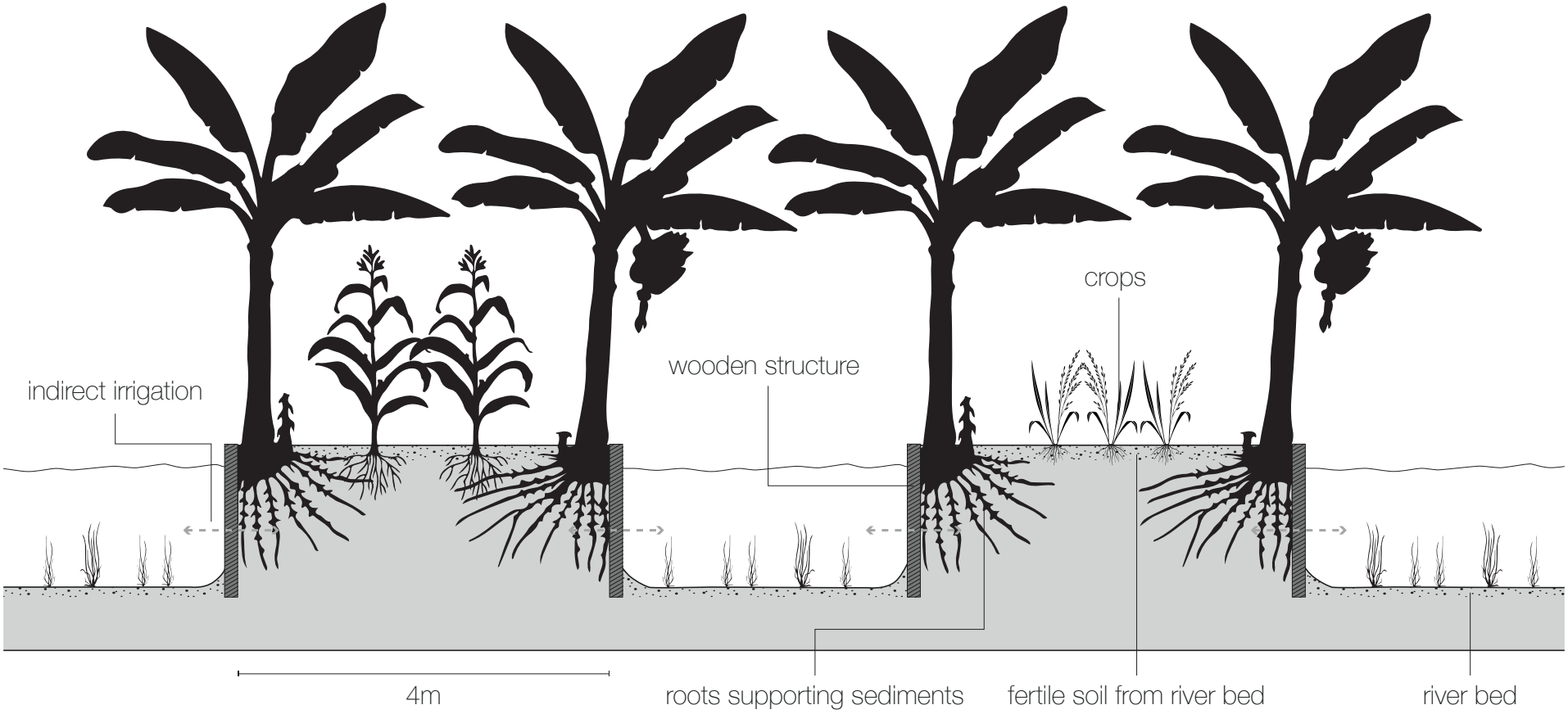
before:



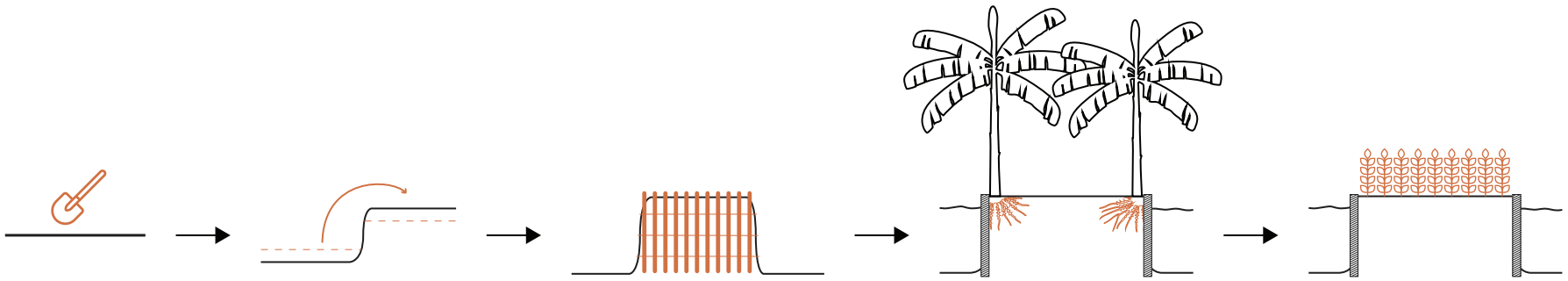
after:



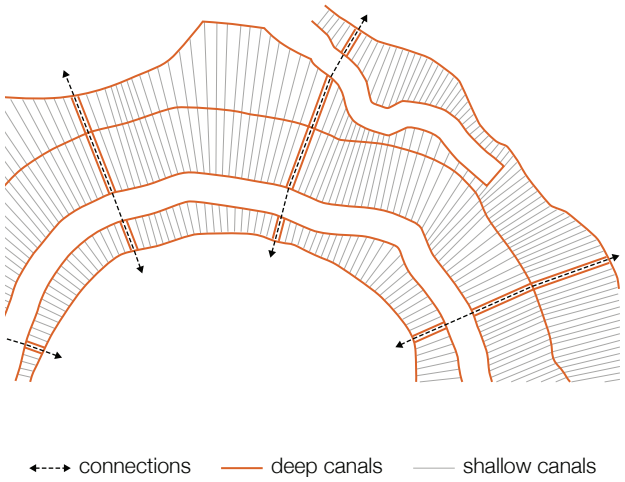
problems addressed:

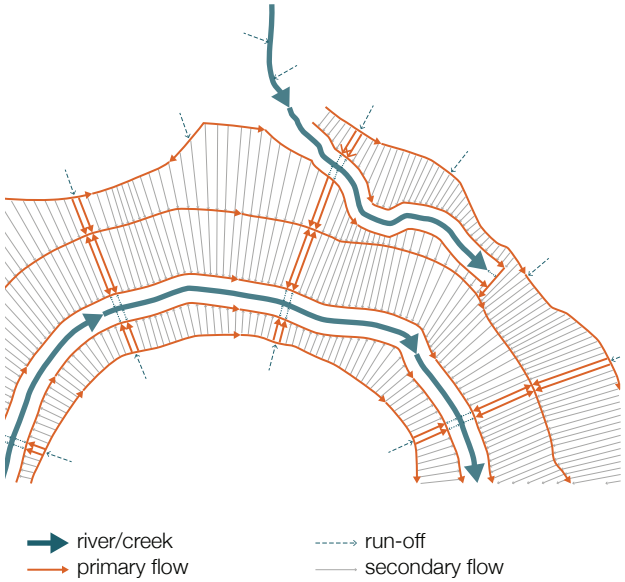

crops
wooden structure
indirect irrigation
4m
roots supporting sediments
fertile soil from river bed
river bed

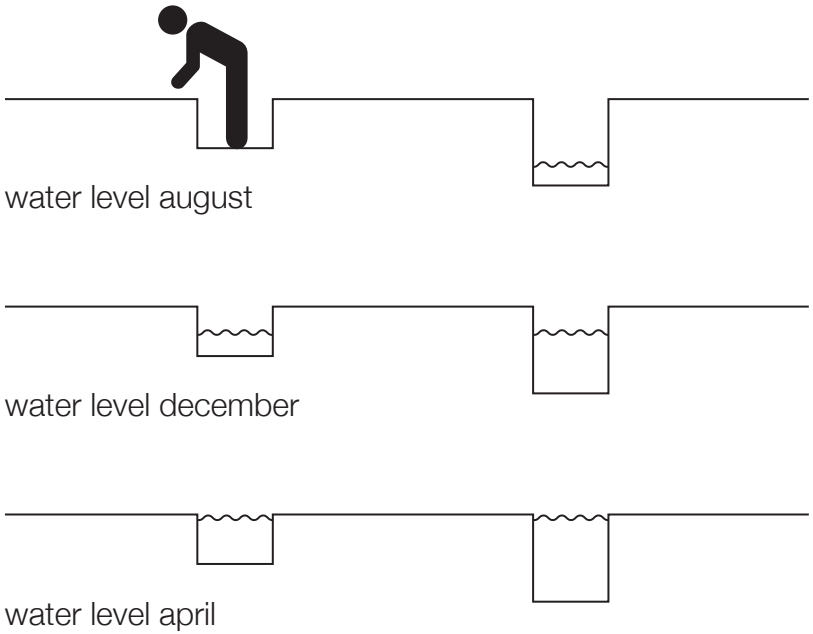
▶ chinampa


dig even ground
pile up soil
build supporting wood structure
plant trees to hold soil
plant crops for agriculture

▶ water capacity

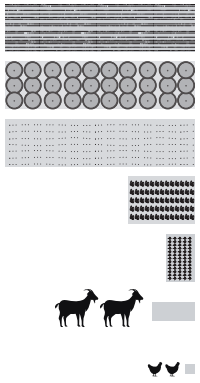





water level august
water level december
water level april

spatial requirements for 1 person/year

contribution to food demand of neighbourhood



wheat 100m²

fruits & nuts 100m²

legumes 100m²

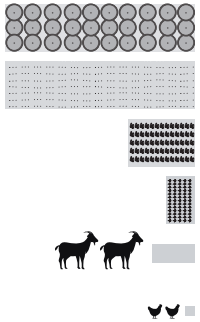
vegetables 35m²

potatoes 15m²

2 goats 9m²

2chicken 2m²

1,12 %



fruits & nuts 100m²

legumes 100m²

vegetables 35m²

potatoes 15m²

2 goats 9m²

2chicken 2m²

1,57 %



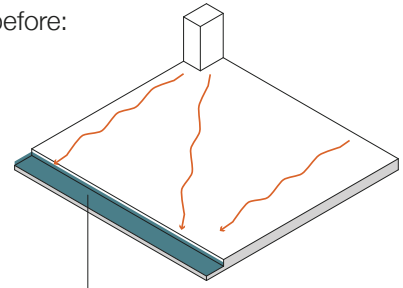
vegetables 35m²

11,52 %

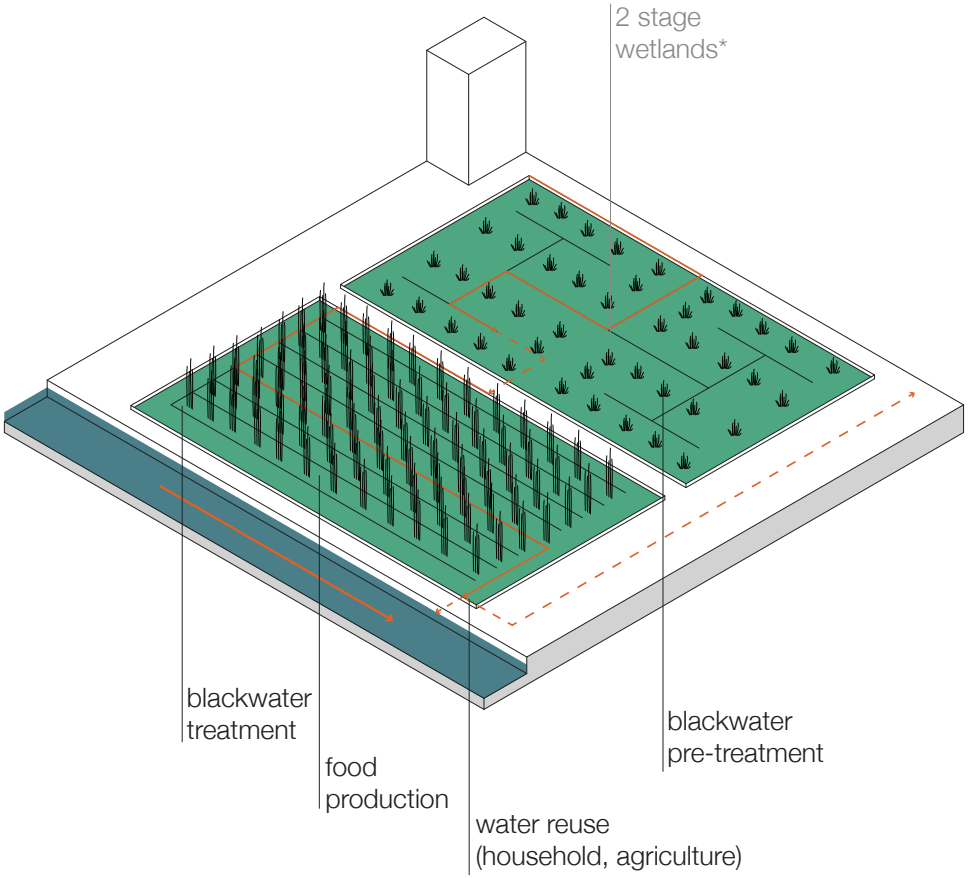
food demand covered by production on chinampas

▶ constructed wetlands

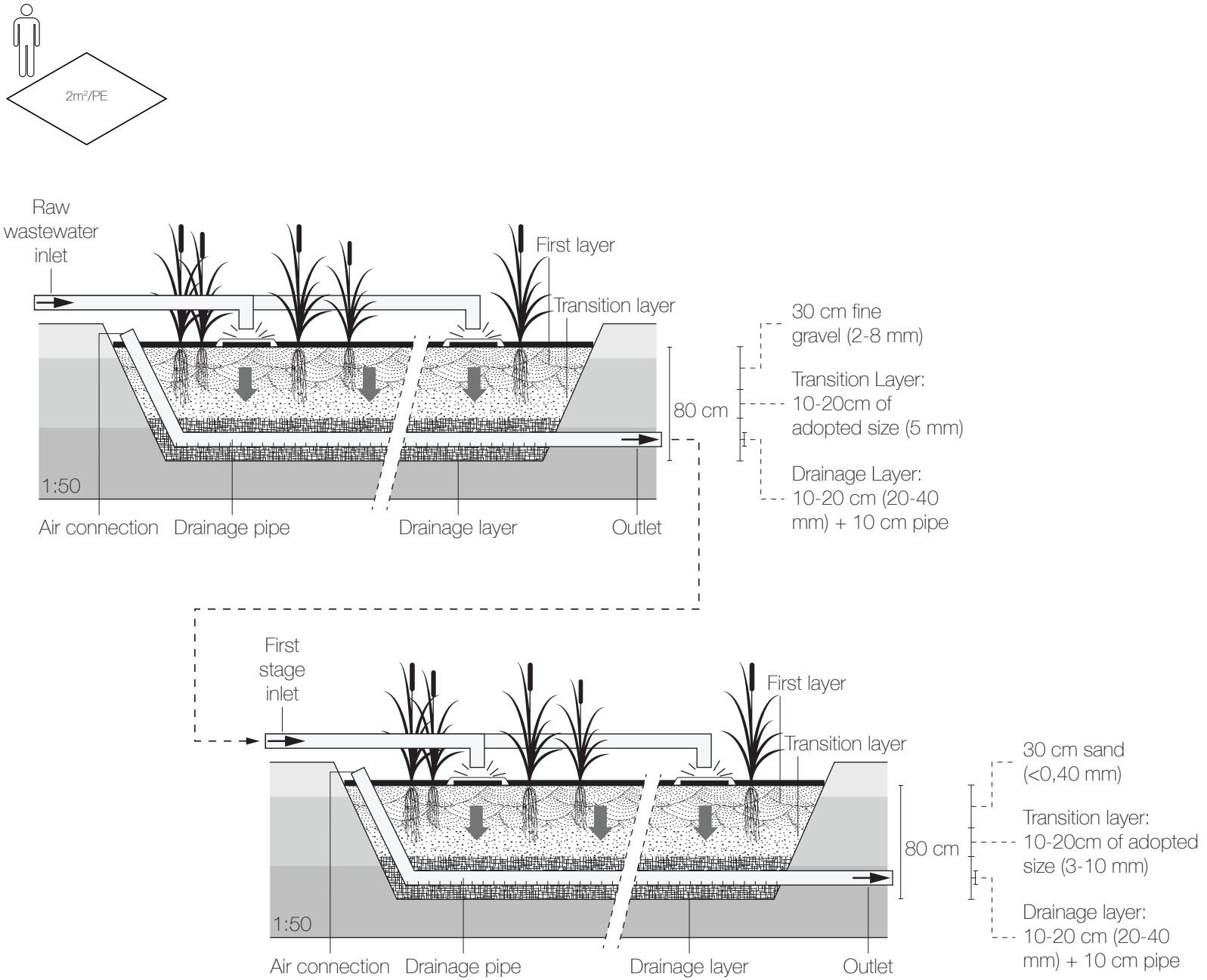
before:



after:

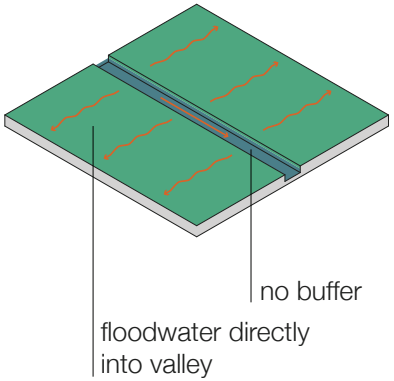


problems addressed:

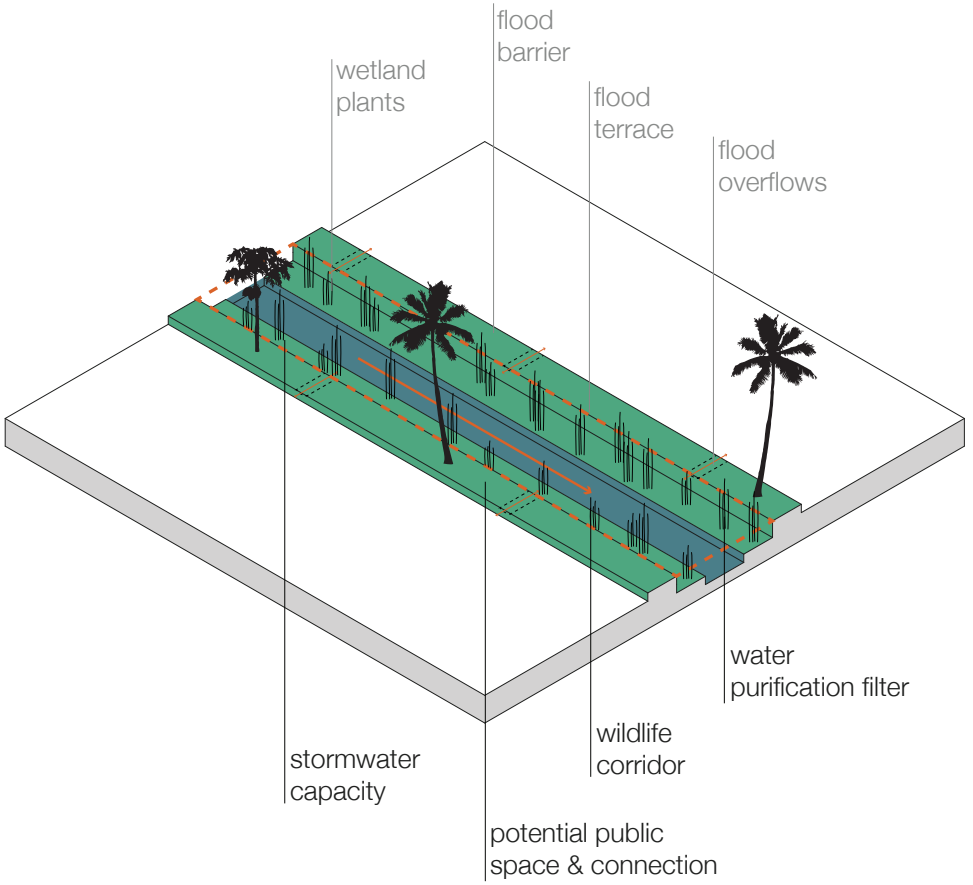

2m²/PE
Raw wastewater inlet
First layer
Transition layer
30 cm fine gravel (2-8 mm)
Transition Layer: 10-20cm of adopted size (5 mm)
Drainage Layer: 10-20 cm (20-40 mm) + 10 cm pipe
80 cm
1:50
Air connection
Drainage pipe
Drainage layer
Outlet
First stage inlet
First layer
Transition layer
30 cm sand (<0,40 mm)
Transition layer: 10-20cm of adopted size (3-10 mm)
Drainage layer: 10-20 cm (20-40 mm) + 10 cm pipe
80 cm
1:50
Air connection
Drainage pipe
Drainage layer
Outlet

▶ riverine buffer zone

before:



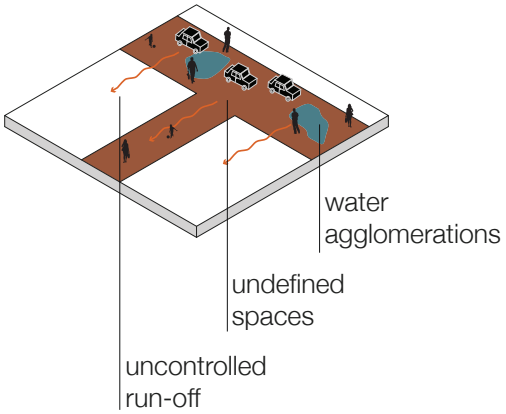
after:



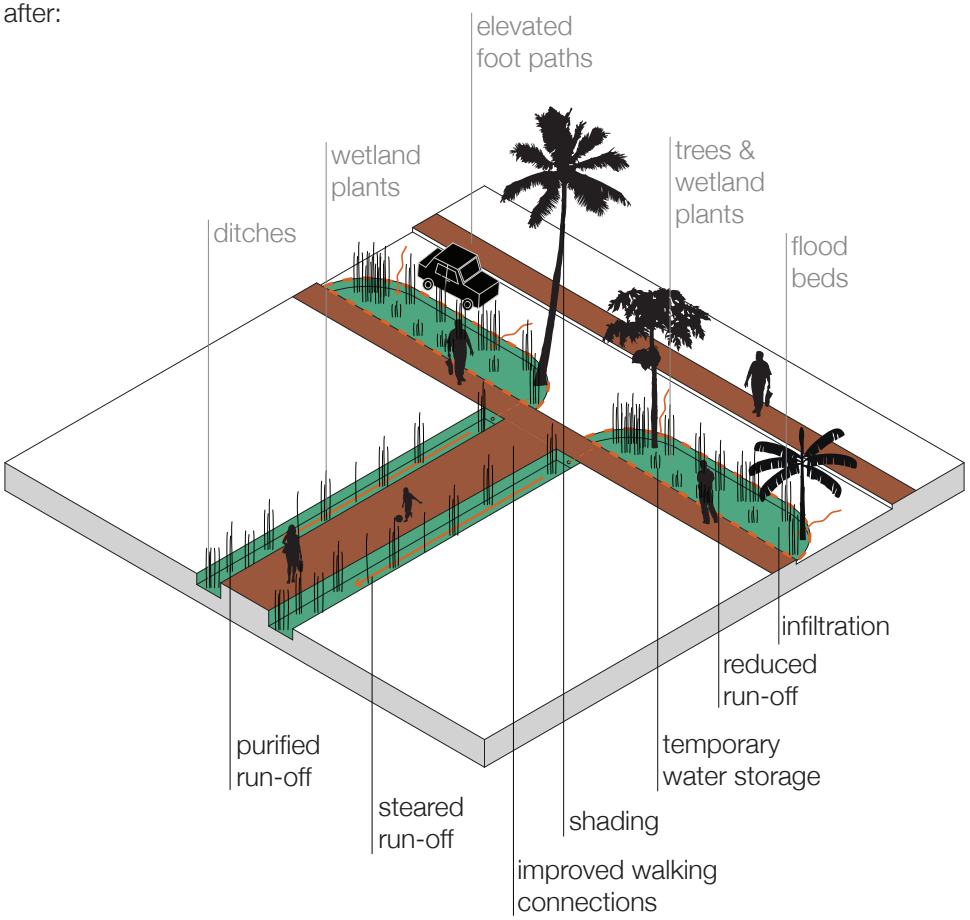
problems addressed:

▶ retention area

before:



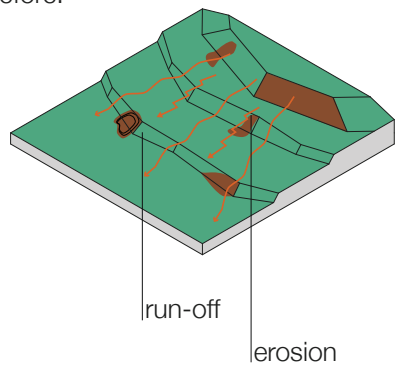
after:



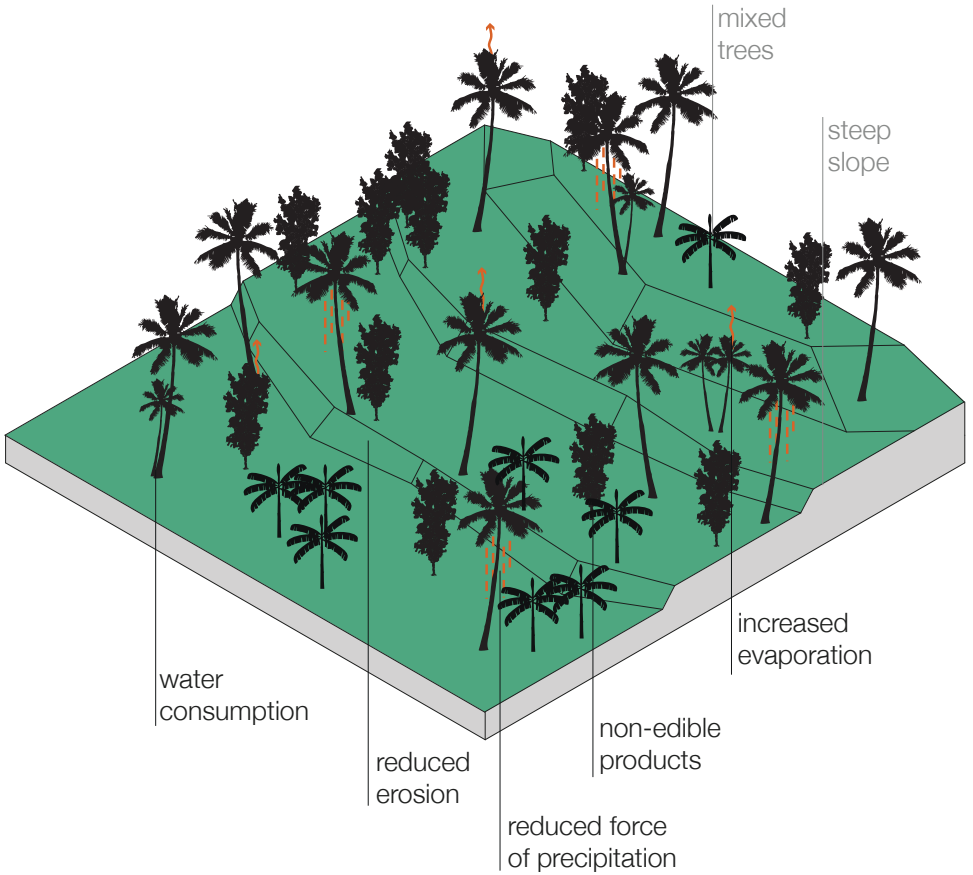
problems addressed:


EL-FALAAH ISLAMIC CENTRE

before:

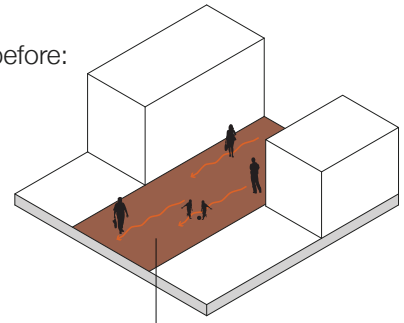


after:



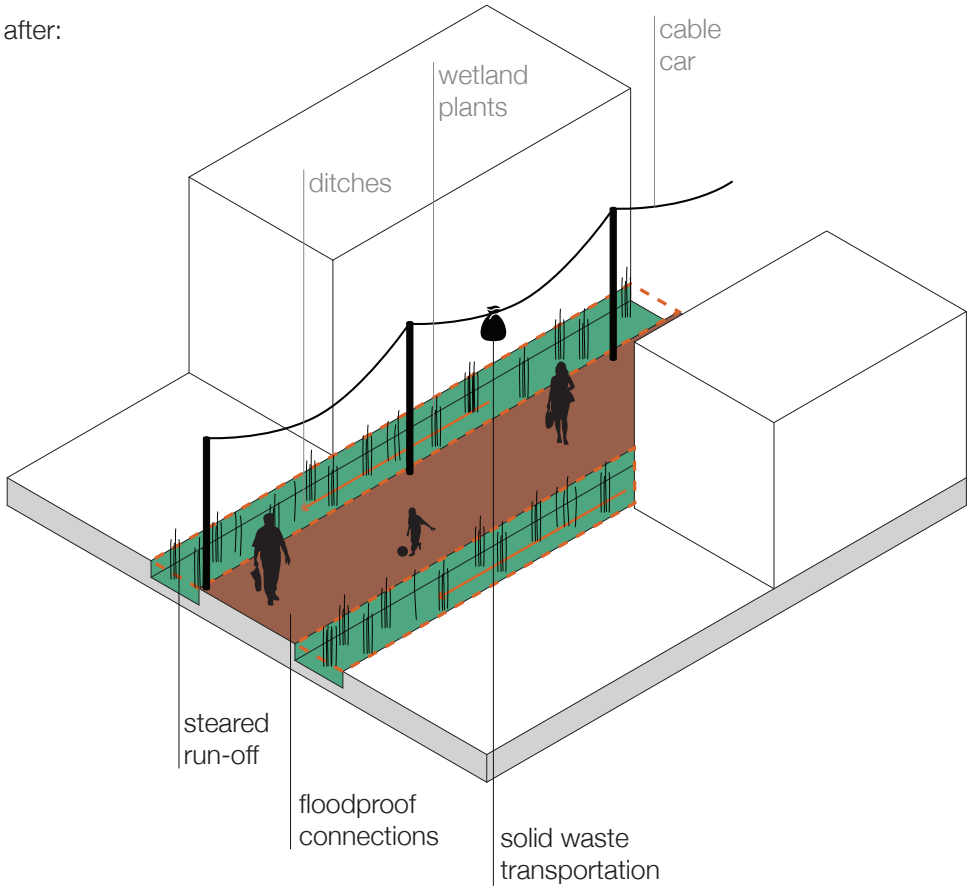
problems addressed:

before:



flooded pathways
during heavy rainfall

after:

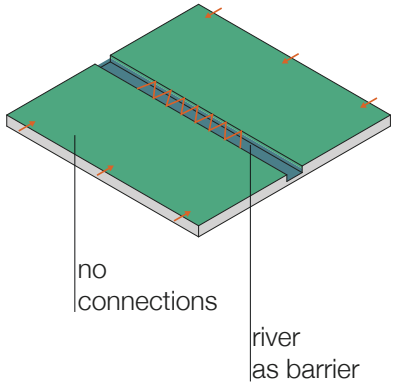


problems addressed:

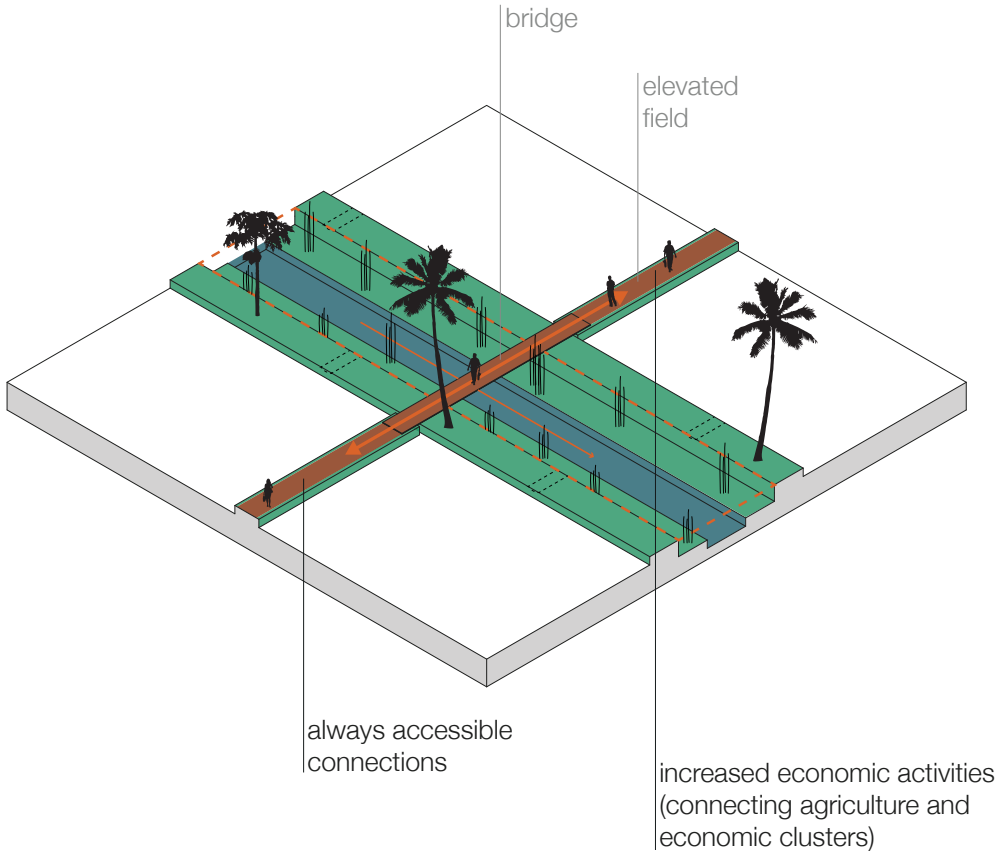


▶ connection valley

before:

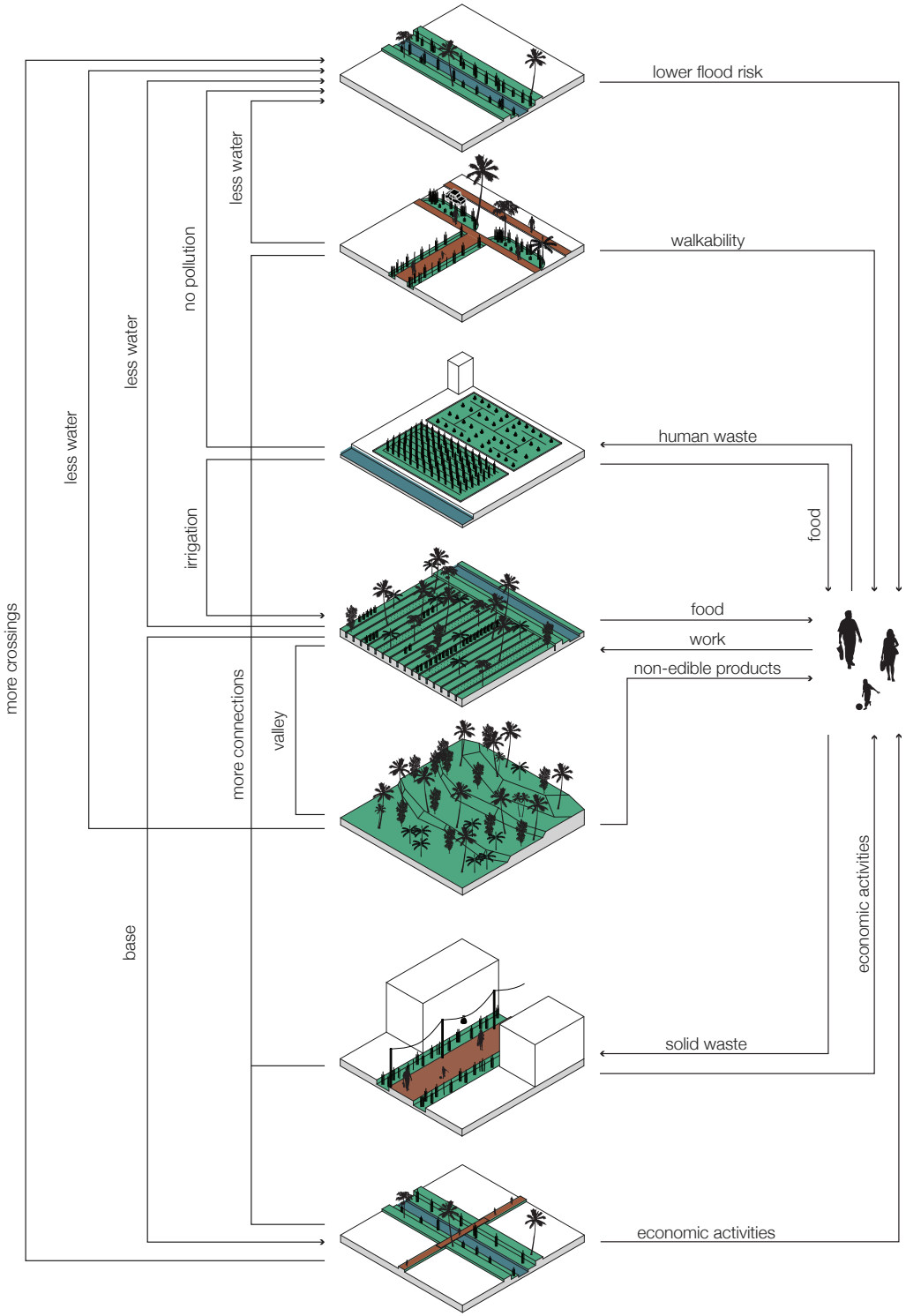


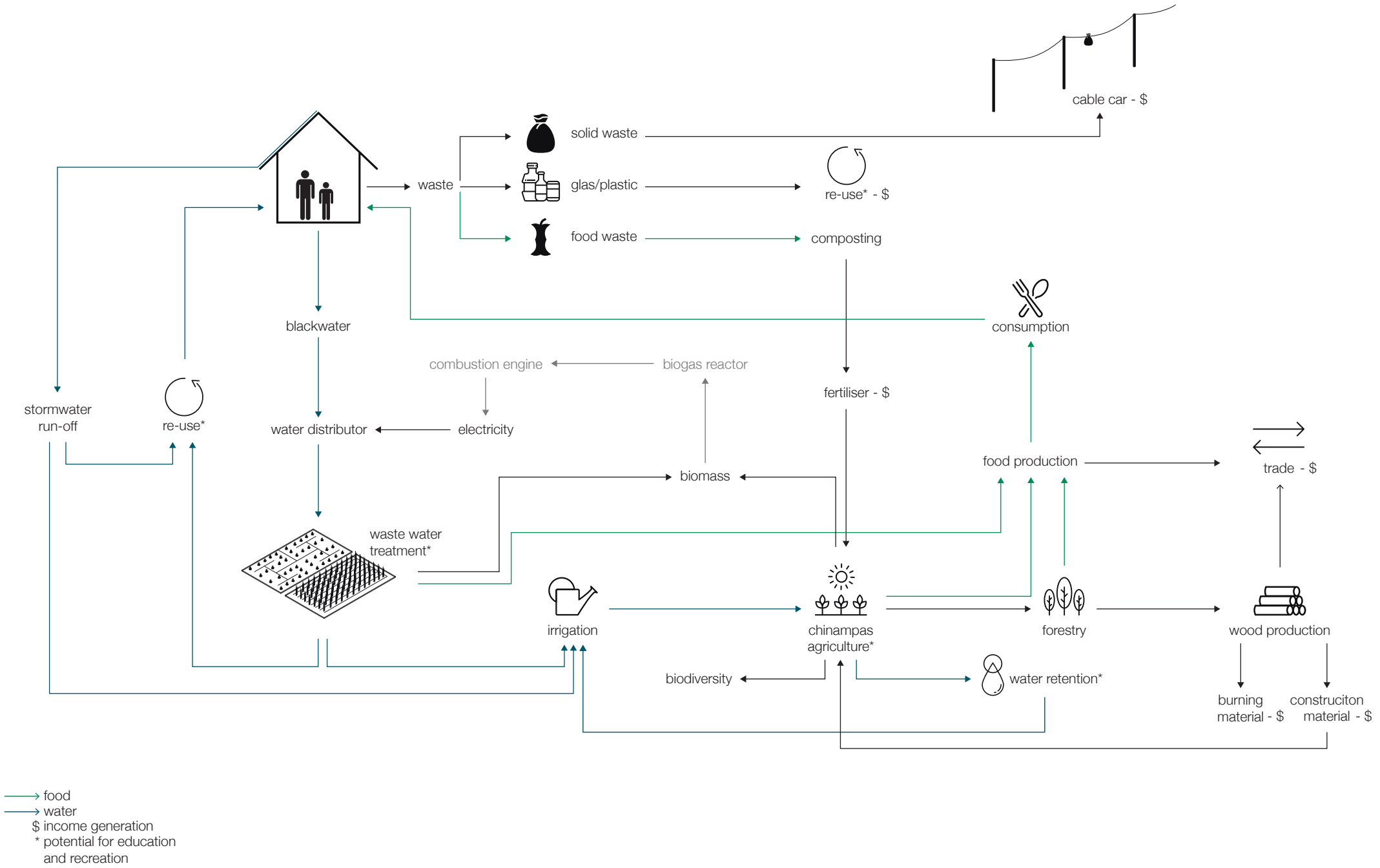
after:



problems addressed:

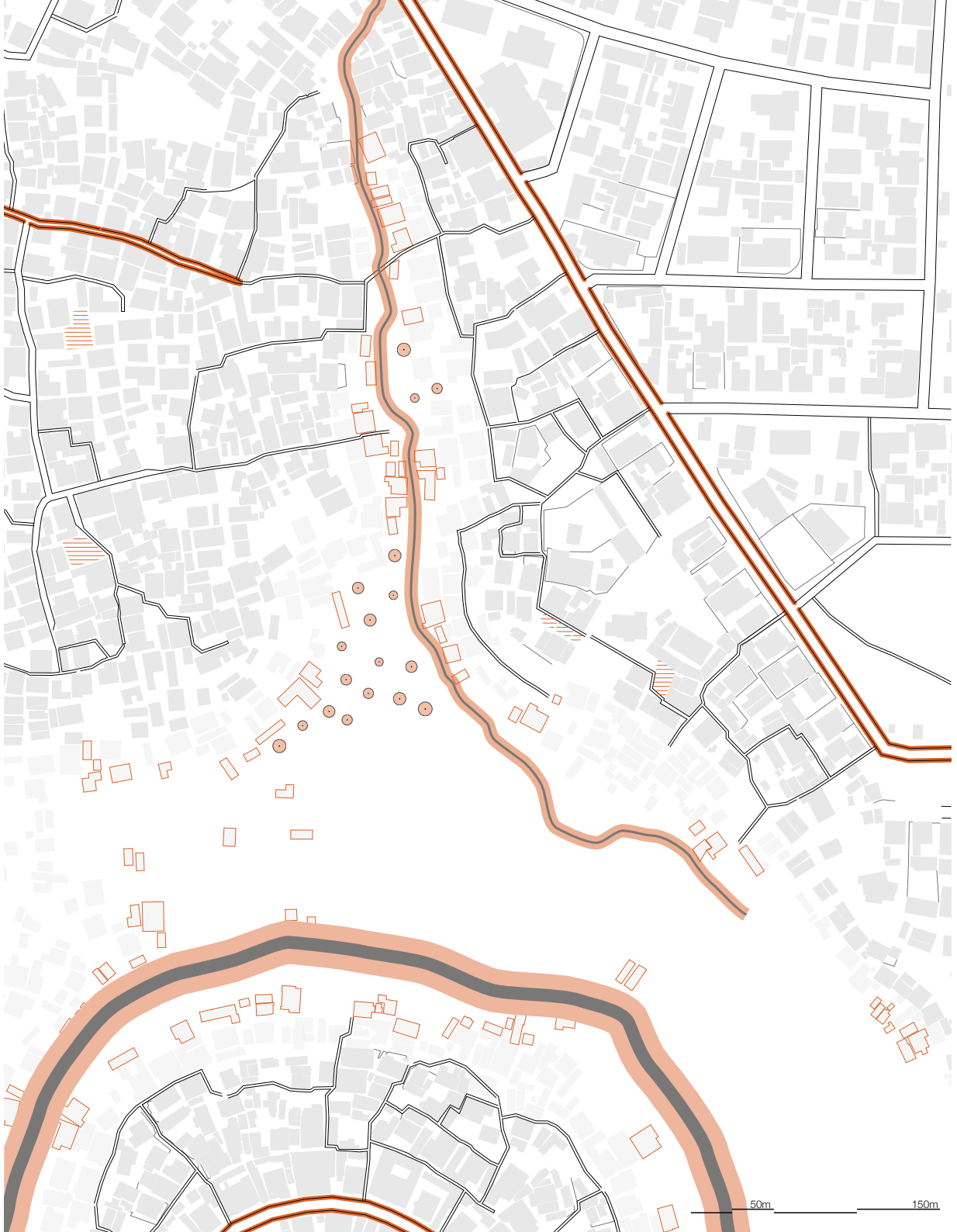
▶ intervention relation





food
water
$ income generation
* potential for education and recreation

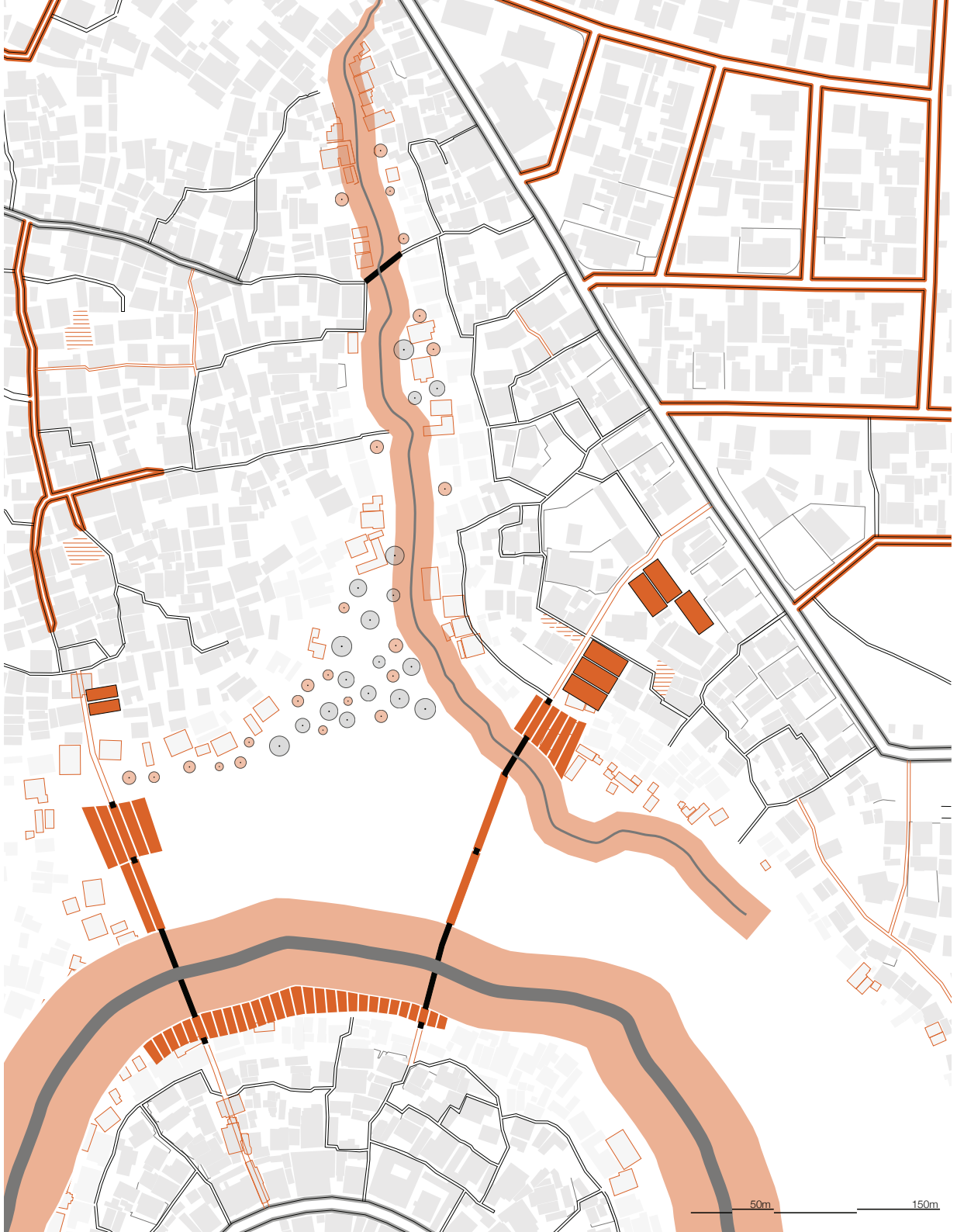
▶ chinampa development



development I

- buildings to demolish
- river/creek
- ditches
- riverine buffer zone
- connections
- agriculture
- trees

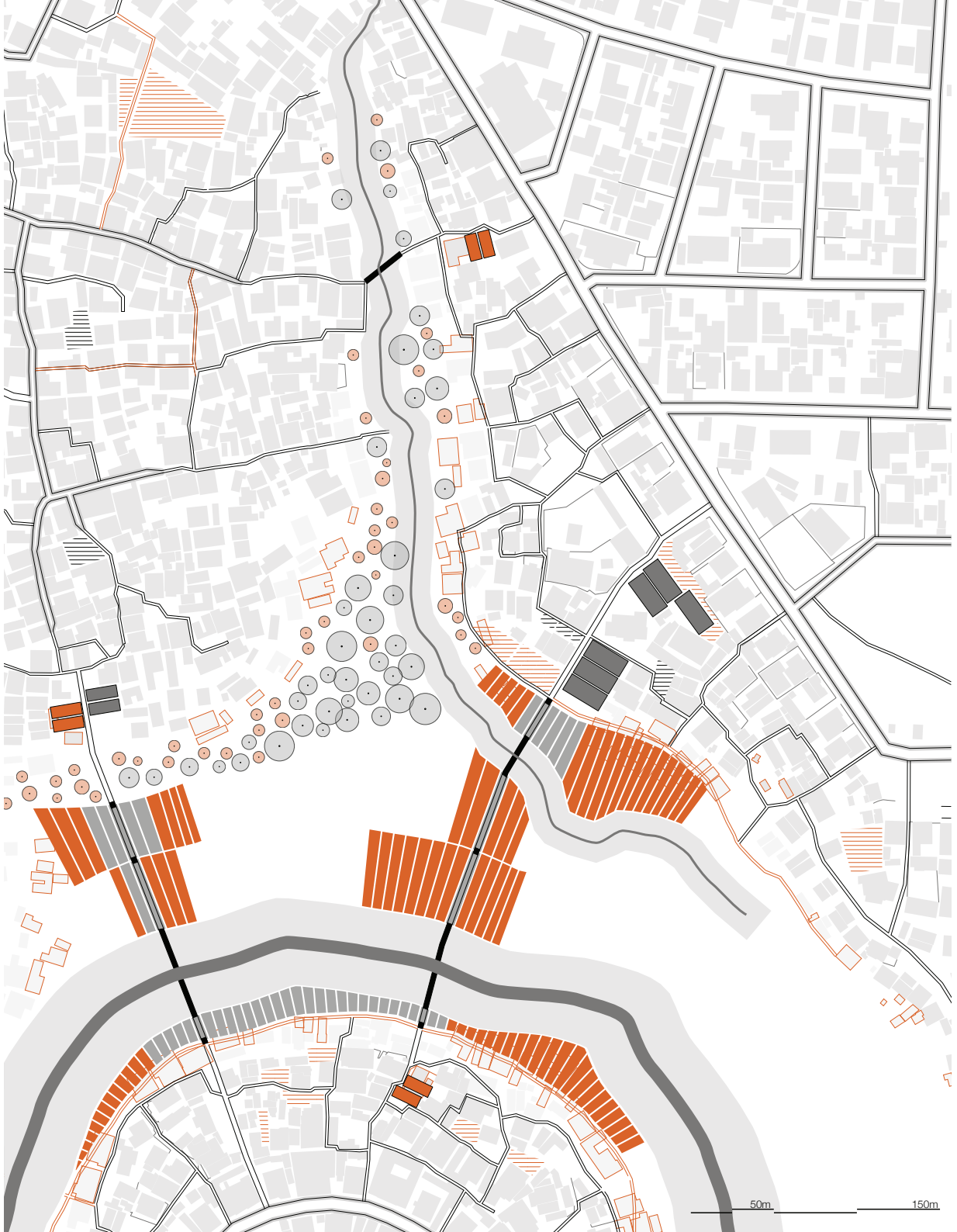
▶ chinampa development



development II

- buildings to demolish
- river/creek
- ditches
- riverine buffer zone
- connections
- agriculture
- trees
- chinampas
- constructed wetland

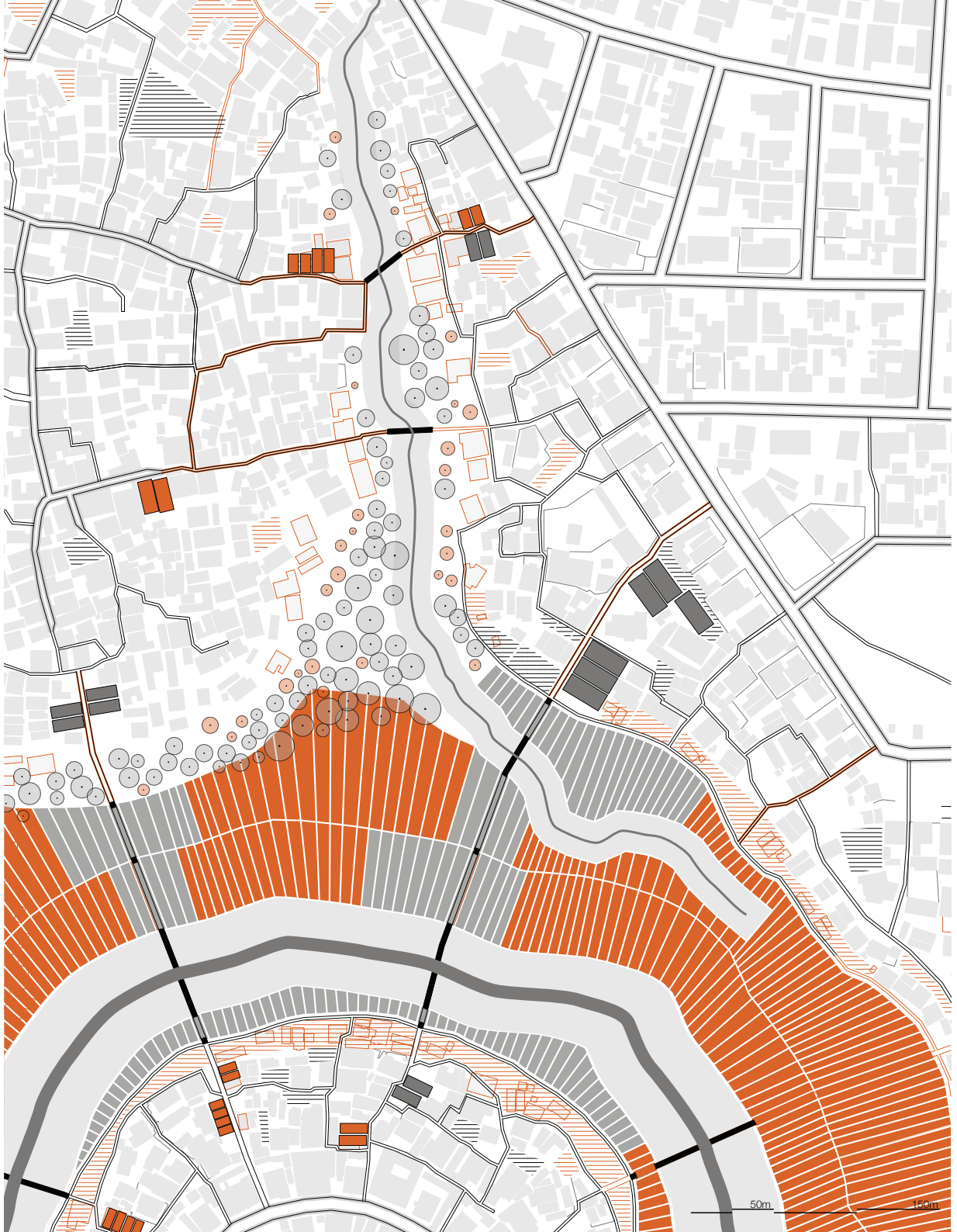
▶ chinampa development



development III

- buildings to demolish
- river/creek
- ditches
- riverine buffer zone
- connections
- agriculture
- trees
- chinampas
- constructed wetland

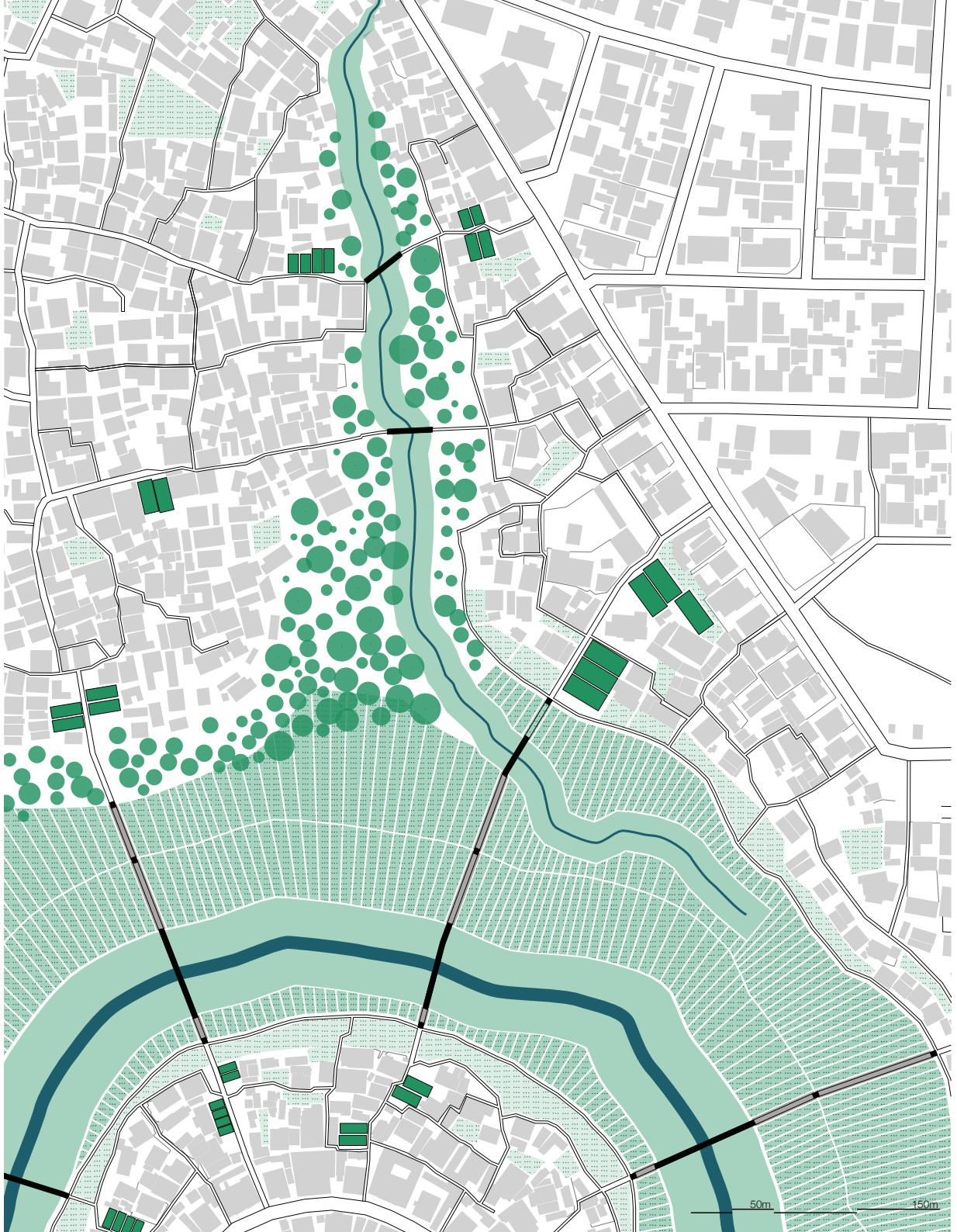
▶ chinampa development



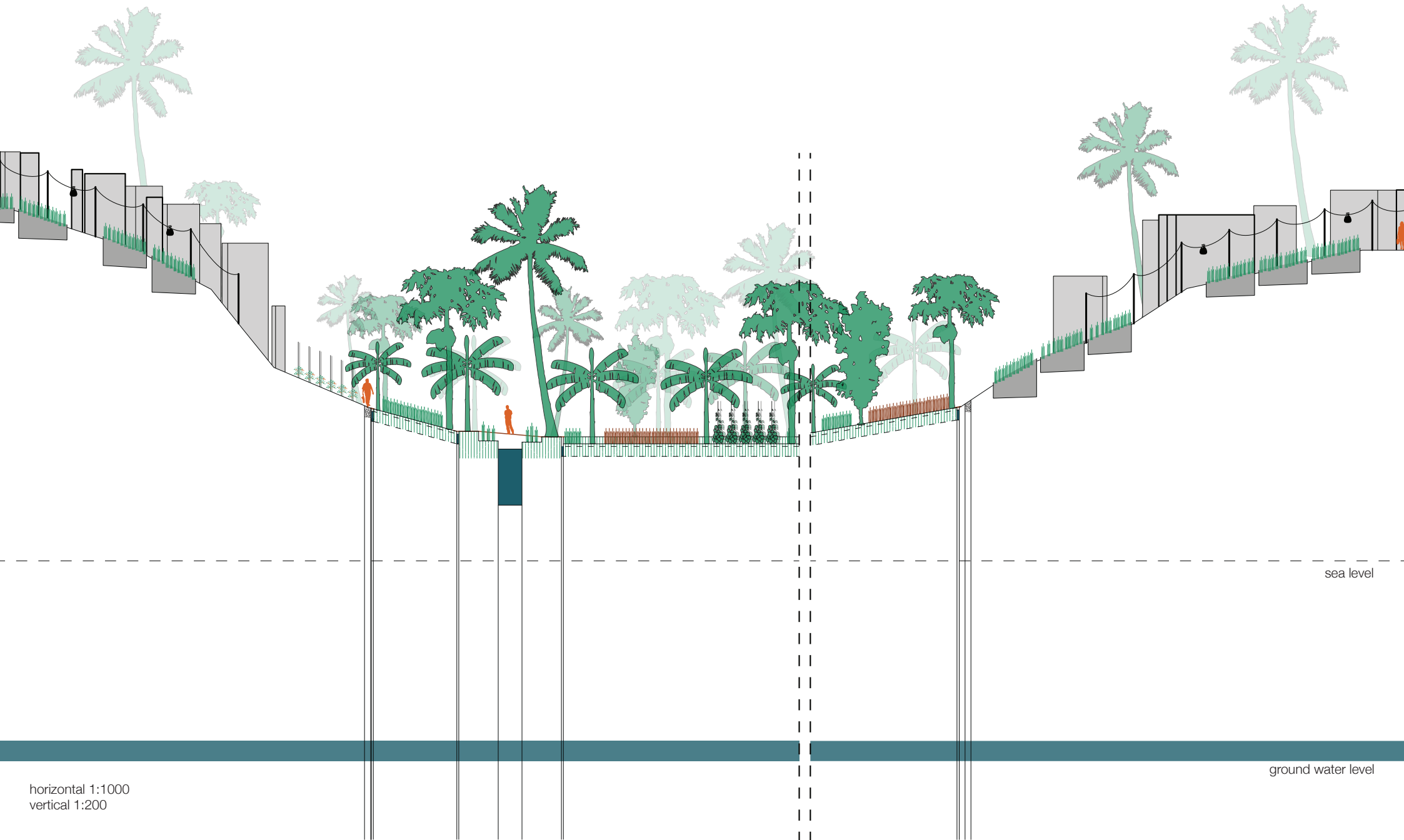
development llll

- buildings to demolish
- river/creek
- ditches
- riverine buffer zone
- connections
- agriculture
- trees
- chinampas
- constructed wetland

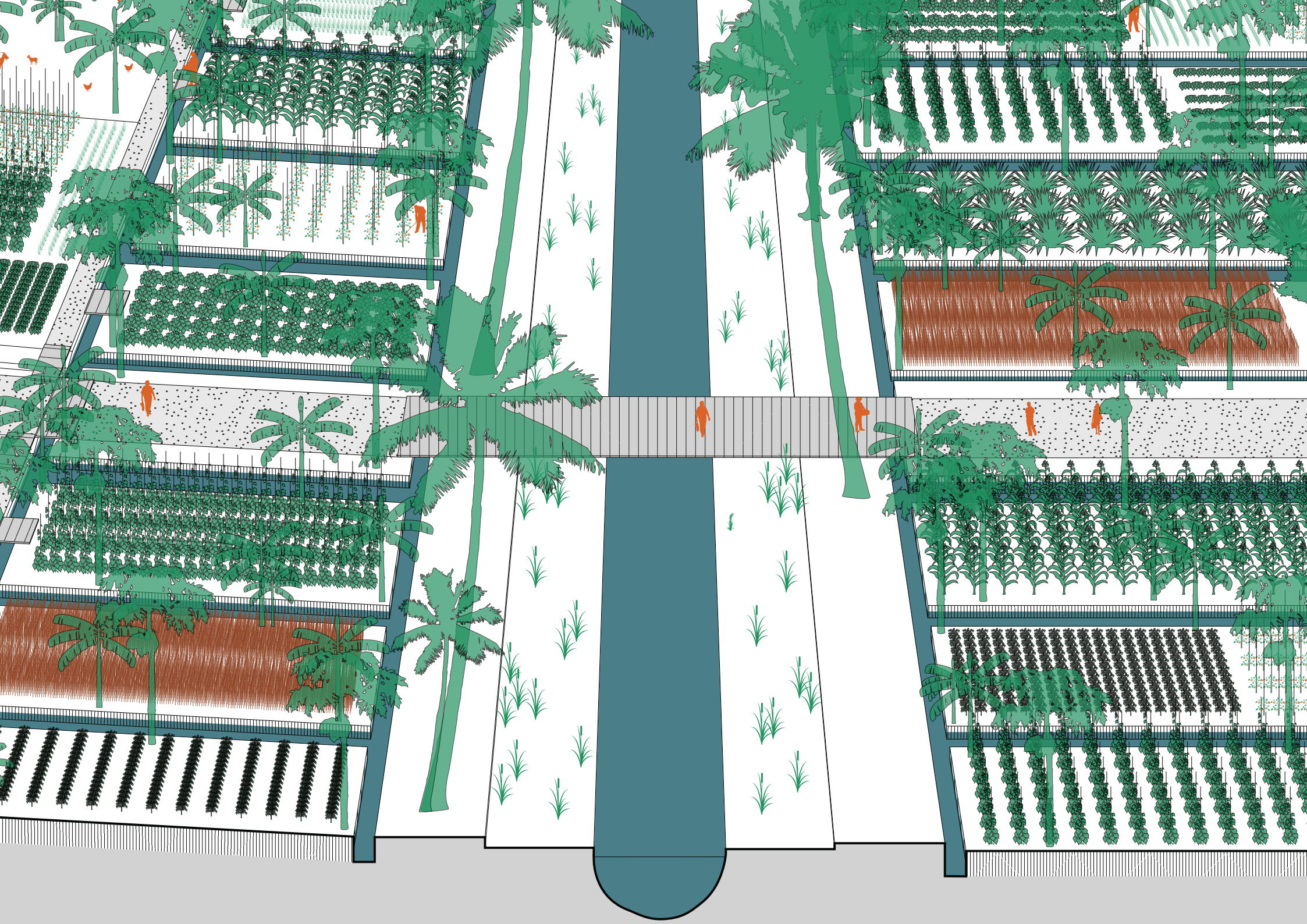
▶ site plan



▶ cross section



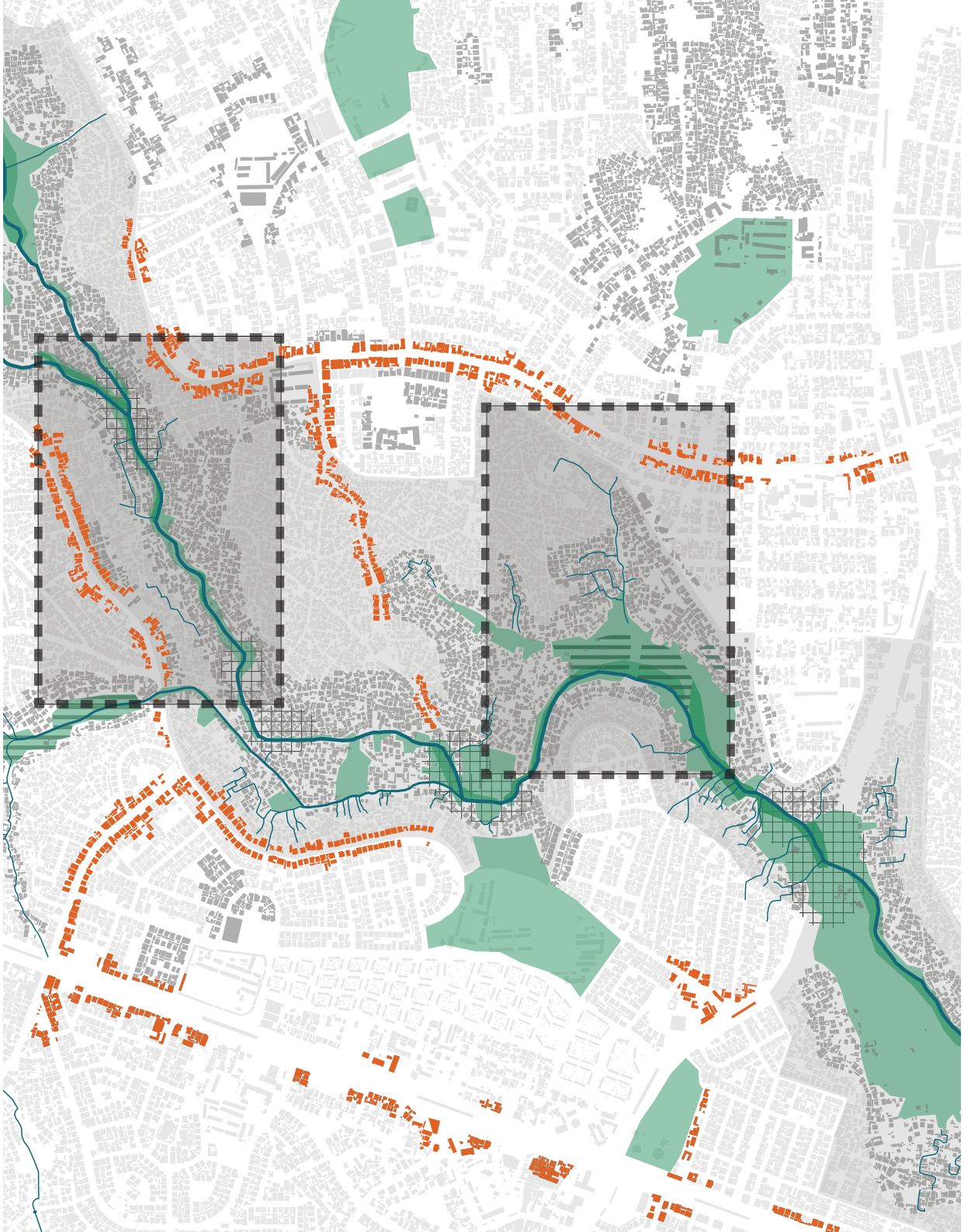
horizontal 1:1000
vertical 1:200







▶ design interaction



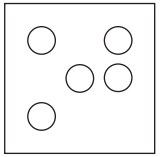
Individual design location

- blue structure
- agriculture
- green structure
- informal settlement
- flood risk area
- waste
- commercial streets
- individual design location

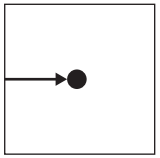
Courtyard



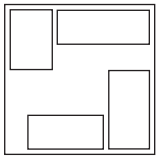
urban



small scale intervention/
implementation

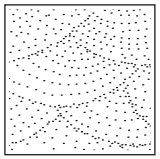


short term intervention/
implementation

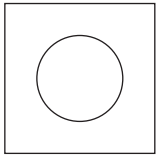


old structure

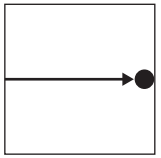
Chinampa



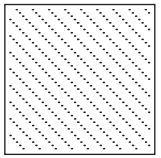
landscape



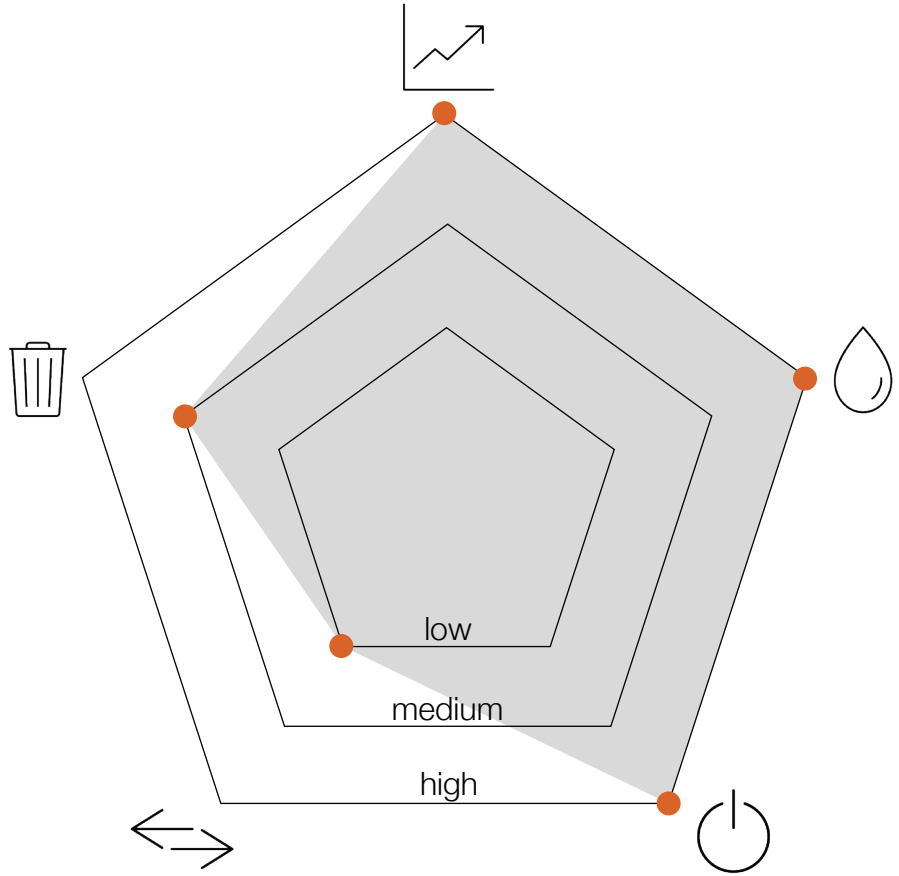
big scale intervention/
implementation

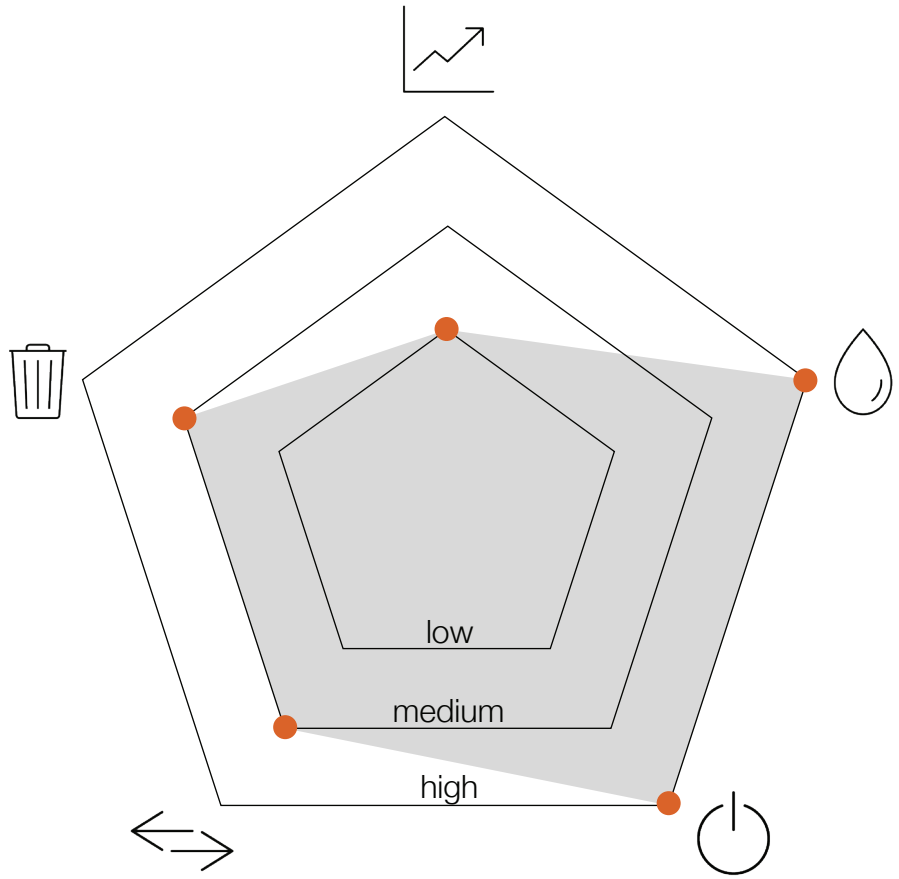


long term intervention/
implementation

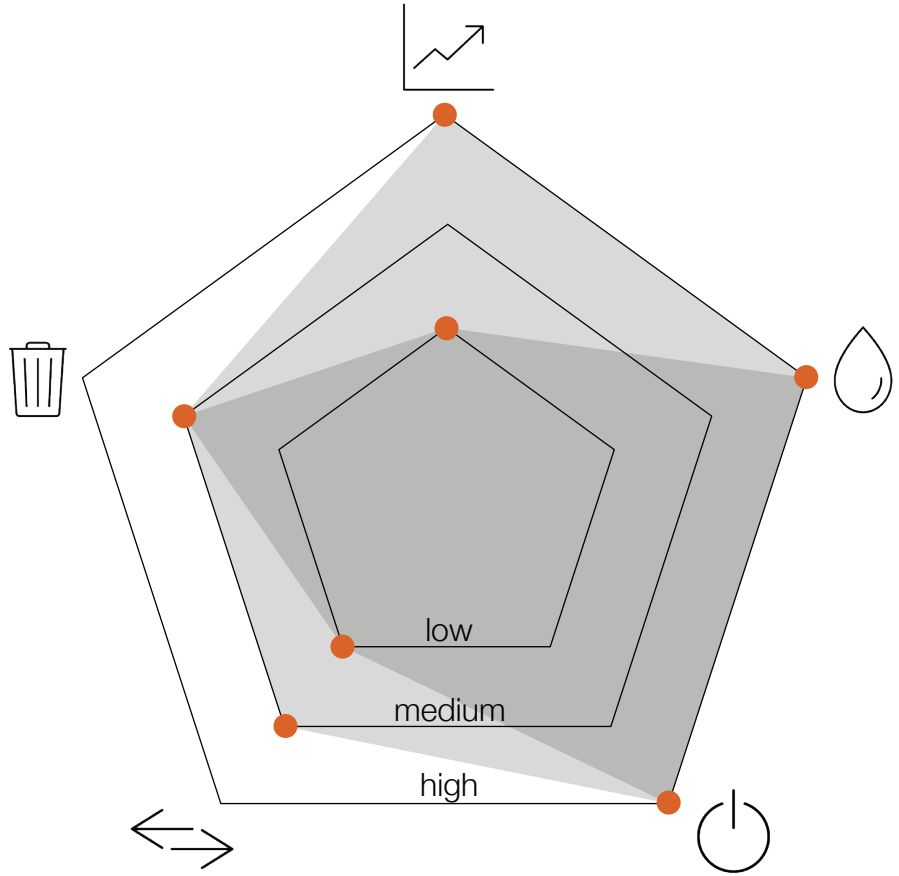


new structure


low
medium
high

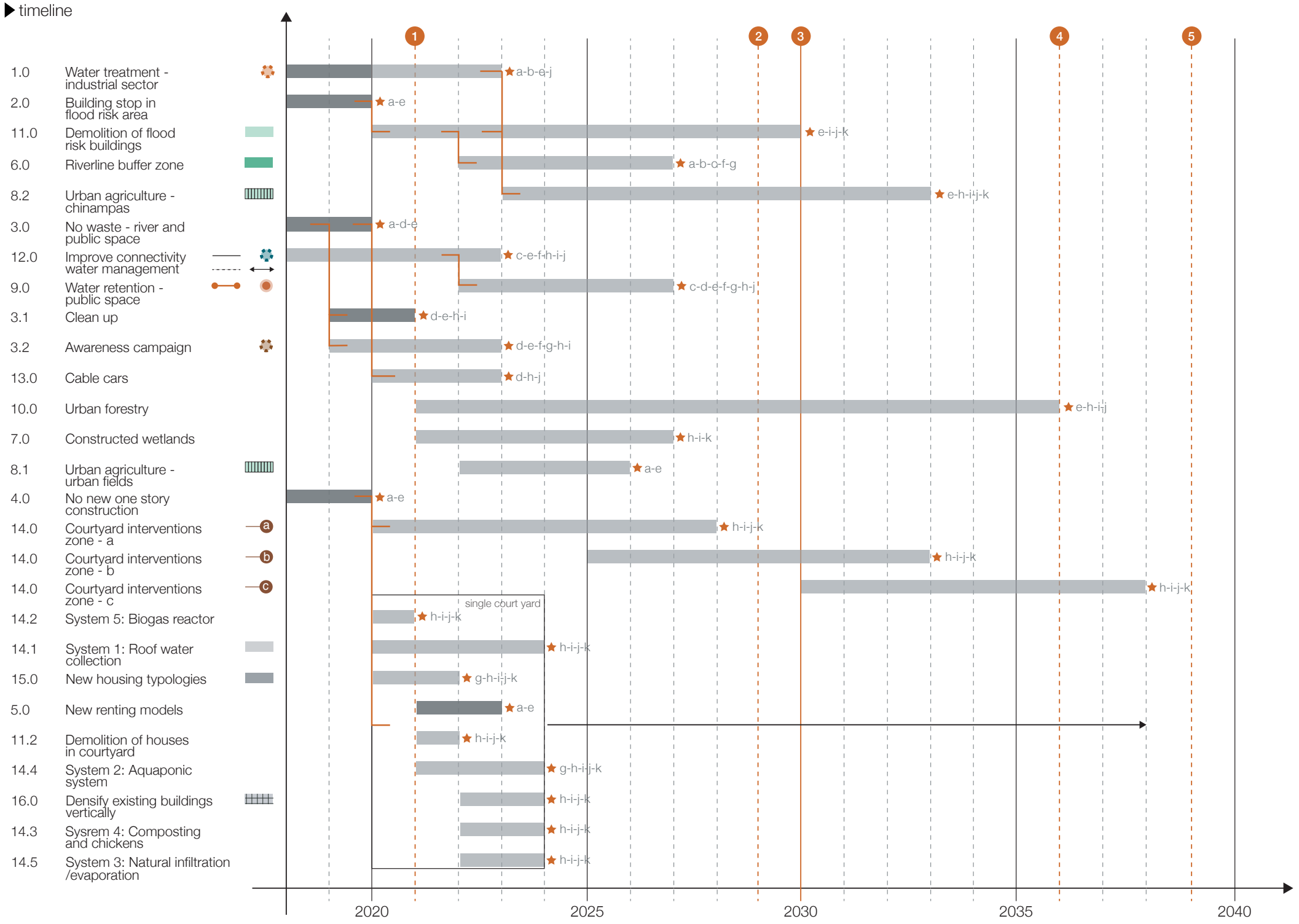

low
medium
high

▶ design reflection - overlay

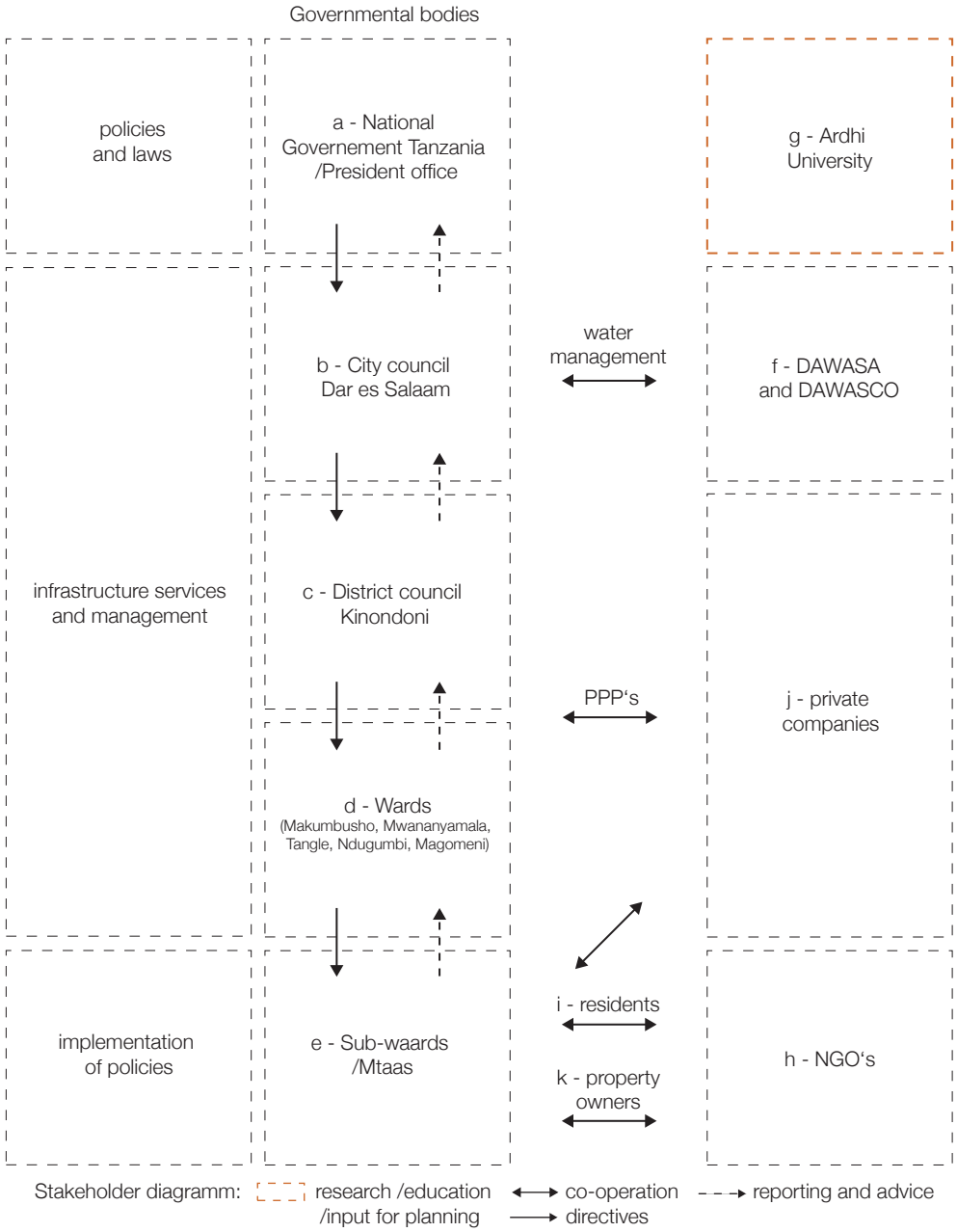


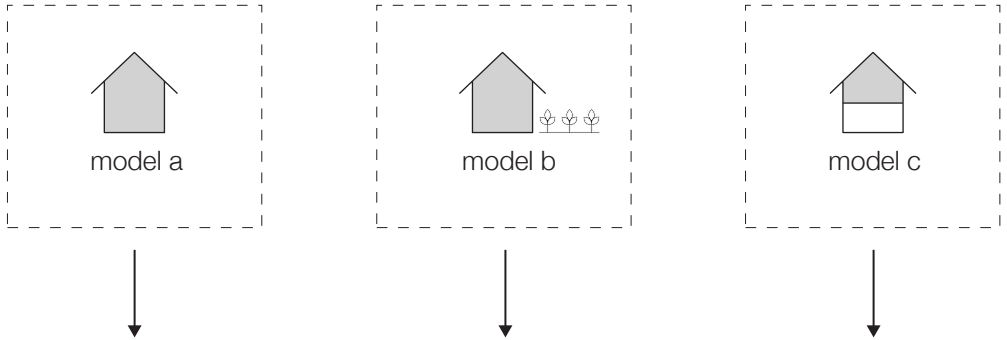


▶ timeline


1.0 Water treatment - industrial sector
2.0 Building stop in flood risk area
11.0 Demolition of flood risk buildings
6.0 Riverline buffer zone
8.2 Urban agriculture - chinampas
3.0 No waste - river and public space
12.0 Improve connectivity water management
9.0 Water retention - public space
3.1 Clean up
3.2 Awareness campaign
13.0 Cable cars
10.0 Urban forestry
7.0 Constructed wetlands
8.1 Urban agriculture - urban fields
4.0 No new one story construction
14.0 Courtyard interventions zone - a
14.0 Courtyard interventions zone - b
14.0 Courtyard interventions zone - c
14.2 System 5: Biogas reactor
14.1 System 1: Roof water collection
15.0 New housing typologies
5.0 New renting models
11.2 Demolition of houses in courtyard
14.4 System 2: Aquaponic system
16.0 Densify existing buildings vertically
14.3 Sysrem 4: Composting and chickens
14.5 System 3: Natural infiltration /evaporation
a-b-e-j
a-e
e-i-j-k
a-b-e-f-g
e-h-i-j-k
a-d-e
c-e-f-h-i-j
c-d-e-f-g-h-j
d-e-h-i
d-e-f-g-h-i
d-h-j
e-h-i-j
h-i-k
a-e
a-e
h-i-j-k
h-i-j-k
h-i-j-k
single court yard
h-i-j-k
h-i-j-k
g-h-i-j-k
a-e
h-i-j-k
g-h-i-j-k
h-i-j-k
h-i-j-k
h-i-j-k
1
2
3
4
5
2020
2025
2030
2035
2040

▶ stakeholder relation





ground floor / 9$ rent per month per room residential /13,5$ rent per month commercial (rent*1,5=commercial) /minimum 3 years renting period for renters

ground floor / 9$ rent per month residential / 13,5$ rent per month commercial (rent*1,5=commercial) /additional agricultural land 1$ per month per 10m^2 or additional agricultural land / 30% of income from agricultural products as rent / minimum 5 years renting period for renters

1st floor or higher / 25$ per month / minimum 1 year renting period for renters

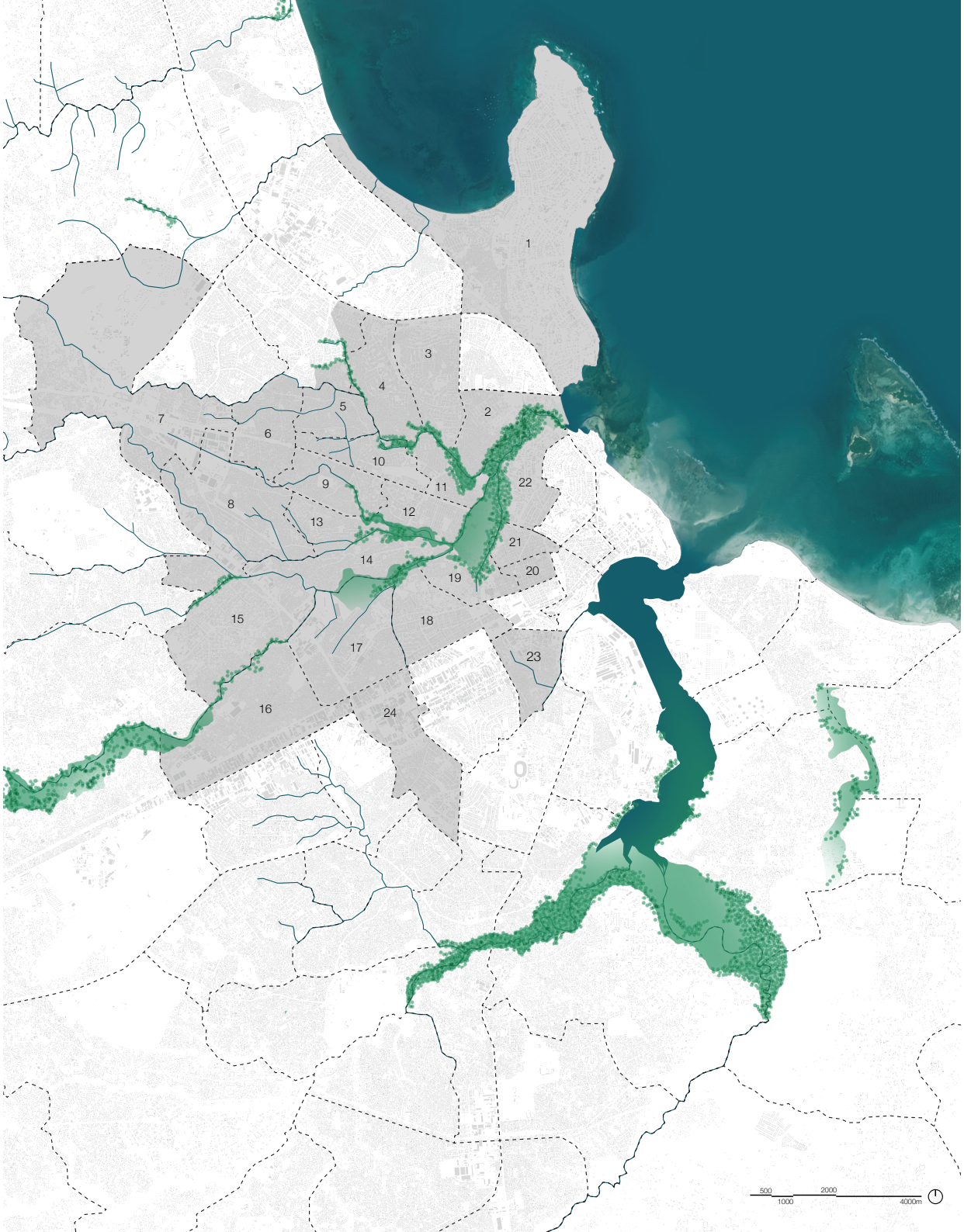
▶ cable car references


Cable car banana transport in Gomera, Spain


Cable car goods transport in Switzerland


Cable car milk transport in Isental, Switzerland


tuin to cross rivers in Nepal


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
500
1000
2000
4000m

1. Msasani
9%
48.920
8.020
2.578
↳ 27

2. Hananasif
31%
37.115
6.528
1.272
↳ 1

3. Mwanan yamala
23%
50.560
9.914
2.863
↳ 21

4. Makumbusho
35%
68.093
7.848
3.053
↳ 19

5. Tandale
30%
54.781
9.504
1.948
↳ 12

6. Manzese
17%
70.507
9.504
1.948
↳ 12

7. Ubungo
6%
56.015
9.282
1.102
↳ 12

8. Mabibo
13%
85.735
16.349
1.519
↳ 2

9. Makurumla
18%
63.352
8.043
1.669
↳ 1

10. Ndugumbi
13%
36.841
5.242
1.137
↳ 0

11. Magomeni
45%
24.400
4.273
1.744
↳ 0

12. Mzimuni
27%
21.486
4.021
959
↳ 1

13. Mburahati
33%
34.123
5.753
1.997
↳ 1

14. Kigogo
48%
57.613
8.869
4.450
↳ 4

15. Tabata
18%
74.742
11.485
2.324
↳ 2

16. Vingunguti
27%
106.946
15.080
5.321
↳ 26

17. Buguruni
20%
70.585
12.315
2.937
↳ 10

18. Ilala
45%
31.083
4.544
2.513
↳ 38

19. Michikichini
49%
25.510
3.551
1.374
↳ 8

20. Kariakoo
21. Jangwani
22. Upanga Magharibi
flood most
often in center

23. Keko
17%
35.163
4.575
961
↳ 0

24. Temeke
4%
26.047
4.246
323
↳ 2

Dar es Salaam wards
most vulnerable numbers
area at risk
number of inhabitants
number of houses
number of houses at risk
↳ schools/hospitals at risk

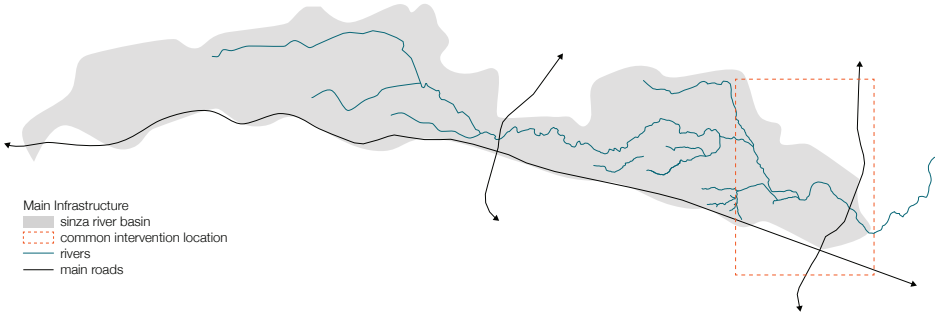
▶ sinza river basin



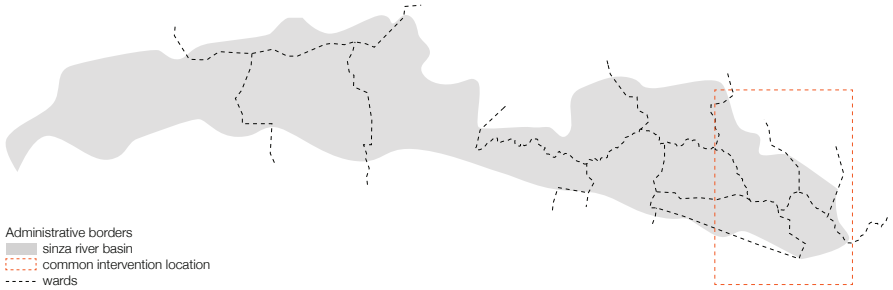
Buildings density
- sinza river basin
- common intervention location
- buildings



Informal Settlements
- sinza river basin
- common intervention location
- informal settlements



Main Infrastructure
- sinza river basin
- common intervention location
- rivers
- main roads



Administrative borders
- sinza river basin
- common intervention location
- wards



Functions
- sinza river basin
- common intervention location
- industry
- commercial
- education

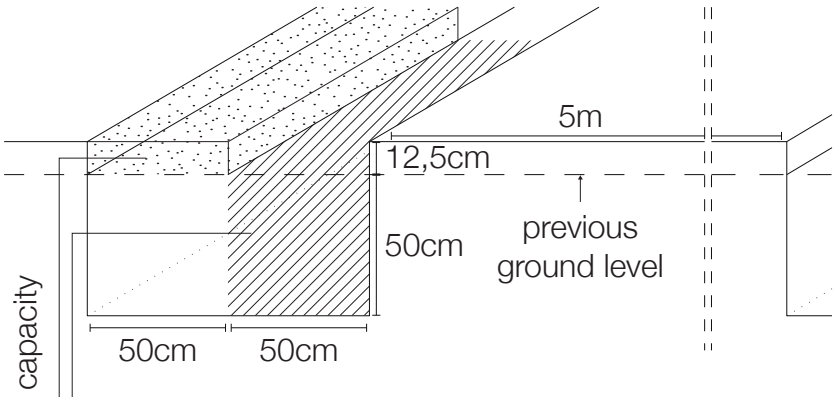


Blue Green network
- sinza river basin
- common intervention location
- rivers
- flood areas
- meadow/bushland
- forest
- cemetery



Food production
- sinza river basin
- common intervention location
- river
- food production
- no information available


3
GOOD HEALTH AND WELL-BEING
6
CLEAN WATER AND SANITATION
11
SUSTAINABLE CITIES AND COMMUNITIES
13
CLIMATE ACTION



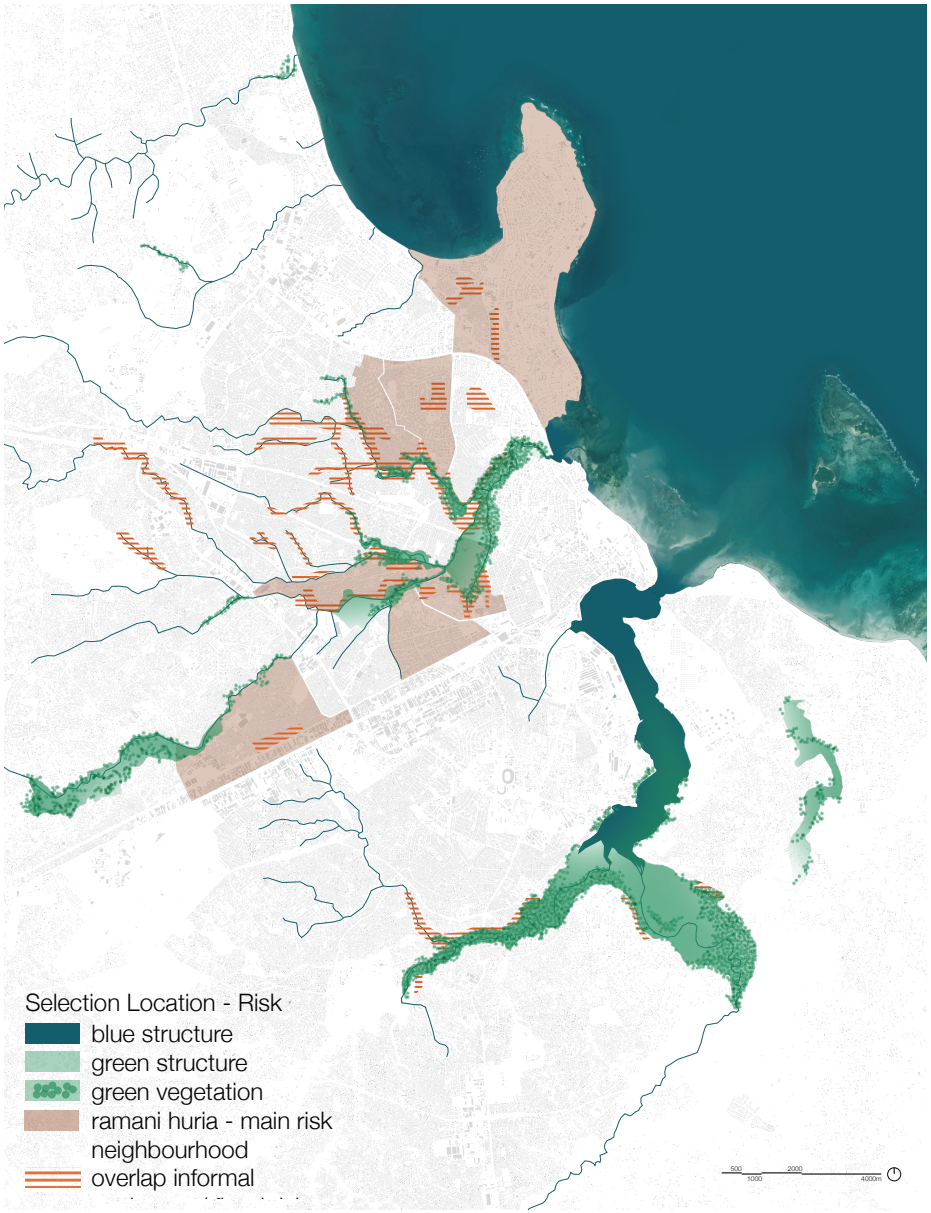
$25m^2*0,5m = 12,5m^3$

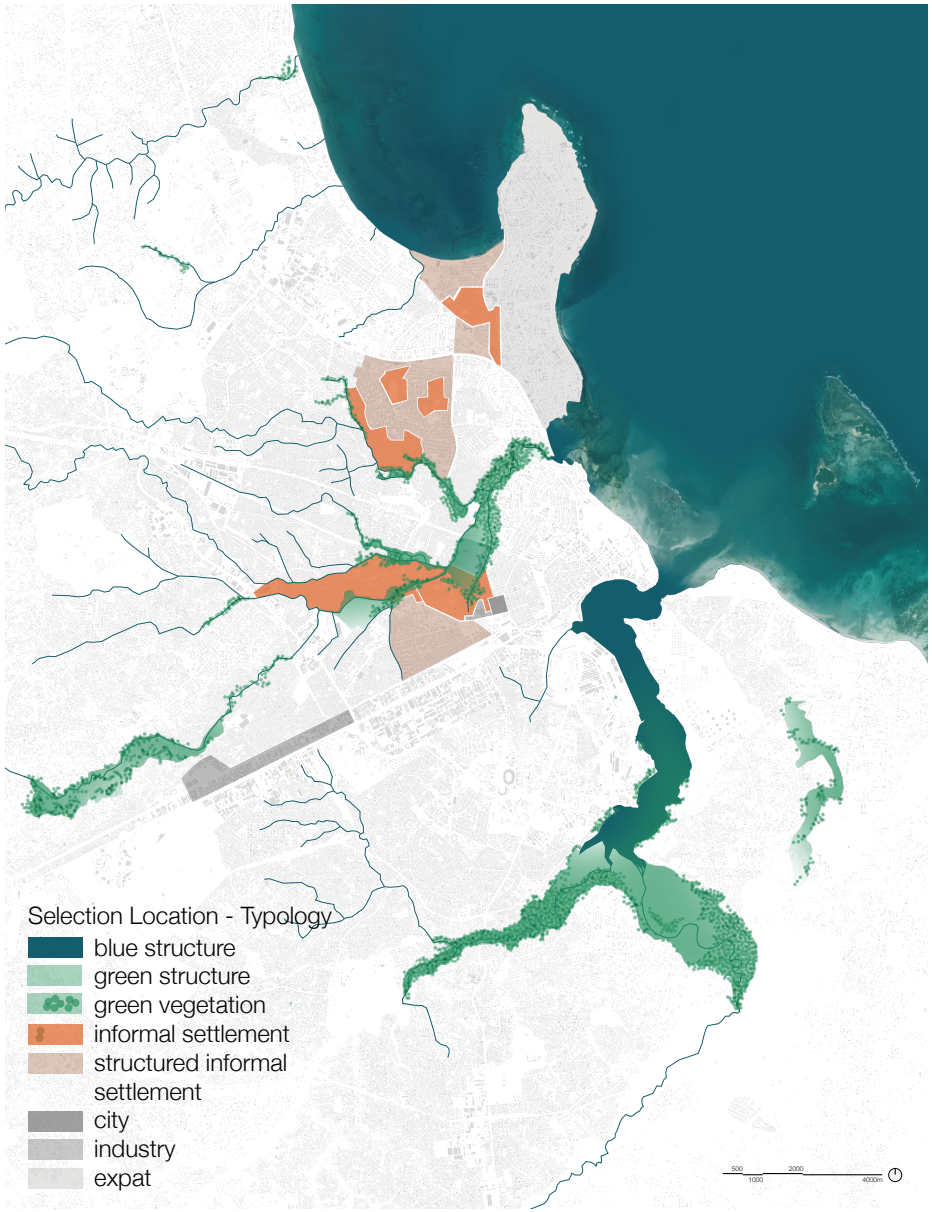
$25m^2*0,125m = 3,125m^3$

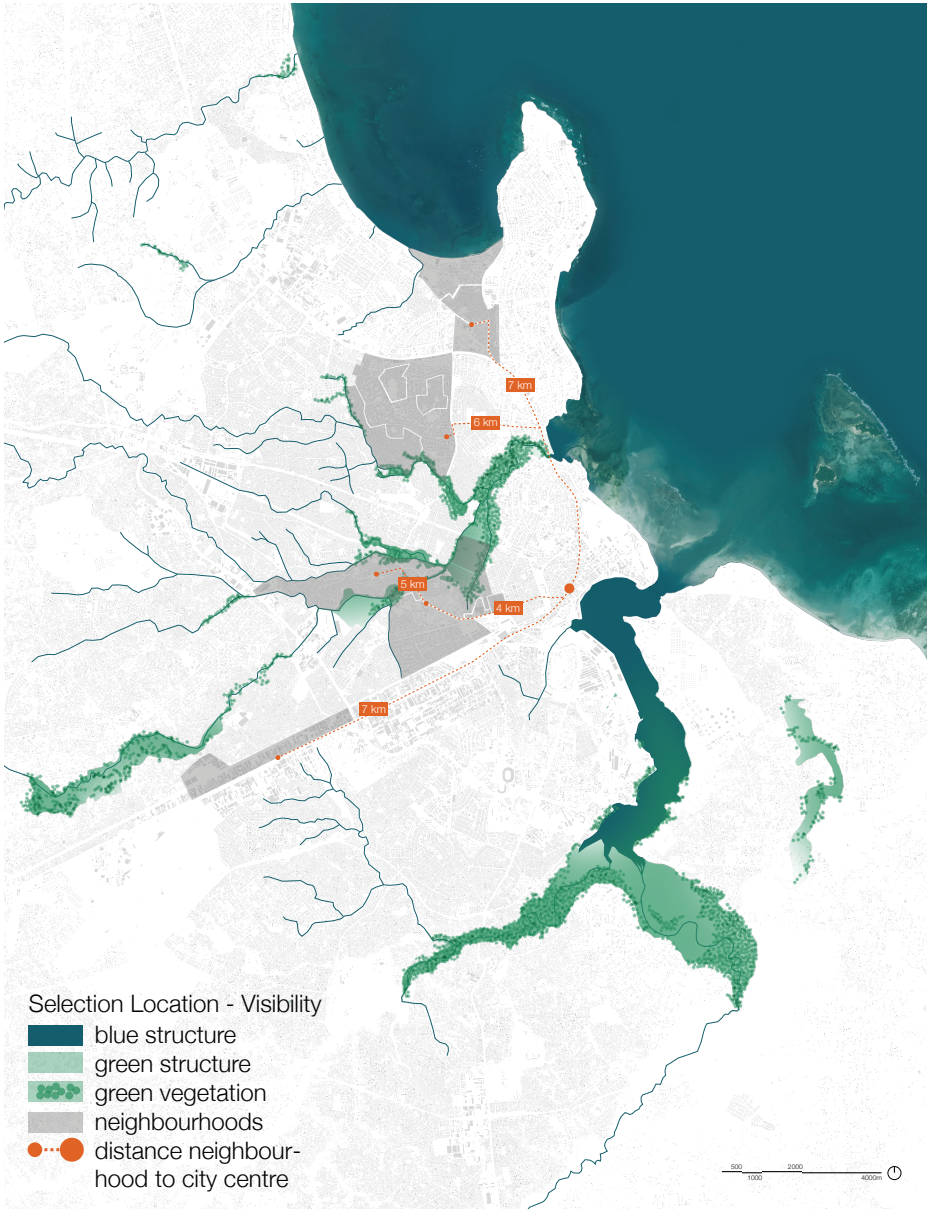
maximum capacity per $100m^2$ chinampa:

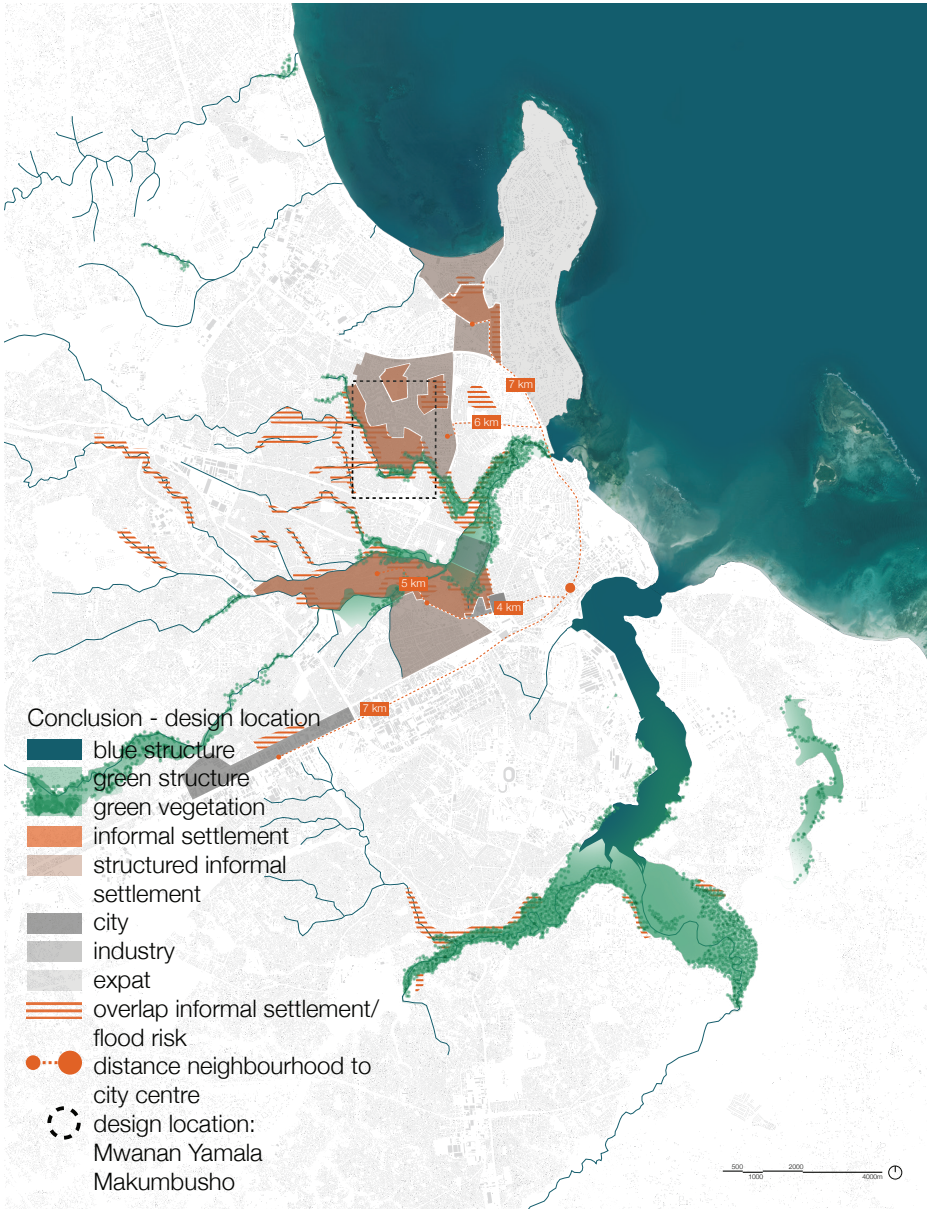
$12,5m^3+3,125m^3 = 15,625m^3$

▶ location selection






7 km
6 km
5 km
4 km
7 km
Selection Location - Visibility
blue structure
green structure
green vegetation
neighbourhoods
distance neighbour-
hood to city centre


7 km
6 km
5 km
4 km
7 km
Conclusion - design location
blue structure
green structure
green vegetation
informal settlement
structured informal
settlement
city
industry
expat
overlap informal settlement/
flood risk
distance neighbourhood to
city centre
design location:
Mwanan Yamala
Makumbusho