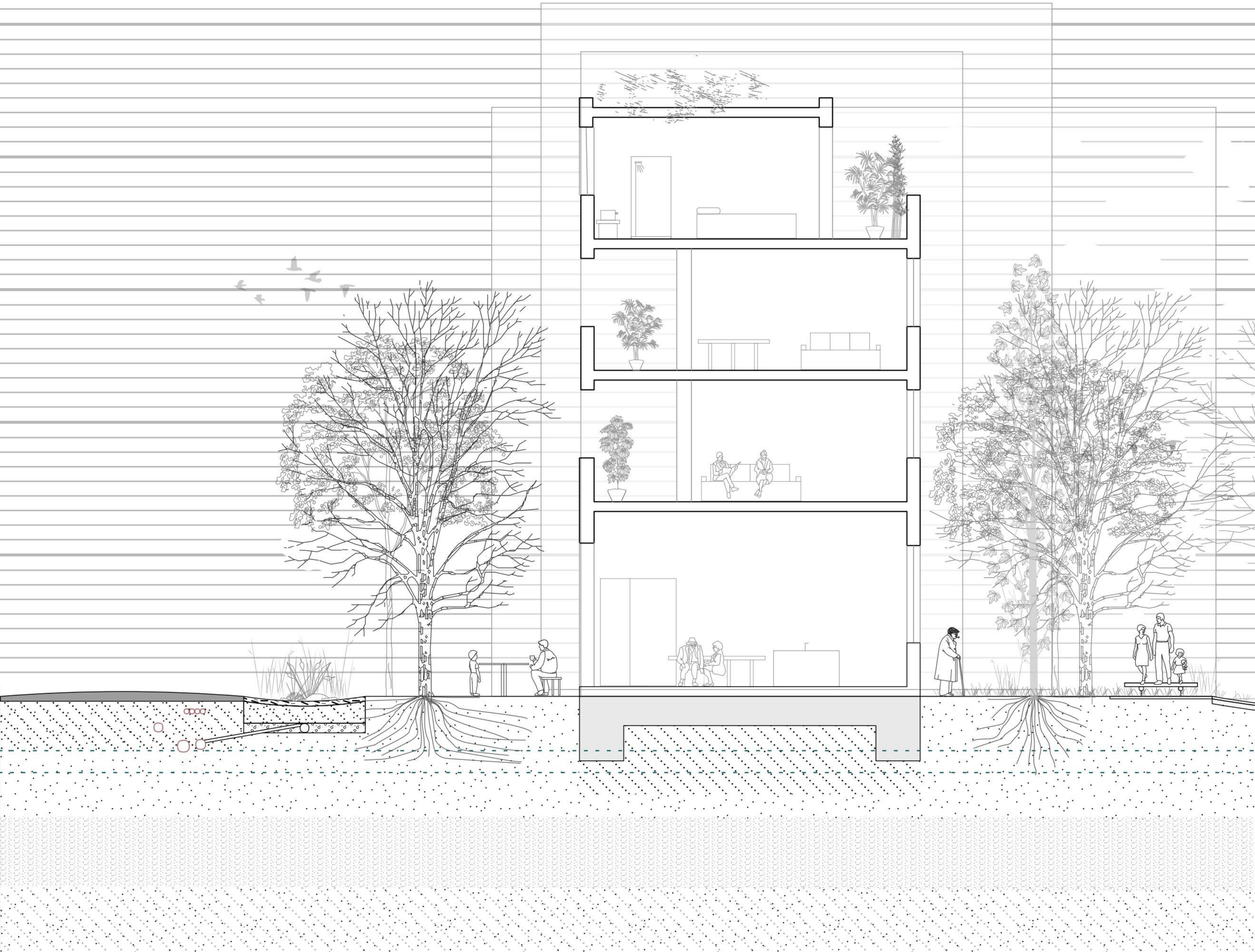
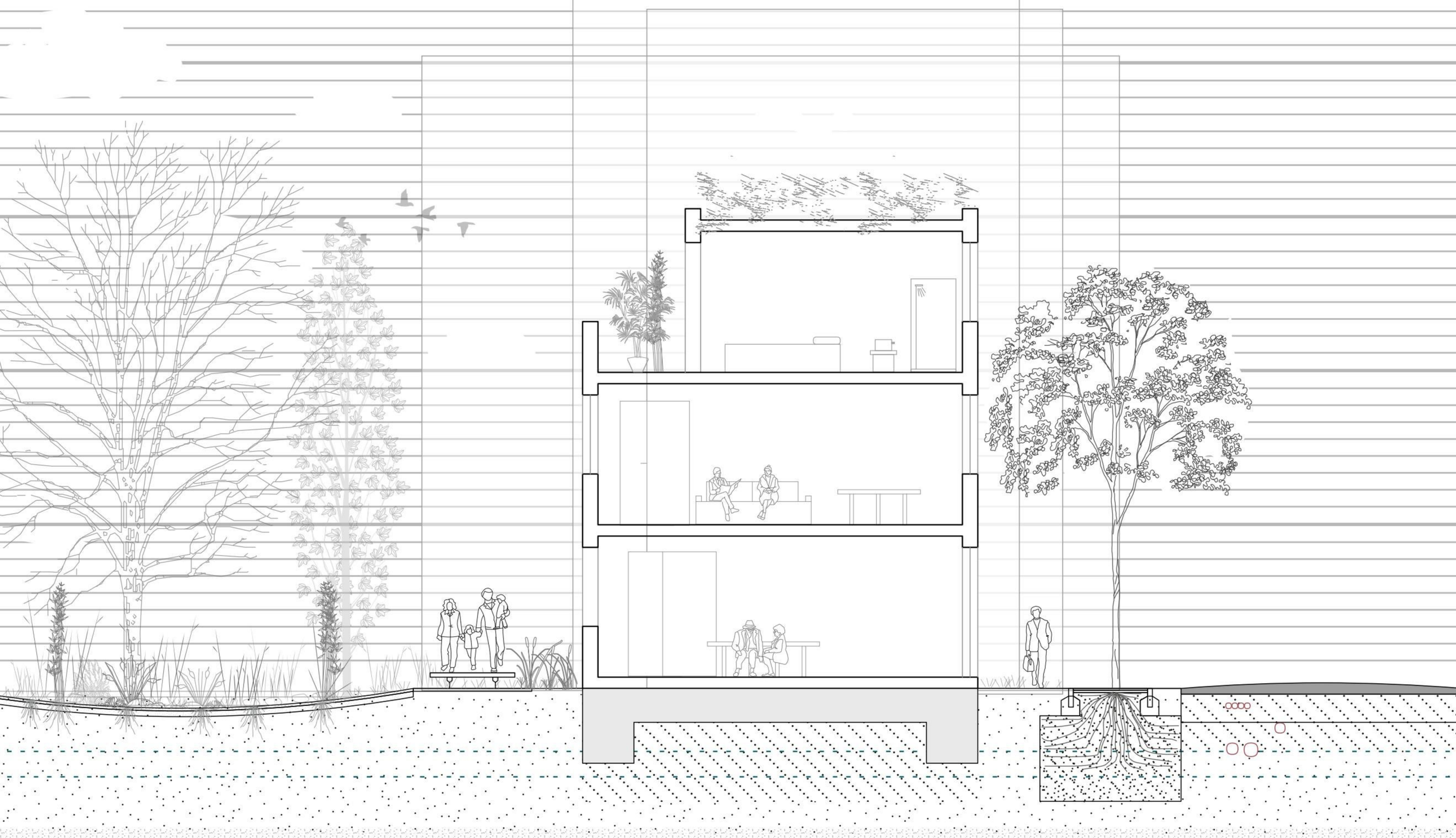
PROJECT

Elaboration on the second provocative design in which all houses are built on piles, and the landscape becomes a wetland to stop the subsidence
The connection between the built-up area and the public space is dynamic and an architectural challenge (Source: Hooimeijer et al., 2018)



Intelligent Subsurface Quality

Drawing the subsurface: integrated infrastructure and environment design



Rotterdam and Leiden (The Netherlands)

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TYPE OF PROJECT Special project

YEAR 2017 and 2018

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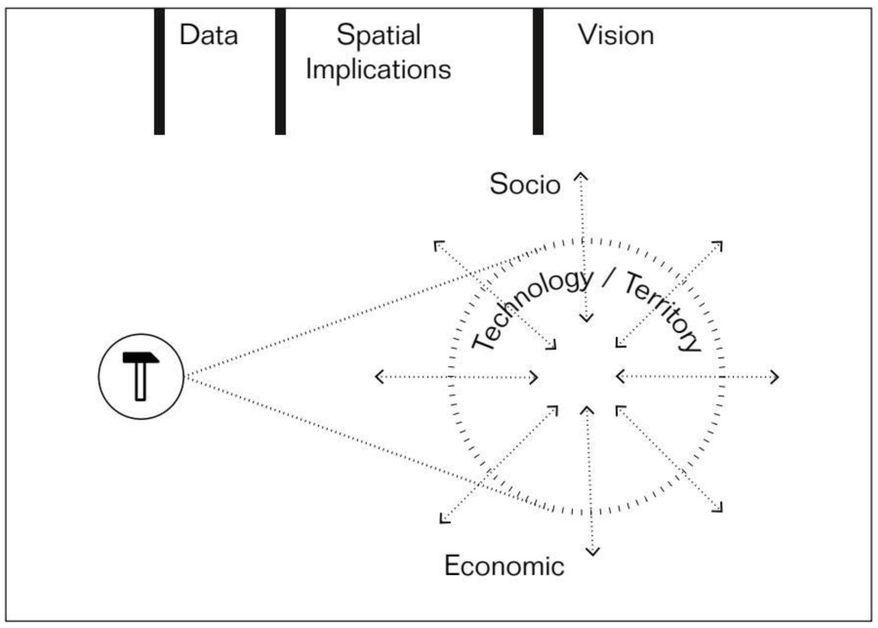
LOCATIONS Rotterdam and Leiden (The Netherlands)

KEYWORDS Oil, Water, Energy, Ecology, Integration

(Source: Hooimeijer et al., 2016)



INTRODUCTION

Integrating the subsurface

The urban subsurface is a hybrid space consisting of intertwined technical and natural artefacts. It plays an important, even crucial, role in tackling issues of the urban climate, global energy transition and ecological crisis. Not only because problems like subsidence, pollution, infrastructure breakages or shortage of space for new urban systems manifest in the subsurface, but especially because it offers options for dealing with flood and heat stress reduction or decentralised energy systems, and because the subsurface is mother earth and the basis of all life. Therefore, it is necessary to include subsurface issues in an integral perspective that focuses on a resilient design bringing together the ecosystem, climate, and urban systems while taking into account the dynamics of the subsoil in general. However, at the moment the subsurface is not a part of spatial planning; it is a hidden domain without order. If we intend to integrate the subsurface in surface planning and approach the two as a whole, knowledge integration and management are crucial. This will mean involving technical information in the planning and design of the city.

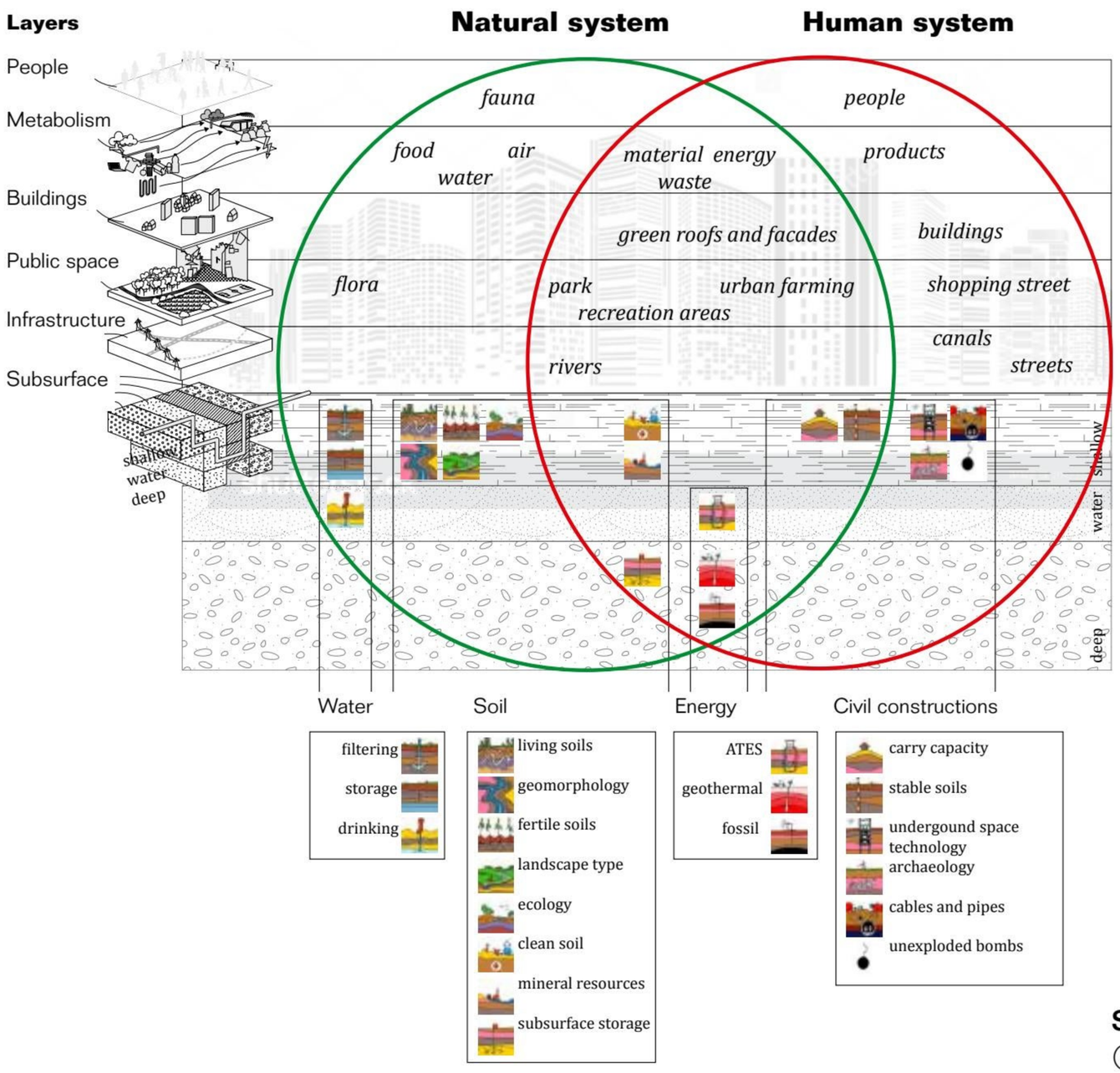
Subsurface vision in cities

The project hypothesis was that in knowledge management, it is crucial to visualise the subsurface as a technical space, the 'engine room of the city', in order to be more innovative and efficient and to make cities more climate-proof, biodiverse, and healthy. To test this hypothesis, the disciplines within TU Delft that work on the subsurface and the designing and engineering departments of the municipalities of Rotterdam and Leiden were brought together in a learning environment. The departments of Urbanism, Water Management, and Geotechnical Engineering took the first step by creating insights into the past, present, and future of their specific disciplines in order to create opportunities to synchronise their disciplinary innovations. The second step was cooperating with the municipal urban development teams. The idea was to use provocative design to see how innovations, or new technologies, would impact the sustainable future of the case studies and so to reflect on the current practice from an outside perspective.

3.4.2 **PROJECT** Intelligent Subsurface Quality

TABLE 1	TECHNOLOGY	DEPENDENCY ON OTHER TECHNOLOGIES	OPPORTUNITIES	SPACE APPLICATION (RELATION TO SPACE)	URBAN MANAGEMENT	CONSTRAINTS	PP: PUBLIC/ PRIVATE
Soil improvement	SCC – Soil carrying capacity (BioGroutt)	UST: carrying capacity to support infrastructures UWM: groundwater flows UWM: water quality	UWM: managing the groundwater table (recharge) Sewer: flexible pipes	- Allows for urban nature ((Relief))	- New maintenance plan - No applied sand - Maintenance of dikes - Quality control programming	- Irreversible? - Time - Governance (urban programming) - Legal - Financial - Technology up-tale (social acceptance and adaptation) - People behavior Extra for QS: - Cost/profit balance - Health	Improve PP S/XL relation
	SP – Soil permeability reduction (SoSEAL)			- Improves functionality ((Robustness))	- Maintenance - Connection to pipe system - Trade off water & public space system		Improve PP S/XL relation
	QS – Quality of soil GRO (field not investigated in the project)		UST: excavation UWM: water quality	- Determines functions - If it is good quality → green spaces (Design with nature)	- Trade off function & remediation - Excavation management		Public
Urban Drainage (Sewer)	- Sink disposal: Organic waste; flexible pipes (more capacity; heat-energy recovery from pipes)	UWM: Separate system + water quality QS - Quality of soil	UST utilities UWM: balancing the capacity of the sewer system (unload the network) SCC	Quantity of space and material functionality	- Waste/sewer community - Sewer planning - Improve system flexibility and material - More systems lead to more space occupied, thus more maintenance is required - More waste utilities involved - No more sand	- Health - Depreciation - Governance (urban programming) - Legal - Financial - Technology up-take (social acceptance and adaptation) - People behavior	- Relation S/XL connections (small/big scale)
	- Source separation: Urine/feces (Yellow/grey/ black water) separation to recover nutrients						
UWM (Urban Water management)	- Smart piping - Infiltration crates - Helophyte filter (water quality) - Underground buildings - Nature based solutions	- Quality of soil Sewer systems UST: groundwater	UST utilities Underground buildings can offer storage Sewer: flexible pipes SP	- Main infrastructure - Design of surface and materials - Use of surface water - Programming (water quantity and quality) + public space	- Water quality (rules) - System of water bodies or flows - Water communities (water boards and polders community)	- Health - Soil sealing - Maintenance - Governance (urban programming) - Legal - Financial - Technology up-tale (social acceptance and adaptation) - People behavior	- Relation S/XL groundwater - Intermediate scale QS
Building-site preparation	- Partial-filling technique - Nature based solutions						
UST (Underground space technology)	Utility tunnel	Soil improvement and UWM: UST deals with soil quality, soil carrying capacity and water flows (groundwater)	Multi-functionality SCC	- Multifunctional land use (public) - Mobility improvement (private) - Maintenance improvement	- Smart pipe management - Street maintenance is about efficiency, flexibility, costs, logistics - Underground space buildings, trade off old/new foundations - Excavate polluted soil	- Risk with excavation - Governance (urban programming) - Legal - Financial - Technology up-tale (social acceptance and adaptation) - People behavior	Community of owners Clustering in smart pipes PP knowledge relation
Values							

Overview of the impact of new technologies in the fields working in the subsurface
What are the dependencies and opportunities, and how do they affect urban management?
(Source: Hooimeijer et al., 2016)



System overview of the surface and subsurface
(Source: Hooimeijer and Maring, 2018)

The stages of the project

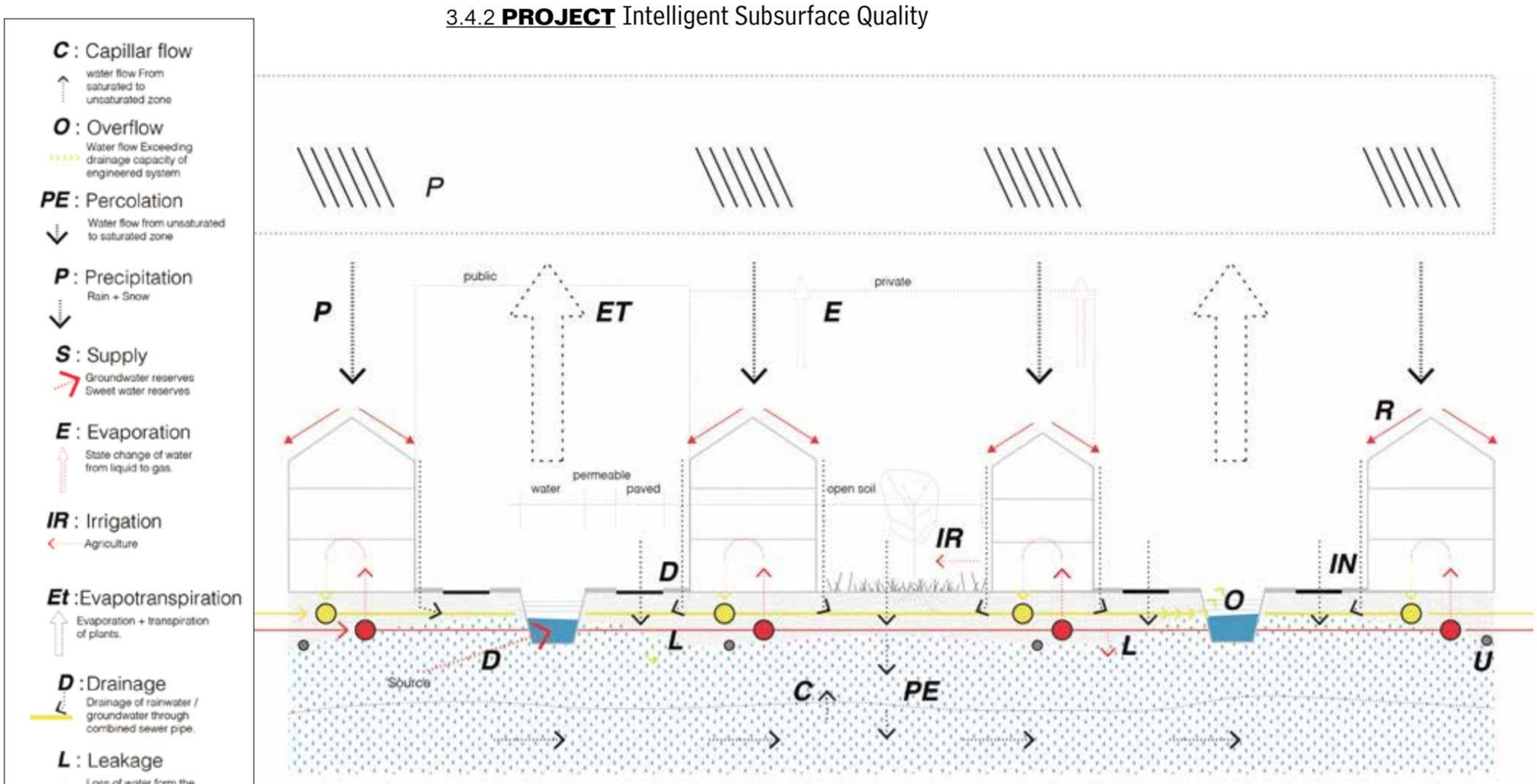
The first 'synchronisation' phase used an explorative method tackling the question, 'how can the different technological artefacts in the subsurface be synchronised to offer more space and add to a higher urban quality?' Explorative research has been helpful in studying wicked problems, i.e., problems that have not been clearly defined. The three exploratory activities were: disciplinary analyses, visualisation, and creating pathways in co-creation workshops. A smaller working group worked out the results in greater detail. The first explorations were done using forecasting, backtracking, and hindcasting (Van de Dobbelsteen et al., 2006), by drawings the lines from past to present to future for each of the participating disciplines and by finding synergy or windows of opportunity between them. Table 1 gives the overview of the impact of new technologies in the fields working in the subsurface. What are the dependencies and opportunities, and how do they affect urban management? These technologies were applied to draft a vision and an adaptive pathway for a densifying and shrinking case study. These were designed and elaborated on in co-creation workshops. Visualisation was the underlying activity explicitly used throughout the process. This approach clarified the direct relationship between technology in the subsurface and urban design to the participants in this project. The focus was on potential future synergies between technologies and their contributions to urban quality.

The second phase of the project focused on 'Architectural representation' and elaborated on an earlier project of TU Delft and Deltares (2010): Design with the Subsurface. This project resulted in the System Exploration Environment and Subsurface (SEES) and the Subsurface Potential Map (See chapter 2, methods, for both). The SEES is a system overview in which the domains involved in urban development are mapped out. Each domain comes with its own specialists, concepts, and language. The Subsurface Potential Map is a map in which the data has been translated into information about the subsurface artefacts in the categories of civil constructions, water, energy, and soil/ ecology. These instruments have been tested in the workshops with the municipalities of Rotterdam and Leiden. The resulting innovations completed the SEES and refined and contextualised the Subsurface Potential Map in the Technical Profile. The improvement added scales to the SEES and the Plan, and a shared legend with solid items and process items. The challenge was to draw the different artefacts in such a way that the relationships between the subsurface and the surface artefacts became clear and thus to enable decision-making about the desired interventions and effects.
In addition, some artefacts also affect the higher scales (such as water, energy, and ecology), while others (such as cables and pipes and ecology) also need to be represented on the small scale of a street section.

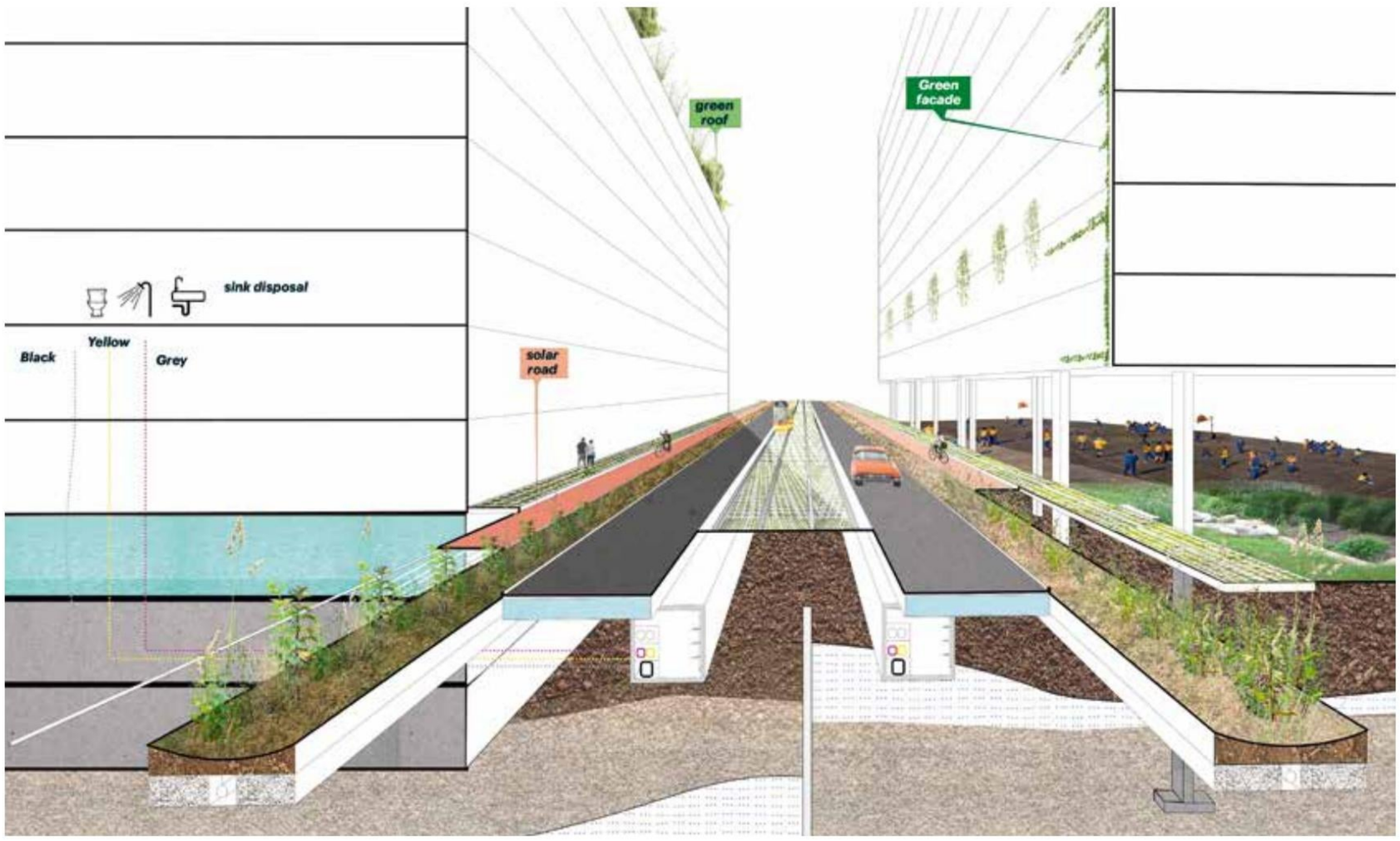
Two workshops were organised to have the participants step out of their silos in the municipalities and away from their protocolised way of working. In the first workshop, the case data was inventoried to provide insight into the context, challenges, and applicability of new approaches or measures. This workshop was structured using the SEES, and its purpose was to create a basis for understanding the disciplinary perspectives. In the second workshop, participants worked in multidisciplinary groups to respond to provocative scenarios. The purpose was to create interdisciplinary design thinking in which potential future synergies and cascading relations between technologies would contribute to urban quality.

Rotterdam and Leiden

The Rotterdam Bloemhof-Zuid case concerns an urban district built in the 1930s that is currently subsiding. The houses in the middle of the area are built on slabs and suffer from high groundwater, while the houses on wooden piles on the periphery would suffer from pile rot if the groundwater level were lowered; it is a very wet and soft terrain with ongoing subsidence. At the same time, the technical state of the houses is not future-proof, and the urban structure with its narrow streets, lack of parking space, green spaces, and playgrounds,



Visualisation of the water system in space as one of the visualisation experiments in the first phase of the project (Source: Hooimeijer et al., 2016)



Visualisation of the warm-densification scenario in a perspective section in which the new technologies are introduced into a new urban system, with more room for nature and its buffering functions (Source: Hooimeijer et al., 2016)

Technical Profile

Rotterdam Bloemhof Zuid

Authors:
dr. F.L. Hooimeijer
ir. Filippo Lafleur

Drawings:
ir. Filippo Lafleur
Jesse Dobbelsteen
Enzo Yap

Cartographic indication

Underground Depth
NAP levels
m / cm / mm
Active items (Legend)
Scale
Geogrpahical coordinates
Zoom in
Direction Sign

TUDelft | Delta, Infrastructures & Mobility Initiative | Urbanism

Macro scale: Territorial condition

75 375 750 m N

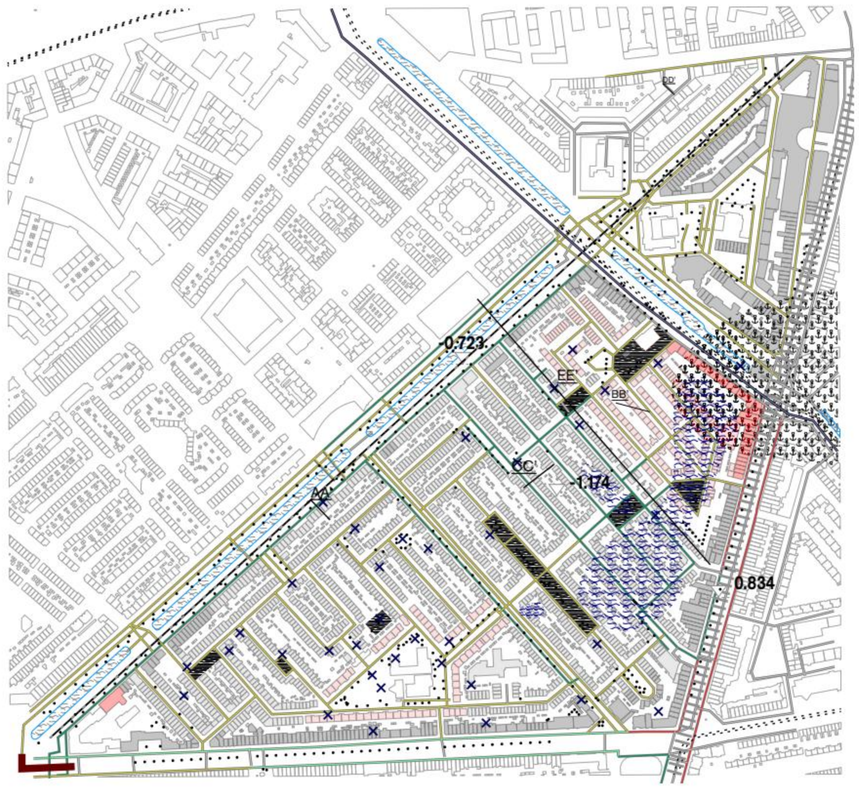
Infrastructures

Water

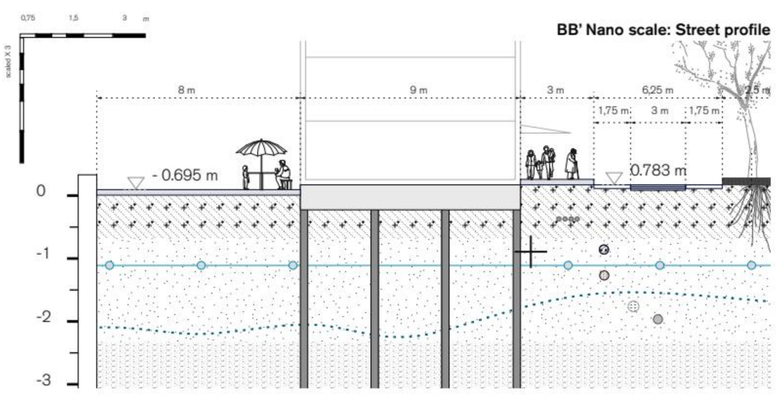
Landscape structure

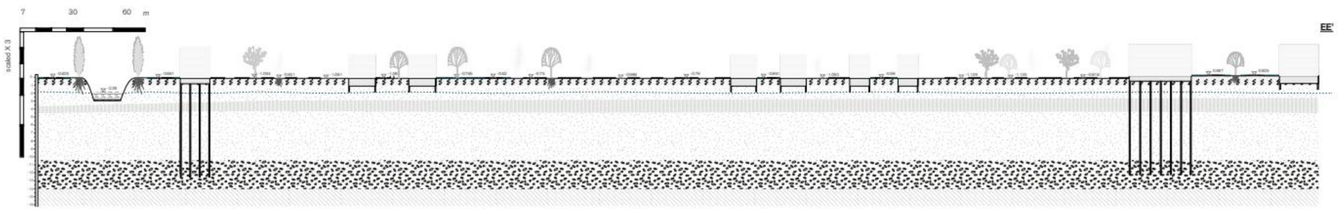
Meso scale: Plan, site investigation

25 100 250 m N

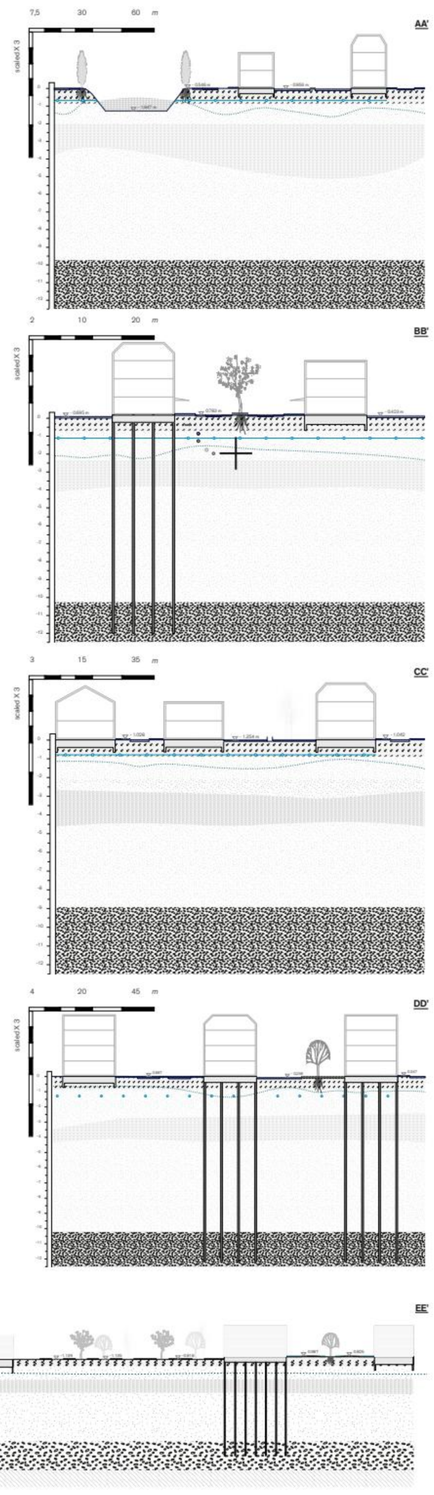


BB' Nano scale: Street profile





Micro scale: Technical profile,



The legend: Reading sites and territories

Conditions present in the area

Subsidence — "Land subsidence in peat areas in the Netherlands damages housing and infrastructure. In other countries where peat areas are located on the coast, these areas are increasingly being submerged due to land subsidence, with all the inevitable harmful consequences". Deltares, 2015

Oxidation — Oxidation is the biogeochemical process that leads to subsidence. Various interrelations between anthropogenic and natural dynamics might effect or speed up this process.

Polluted soil — Soil pollution is the so called: immobile pollution. In this particular case is believed that the contaminants came with sand from the harbour needed to make 'building site preparation'.

Monuments on slabs — The colour shows the combination of buildings on slabs foundations and their legal and cultural condition as monuments.

Monuments on wooden piles — The colour shows the combination of buildings on wooden piles foundations and their legal and cultural condition as monuments.

Seepage — Seepage, in soil engineering, movement of water in soils, often a critical problem in building foundations. It depends on several factors, including permeability of soil andother factors. Encyclopedia Britannica, 2008 In the area is 1 to 0,1 mm/day

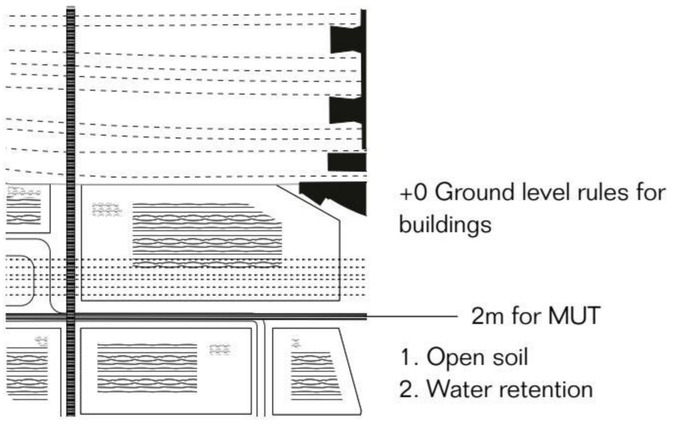
NBW norm — The area is not in line with NBW norm regarding the height of gorundwater level.

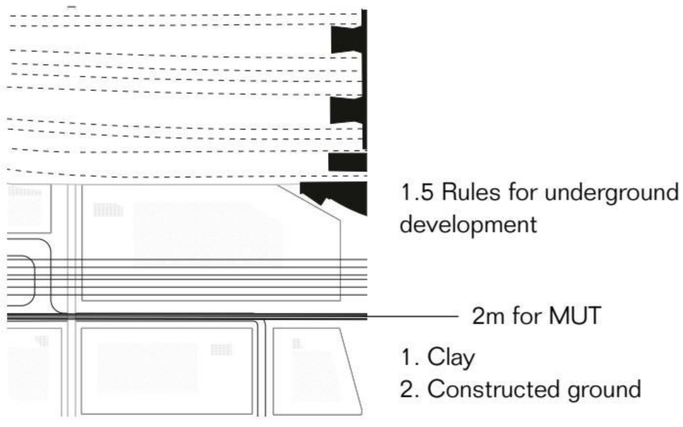
Static and dynamic conditions

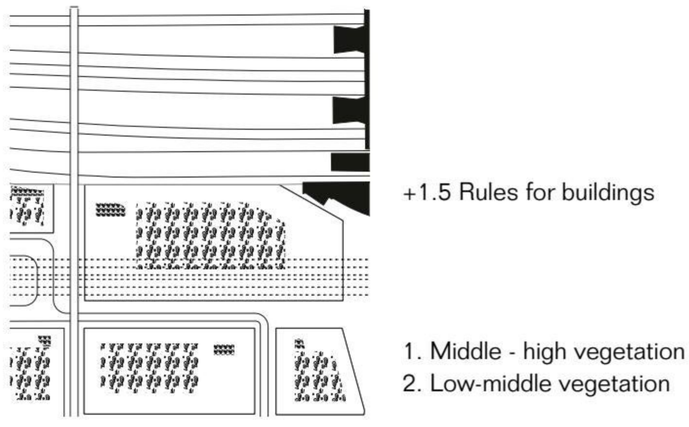
	Solid \ static conditions	Processes
People		
Metabolism		Energy, Water, Waste, Material, Food, Soil, Air
Buildings	Footprint; Rooftop orientation; Monument	Programmatic change
Public space	Open soil; Grass; Low medium vegetation; High vegetation	Biota Flows; Growth / succession
Infrastructure	Asphalt; Permeable pavement; Road; Public transport	Movement - flows
Civil constructions	Underground Building; Utilities Cables and Pipes (Gas, C. Sewer, Heat, Electricity, District Heating); Archaeology; Explosives; Dike	Partial filling; Site Grading; Integral filling; Combined Utilities Sewer Age (<< 25, 25 - 40, 41-60, >60)
Energy	Fossil Fuel Energy; Geothermal Energy; ATES (Aquifer Thermal Energy)	Electricity; Heat
Water	GroundWater; Drinking water resources; Open Water; Rain; Underground drainage; Macro map: Water Input/output Connection, Water level district	Rainfall return period: 1/year; Euthrophication; Infiltration; Runoff; Drainage; Evapotranspiration
Soil / ecology	Sand, Silt, Peat, Mulch, Gravel, Clay, Humus, clean soil, Bedrock, Polluted soil (Height difference); Trees; Macro map: Main green structure, Secondary green	Subsidence mm/year; Oxydization; Crop Capacity; Rhizosphere processes; Contaminants; Subsoil Life (microrganism)

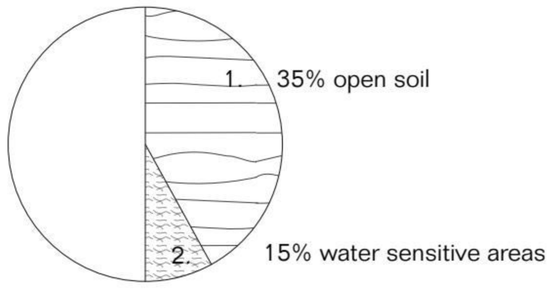
Technical profile Rotterdam Bloemhof-Zuid showing the problem of the houses on piles on the outside and the houses with slab foundations in the middle X marks the houses on slabs that have installed pumps because they tend to flood. (Source: Hooimeijer et al., 2018)

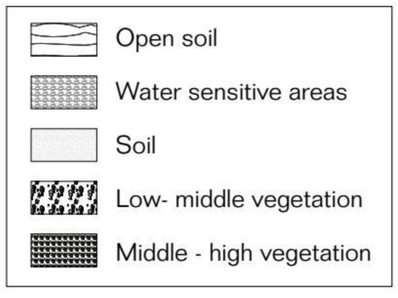
Provocative design for a new polder around the houses on slabs, with the added benefit of a high-quality green walking path structure The houses outside the green belt would have to be rebuilt on piles. The groundwater level could be lowered within the green belt, and the houses could move flexibly with the subsidence. (Source: Hooimeijer et al., 2018)











The zoning is not just about land use or public and private land; it lists open-soil surface and water storage percentages in the lot passports The zones are not just defined for the ground floor levels but also for lower and higher levels. (Source: Hooimeijer and LaFleur, 2018)

does not meet modern requirements either. Given the subsidence, the question is how the real estate can be renovated in the long term. Therefore, the municipalities of Rotterdam and Woonstad are drafting a vision document in which the technical condition, or the technical profile of the district, plays an important role.

The Leiden central station area faces the question of using innovative technologies to support the energy transition, adapting to the changing hydrological cycle, and increasing the biodiversity in the Leiden, Katwijk, Oestgeest, Leiderdorp, Voorschoten, and Zoeterwoude regions. As part of this project, an inventory was drawn up to determine how innovative technologies could be integrated into the current urban constructions and systems in the Leiden central station area, where cascading effects could be positively utilised. The project revealed that addressing the water issue is crucial to solving the energy problem. With this aim, a zoning instrument was developed that mandates specific water performance for each lot in the area, which will help establish a well-functioning water system in the area.

The BioScience park in Leiden is an example of public and private partners collaborating to integrate climate-proof measures for private and public spaces. With extreme urban design, another integration of this relationship was explored in workshops with the municipal team of experts.

Scenario ‘Extreme Green Privat’

Scenario ‘Extreme Green Public’

Provocative design for Bioscience in which private space is dedicated to nature and public space to public utilities (top) or the other way around (bottom) (Source: Hooimeijer and Van der Heijden, 2018)

Result of the multidisciplinary workshop in which the team elaborated – within set specifications – on the model in which the private space was dedicated to nature (Source: Hooimeijer and Van der Heijden, 2018)

EVALUATION

Bridging theory and practice

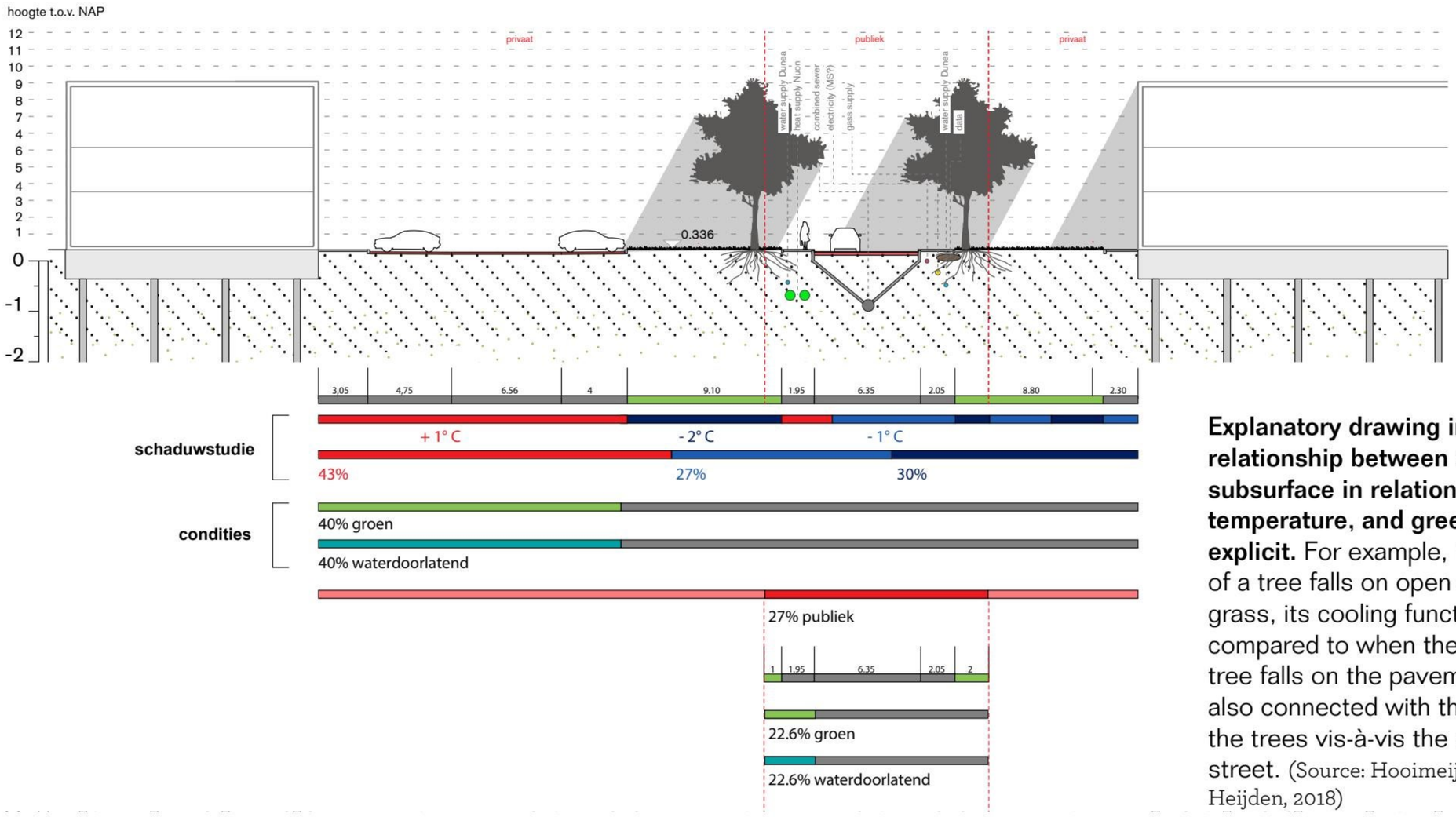
The Intelligent Subsurface Quality project focused on interdisciplinary design, including the disciplines working in the subsurface at TU Delft as a whole. The project was transdisciplinary because the cooperative research was carried out with the municipalities of Rotterdam and Leiden. The fact that it was a practical challenge means it was not always easy to frame it as a scientifically relevant challenge. It was not easy to pin down because it adapted protocolled ways of working and transitioned towards doing things differently in terms of organisation, data, and design. Even though much is happening already, these steps still need to be translated into fundamental knowledge to grow confidence and trust in the new approach. This means that on the scientific side, innovation lies in new approaches, methods, and integrated design, which are not technical innovations in themselves.

The project provided an opportunity to explore this gap and develop clear interdisciplinary and transdisciplinary learning outcomes and methods like the SEES, the framework used to understand the opportunity for coupling the Technical Profile as the visualisation of the disciplines in the subsurface with the urban design (presented in chapter 2). It was made clear that in the field of urban infrastructure environment, in particular, it is important for research to be coupled with practice to create new research fields. This study did not involve education directly, but the know-how and instruments that came out of this study are part of the curriculum of the master's programme in urbanism in the Sustainable Engineering of Territory course.

Longue Durée

The Longue Durée aspect of this topic is relevant in two ways. Longue Durée is a concept which acknowledges that some natural and human structures are so definitive that they remain in place over a long time and should be included in developments as a quality. First, the fact that urban systems produce artefacts in the subsurface enables us to look back in time. This is very literally the Longue Durée as reflected in archaeological findings, but we also need to take this into account when redeveloping areas with a view to risks and opportunities. The second point is that the water and geomorphological systems of the subsurface are Longue Durée structural, spatial elements. The man-made system also creates a (shorter) Longue Durée because these systems define the urban tissue: for example, the networks of cables and pipes are like corsets for the urban layout and are difficult to change.

The project brought forth a new community of practice within the TU Delft and its partners by creating a body of knowledge and tested instruments that are now used in practice and education. Moreover, the role of speculative design in rethinking the impact of new futures on day-to-day ways of working within urban maintenance and development made the participants from the municipalities aware of the relevance of the subsurface for surface development.



Explanatory drawing in which the relationship between surface and subsurface in relation to water, temperature, and greenspace is made explicit. For example, if the shadow of a tree falls on open soil such as grass, its cooling function is doubled, compared to when the shadow of a tree falls on the pavement. This is also connected with the position of the trees vis-à-vis the sewer and the street. (Source: Hooimeijer and Van der Heijden, 2018)

CONCLUSION

Visualisations in interdisciplinary co-creation

During the first phase of the project, the explorative method brought forth insights and design methods for the urban renewal of delta metropolises in which resilient, durable subsurface infrastructures are carefully balanced with the parameters of the natural system. The question 'how can the different technological artefacts in the subsurface be synchronised to offer more space and add to a higher urban quality?' was answered by taking procedural steps away from the technology to the design of public spaces and major urban structures. At each step, the translation from the engineering language to the language of urban designers, and vice-versa, produced an informative and helpful overview of relating technological artefacts to urban quality.

The second phase of the project focused on the question: In what way must the subsurface be architecturally represented to support a new script that consciously links the surface to the subsurface in urban development processes and products? The research was done through analyses of visualisations of the different disciplines, a literature review on the design notions stemming from Landscape Urbanism, and by using the agencies of visualisation and drawing to provoke and instigate interdisciplinary co-creation as well as advancing the project of Integrated Infrastructure and Environment Design.

The main conclusions of the project are that visualisations (especially the section) are not only a way to communicate an analysis but also a means for the internalisation of different types of data. The technical profile that was drawn up helped the urban designer better understand the technology in the area rather than being used to communicate this information to a broader audience. Interdisciplinary research has shown that the future legacy of various disciplines is moving toward the manifestation on the surface of previously 'hidden' technologies. Thus, the relationship between engineering and urbanlandscape planning and design will become more reciprocal than ever. This will require new ways of working and new methods of engagement in urban design and maintenance and a new attitude towards natural capital. The project laid the foundation for further research in the *Highway & City*, *City of the Future*, and *City x Space* projects.

Colophon

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