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## Drawing the subsurface: Integrated Infrastructure and Environment Design Intelligent SUBsurface Quality 4

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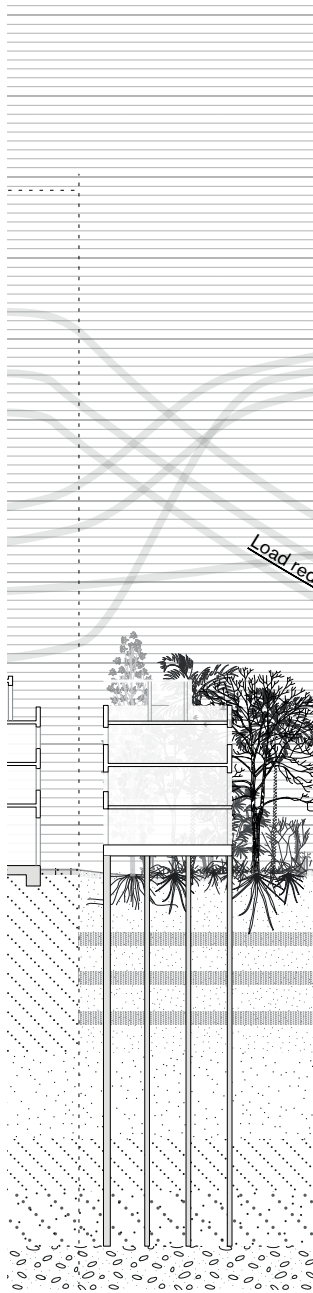
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# Drawing the subsurface:

## *Integrated Infrastructure and Environment Design*

DIMI Special Project Intelligent SUBsurface Quality





## Colophon

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Cities are the reconstructed constructed landscape of artificial and natural systems. Most of these systems are below ground, invisible but underlying and crucial for processes of urbanization. Subsurface space should be considered an integrated part of the surface, it should be acknowledged and designed as one united space. To be able to truly integrate those spaces there is a need for integrated design. Hugh Dutton (2000) argues on the integrated approach to design:

*For an integrated approach to design, borders between the distinct professional, industrial, and construction territories must be transgressed. The success of this exploration depends on architects understanding of the capacities and constraints of each separate field during the design process.*

To integrate the subsurface into urban planning and design this understanding needs to be part of the design process, as well as governance processes and products need to be innovated. Spatial planning of the subsurface should be a self-evident part of the surface system and reflected as - or seen in relation to - the basis of (surface) spatial morphology.

The objective of this research was to question the role of architectural representation of the subsurface in the making of territories. Discussing architectural representation should include 'design thinking'. Most authors that discuss the design thinking process, among which Change by Design (2009) by Tim Brown, highlight the value brought by use of visual representation. With some authors even calling visualization tools 'the mother of all design tools', because they are used in every stage of a design thinking process (Liedtka and Ogilvie, 2011). Another important part of design thinking are the concepts that are used to guide the design process. How is the subsurface represented in concepts like: 'constructed ground', 'mat urbanism', 'drosscape', 'thick infrastructure', 'field operations', 'machine landscape' and 'synthetic surfaces'? (Corner, 1994; Allen, 2001; Mostafavi, 2003; Berger, 2006; Waldheim, 2006; Pollak, 2006; Belanger, 2006). In these concepts that come from Landscape Urbanism discourse, the natural system is put forth as leading operational logic and landscape architecture is granted the ability to make urban structures more durable and sustainable.

In this research project another interpretation of Landscape Urbanism is proposed, as one that seeks (through design thinking) and integrated approach

between disciplines that master the natural system and the ones that master the technology to deliver shared benefits at multiple scales. Thus not only taking the operational logic of the natural system in itself as leading, but also together with the agency of the technological urban constructions that are already in place. This is presented as the concept Reversed Engineering with Nature (Hooimeijer and Maring, 2018). Reversed Engineering with Nature is a concept that aims at creating novel balances and cooperation between the technosphere and the biosphere. It relates the tame and wicked knowledge fields, actors and looks at the city as a hybrid performance landscape. Thus, not only allowing the operational logic of the natural system to take the lead, but also working together with the agency of the technological urban constructions that currently exist. Synchronization in time, space, technology and interests is one of the main goals.

To add to the representations of the subsurface in urban concepts this research proposes different methods of mapping, framing and projecting which aim is to advance the collaboration between engineers and designers. The project focusses on delta cities where issues of water and subsidence are prominent part of urban development. The reconstruction and synergy of urban systems that are natural and human infrastructure is studied to develop an integrated spatio-temporal approach. This is done through drawing the 'technical profile' and 'design provocation'. The technical profile of a site consists out of plans and sections drawings on different scales representing the natural and technical artefacts in the categories civil constructions, water,



Fig 0.1. Freud Unlimited, Madelon Vriesendorp 1975

This painting of Madelon Vriesendorp (O.M.A) reflects on the unconsciousness of the city. It was first published 'Delirious New York' by Rem Koolhaas (1978) which is about the new and complex culture of congestion and verticality of Manhattan Island. Interesting notion of unconsciousness and underground depicted here together, reflects on the purpose of this study.

energy and soil/ecology as a starting point of the understanding and framing of the field: a system of systems with specific natural and manmade palimpsest. Thus the 'agency of mapping' guide and inform the projective and provocative phase in which design strategies are delivered under the forms of spatial scenarios and projective 'scripts'. These scenarios and scripts are purposely proposing extreme interventions to support the process of 'design provocation' and stimulate interdisciplinary working.

This publication gives an overview of the research results of the project Intelligent Subsurface quality starting in the first chapter with the challenges. In the second chapter the context and approach towards dealing with the challenges is explored by framing the need for Integrated Infrastructure and Environment Design. The final two chapters are reflecting on the drawing of the subsurface in projective and provocative manner.

## 1.1 Delta cities, water, subsidence

Under the framework and goals of the project Intelligent subsurface Qualities, delta areas are regarded as extremely interesting and strategic case studies in order to generate, test and underpin the knowledge produced by the research project. The focus is on the urban renewal of (delta) metropolises and concentrates on the question how to design resilient, durable (subsurface) infrastructure when using the parameters of the natural system – linking in an efficient way the hydrological and water cycle, the soil and subsurface conditions and soil improvement technology.

Ongoing urbanization are projected to add another 2.5 billion people by 2050 to the World's urban population (UN, 2014, UNDP, 2016) of which most is concentrated in low-elevation flood plains and coastal zones. These are the areas where economic activities are thriving and where ecological pressures and uncertainties are at their highest (Meyer and Nijhuis, 2014).

Generally, advancing the knowledge on the making of 'delta territories' is perhaps one of the most pressing and urgent challenges for researchers and designers as most of the world population (following historical patterns of primary, agricultural and later commercial settlements) live not more than 100 meters (in elevation) from the coast (Belanger, 2014).

Built on soft soils, these areas have undergone and still are experiencing massive bio – geo – physical transformations (Meyer, 2014), although their geographies and endogenous characteristics are very different, the pressure that they face are global in their nature (Belto, 2014) as it is visible in figure 0.2 and 0.4. The question of urbanized deltas asks professionals, academics, designers and planners to reconsider in a

broader sense the relation between urban development and the natural environment. This historical dichotomy, can no longer be seen as such, as a counter proposal the natural and human domain should be seen as interconnected systems and mutually dependent, and thus planned, designed and thought synergistically within a frame where they are mutually supporting (Sijmons, 2014; Mostafavi, 2010).

In this project one specific aspect of delta cities was researched more in detail: the question of land subsidence which became the starting point to rethink the misbalance between 'air land water dynamics' (the biophysical systems) vis á vis the needs of urbanization. As shown in the diagram (fig 0.2) the level of subsidence in world cities is increasing and it's causing billions of dollars of annual damages, which makes it one of the world's most underrated problems (Deltares, 2015).

Subsidence refers to the movement of soils and grounds with consequences for building walls and foundations (the whole real estate stock, private and public), cables and pipes and public spaces. The sinking of land has two causes: first natural by movement of the earth plates (Deltares, 2013) and secondly by processes of urbanization. The Netherlands suffers from both; the west part of the country subsides because of moving plate, and due to the pumping of groundwater the subsidence has been progressed over centuries (Deltares, 2015), see fig 0.4.

Weather its extraction of oil and gas, deep groundwater extraction, disruption of shallow groundwater tables, drainage of peat lands, erosion of soils due to land use

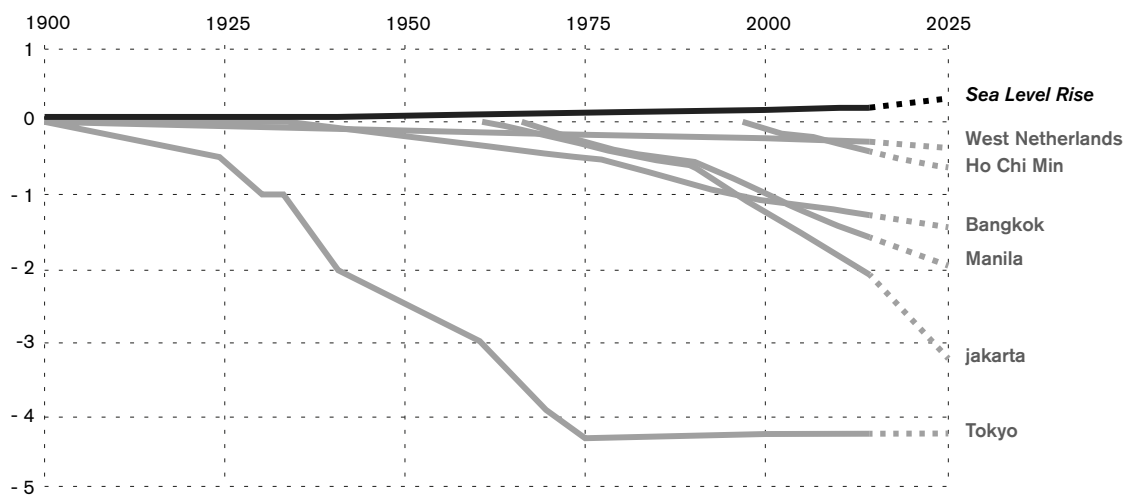


Fig 0.2. Projected subsidence in world cities. Adapted by author, from: Deltares, 2010

change, or deforestation, subsidence can't, and must not be solved technologically, but with systems solutions in a long term change perspective. Local sites can also subside due to alteration of surface-subsurface permeability rates (alteration of soil, from clay to sand for example), with a diminishing of groundwater table, causing peat and clay soils (typical of delta regions) to be drier (reduction of water percentages), and consequently to oxidize.

These general premises open up a variety of challenges, from a design and planning governance perspectives, from disciplinary fields integration to the question of time and scales. In order to prevent and design subsurface-surface systems to mitigate or adapt to subsidence, it is useful to gain further knowledge on subsurface space. The subsurface is the beholder of human infrastructures (like cables and pipes, underground space technology) but also of vital elements of soil, water and microorganisms. This exchange and generation of economies and ecologies are what is called 'engine room' of the city (Hooimeijer and Maring, 2013) for its features to make the urban machine running.

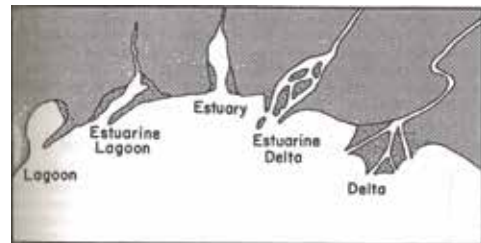


Fig 0.3. Representation of lowlands types. Davis, 1973

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*"The slow but steady natural process of land formation and land rise changed into land erosion and land subsidence; extensive flood plains changed into narrow channels; gradual transition of fresh to brackish to salt water zones changed into sharp separations between fresh and salt water. Rivers lost their room to expand during peak discharges; the consequences of floods became more serious because of land subsidence; ecosystem were destroyed because of the loss of sediment and nutrients. Estuaries and deltas, which represent some of the world's richest ecosystems, are threatened seriously with the loss of their richness"*

Han Meyer in *Urbanized Delta in Transition*, 2014.

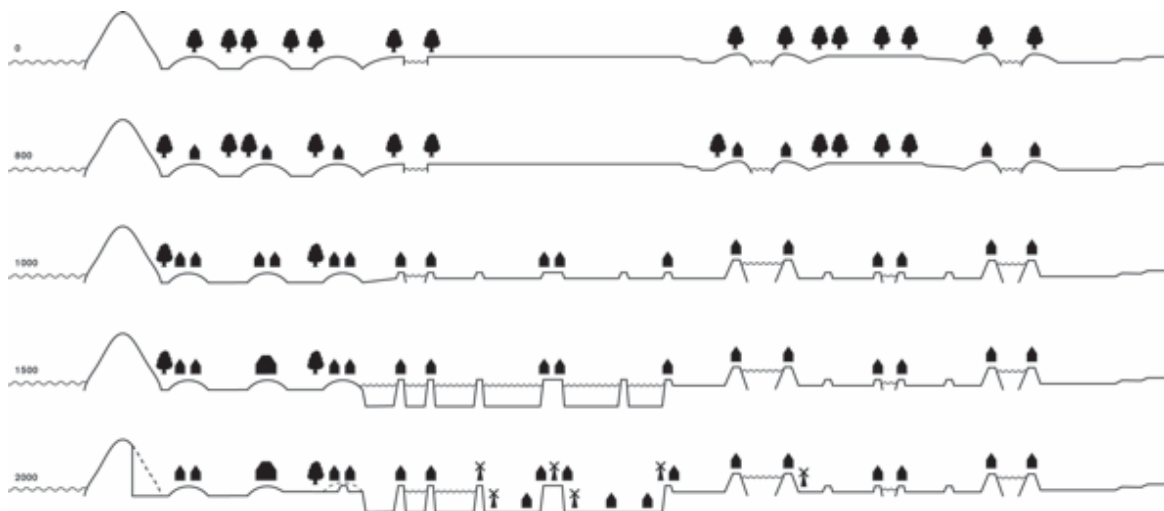


Fig 0.4. Sequence of subsidence over centuries in the west of the Netherlands (Hooimeijer et al., 2005)

1.2 Infrastructures

The practice of spatial planning and research into Delta Urbanism (Meyer, 2010) takes the Layers Approach (De Hoog, Sijmons en Verschuuren, 1998) as ordering principle. In this approach, three types of connected layers are distinguished as characterized by different rates and types of spatial development and change: substratum (soil, water, nature, and landscape), network (infrastructure) and occupation layer (living and working). Here it can be understood that occupation is facilitated by the infrastructure layering taking control over the dynamics in the substratum layer. In this way infrastructures and environment (the substratum) are the systems that create, support and facilitate urban occupation and economies.

The agency and legacy of infrastructure in the light of the challenges of climate change and opportunities of

energy renewal ahead makes it opportune to rethink infrastructure in novel ways. In this project the first step toward a broader inquiry on infrastructure were done by projecting scenarios for urban streets. There the biophysical layer of nature was re-tuned and re-integrated as potential design and planning concepts in which the agency of technology, ecology and engineering are integrated.

When soil and its stratification are considered as infrastructure for its continuous functioning, de-re composition, live matter interactions like microorganisms, nitrogen and carbon cycle, it becomes a more self-evident part of urban planning and design. It offers infrastructure the result of ever changing functional processes of interactions between air-land and water (Pileri, 2015).

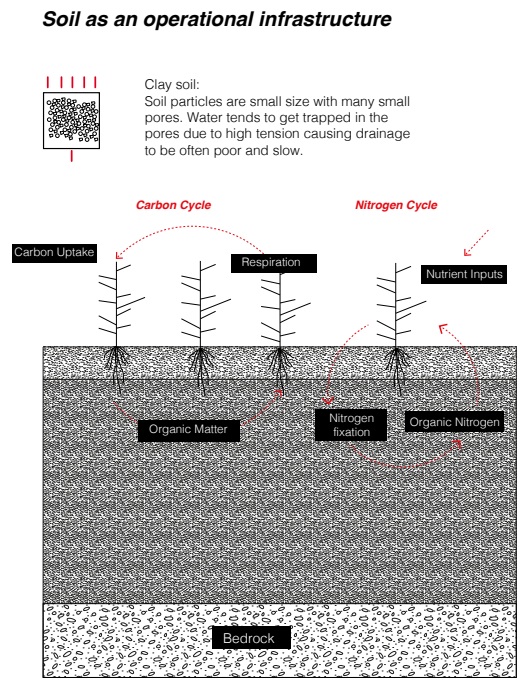


Fig 0.5. Soil functioning and mechanisms. LaFleur, 2016

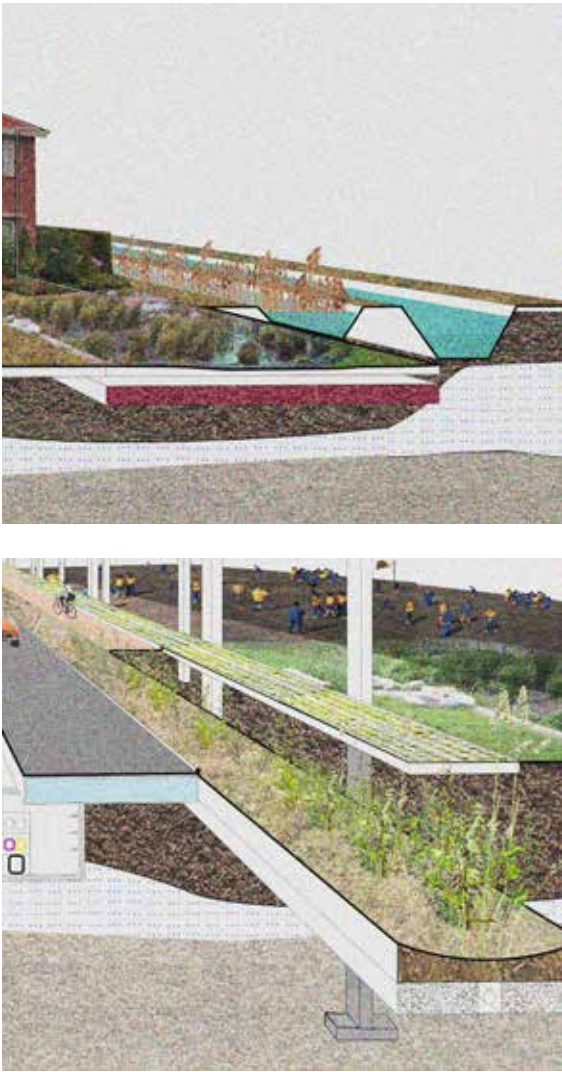


Fig 0.6. SubSurface Infrastructure design. Hooimeijer, Bacchin LaFleur, 2016

### 1.3 Interdisciplinary approach

This project is part of the interfaculty research initiative DIMI, Delft Delta Initiative on Infrastructure and Mobility in which an interdisciplinary perspective is stimulated. To reach interdisciplinary understanding and approach, drawing and representation has been the starting point to develop interdisciplinary research and process by design knowledge for the transformation of deltaic regions. Much has been written about the need for inter-, trans-, and multidisciplinary research and actions (Marescotti, 2011; Jensenius, 2012) as essential conditions for the sustainable development of human habitat (Petrisor, 2012). As a new working method, it holds the potential to unveil interpretative, analytical, descriptive, and projective tools to frame complex societal and ecological dynamics. The disciplinary separation and sectorial research is something that unconsciously is inherited from a purely deterministic, mechanistic view and paradigm of the world. This thinking is increasingly shifting toward complex dynamic systems theory and non-linear systems theory (Liening, 2013). It is a shift that is first and foremost philosophical, with repercussions on potentially every discipline involved in the shaping of the world. The notions of non-linear and open systems require us to rethink the roles and interlinks between engineering, technology, design culture, thinking and visualizations. If the societal and ecological challenges ahead of us are related to the way we transform the land (Rockstrom, 2010), such a synthesis of knowledge and action will necessarily entail a reintegration of the arts, humanities and sciences into a new transdisciplinary perspective that will guide collaboration and research (Wahl, 2017). This can also be seen in the strategic education framework of DIMI that advocates T shaped professionals (vertically professional knowledge of a single discipline and a systematic relational knowledge of various others disciplines) as a necessary condition for higher education curricula. As will be argued below, visualization and design thinking become a fundamental trigger for system and disciplinary integration.

### 1.4 Representation and Design Thinking

As stated in the introduction, the goal of this research project is to question the role of architectural representation of the subsurface in the making of territories. It is evident that in this discussion, the role of visualization and 'design thinking' is a central task (Brown, 2009).

#### 1.4.1 Representation

As recently showed by an array of design disciplines which deals with a 'visual renaissance' among all, service design, it is clear that the value brought by means of visual representation is most of all a procedural, participatory and creative one, which seeks synergies between seemingly unrelated fields. The act of mapping, drawing, representation, visualization, are seen as methods of research and ways in which knowledge and disciplinary integration can be advanced. Representation as a form of research can reveal complex processes of subsurface and surface, tangible and intangible interactions, linking technological, ecological, economical, societal and design challenges. Moreover, the representation of the fourth dimension of time, to synchronize performances and indicators is crucial in order to project future transformation and their implication in time and space.

This role of visualization and mapping is well described in two major publications that come from the American literature. The first one is by landscape architect James Corner, 'The Agency of Mapping', in which he advocates for a repositioning of the intrinsic qualities of mapping and drawing as a cultural project. Mapping as a project that deals with imagination, abstractness, relations but also preciseness and aesthetic conditions.

*"Through rendering visible multiple and sometimes disparate field conditions, mapping allows for an understanding of terrain as only the surface expression of a complex and dynamic imbroglio of social and natural processes. In visualizing these interrelationships and interactions, mapping itself participates in any future unfolding. Thus, given the increased complexity and contentiousness that surrounds landscape and urbanism today, creative advances in mapping promise designers and planners greater efficacy in intervening in spatial and social processes"* (Corner, 1994).

Corner also advances the seemingly banal notion of the 'site' as 'field'. A surface – field as an open system, subject to external and internal forces, making the field an open-ended entity accommodating and adapting to change in time. This calls designers and planners to understand and represent sites as intrinsically dynamic entities, adapting and changing to socio-economic and bio geophysical conditions.

The second publication is 'Cartographic grounds, Projecting the landscape imaginary' edited by Jill Desimini and Charles Waldheim (2016).

The book holds various sections in which methods of representation and projection are described. Here again,



the emphasis is on a shifting discourse, as anticipated by Corner, from the representation of physical conditions of the ground toward the visualization of often immaterial elements, such as forces, flows, dynamics and processes.

Under this outlook, the research project Intelligent Subsurface Quality, aims at reuniting the technical precision and idea of the map with the often unseen geographies and elements that it evokes or entails. Furthermore, the project focuses on two main tools of representation: the legend and the section.

The legend is seen as a strategic element in order to build a common language between various disciplinary fields. Composed of hatches and patterns, the legend describes the often-overlooked ingredient of the territory, both as static and dynamic entities. Secondly, the section is used as a strategic tool in order to understand material and immaterial properties but also the dynamic and structural relation between air, land (including subsurface) and water. Nevertheless, this instrument of representation can showcase several layers of complexities in one media, adding the temporal dimension next to the material one.

Mapping and visualizations techniques were used throughout the project to engage and generate various means. First, to appropriate and understand the spatial implications of hydraulic, civil engineering and geosciences, secondly to analyse hidden (physical subsurface) and immaterial (dynamic conditions) of the field investigated. Moreover, it is used to create a common language that is able to explain multiple layers of complexity of different disciplines within one common protocol (the Legend). Eventually, various methods of visualization, from scenarios, to section, from plans to axonometry and from collages to scripts unfold throughout the project.

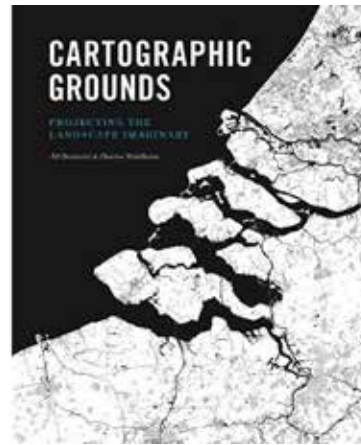


Fig 0.7. Book cover, Cartographic grounds.  
Waldheim and Desimini, 2016

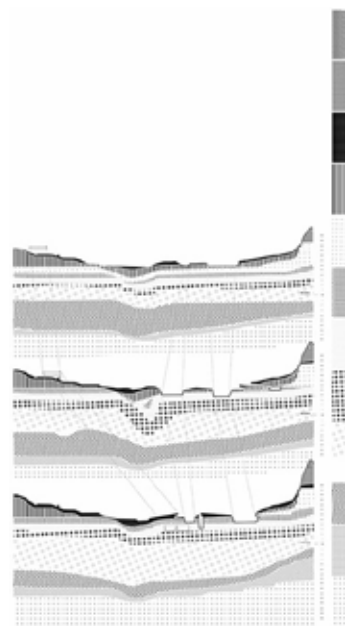


Fig 0.8. The cross section  
Waldheim and Desimini, 2016

### 1.4.2 Design thinking

As a young disciplinary field, design thinking requires a deeper understanding of its legacy to incorporate its potential in interdisciplinary research. Design thinking refers to specific cognitive procedures that designers operate during the design process. Introduced by Herbert A. Simon in 1969 it refers to the ability of the designer to embrace a complex thinking process in which convergent and divergent thinking coexist and reinforce each other in a nonlinear way.

As Tim Brown, CEO of successful business design company IDEO, puts it: *Design follows a series of divergent and convergent steps. During divergence we are opening up choices and during convergence we are choosing them. Divergent thinking gives us the potential to imagine and to generate new possibilities, while convergent thinking takes decisions, focuses on specific goals and test and reflects on the design outcome* (Queen, 2015).

As opposite to classical engineering techniques in which the focus is on problem solving, design focuses on problem framing and on the relations and interplays between parts. As argued by several designers and thinkers, complex, relational and design thinking gives us the ability to decodify the complexity of the layers shaping territories and to project its recodification (Belanger, 2010; Corner, 1993; Rizzi, 2007).

This process enables the exploration of seemingly hidden interrelations between the surface and the subsurface, the biotic and the abiotic and between the macro and nano scales.

Operatively, design thinking is deployed through the medium of representation, thus informing the interplays between engineering, technology and ecology. The process as described in the logic of the publication unfolds its discoveries in two major chapters. Framing and understanding (analysis), chapter 3, through

drawing as knowledge brokerage that feeds into a second part in which the projection of integrated infrastructure and environment alternatives is proposed in chapter 4, this is done through scenarios and an urban-landscape-technology script which consciously links subsurface programming with surface qualities (synthesis).

The relation between analysis and synthesis is crucial for the consequences and implications of disciplinary integration and involvement in each of the two steps. This link between almost two mindsets related to a project development is here described according to what Patrick Geddes, the founder of ecological planning and design (Wahl, 2017), in the 1920's developed. According to him, design should act as an integrator of knowledge and a facilitator of cultural transformation towards long-term change. In addition to this, he advocated for the central role of design as a facilitator of processes of co-creation as well as mediator between theory and practice.

*"Nonetheless the difference between science and design thinking should not be underestimated or obscured; Science emphasizes the study of the natural world, design the manipulation of the artificial world. The scientific method relies on controlled experiment and classification; design methods favors modeling, prototyping, pattern forming and synthesis. Above all science privileges objectivity, rationality and neutrality, whereas design favors practicality, ingenuity, and appropriateness or fit. Bringing scientists and designers together in an exercise of design thinking requires a capacity for 'mode2' knowledge generation, transdisciplinary methods, and synthesis that is significantly helped by a careful design of the process of interaction itself. The concept of design labs offers a variety of multi-stakeholder creative problem solving approaches informed by design thinking".*

Frances Westley and Katharine McGowan, 2015

The larger context of this project is the conceptual field of urbanism. In order to frame the project three fields are studied: Landscape Urbanism, drawing the subsurface and surface-subsurface space and relations. The first one it's about studying of design concepts stemming from the Landscape Urbanism field; the second studies the different visual legacies of various disciplines and the third summarizes previous work which dealt with inter- and multi-disciplinary working in order to find important conclusions to frame and pave the way for possible integrated infrastructure and environmental design projects.

### **2.1 Studying into the concept stemming from landscape urbanism perspective**

Landscape Urbanism is a discourse that started in the USA that promotes a novel landscape based approach to urbanism (Mostafavi, 2016). Among all it aims to rethink the relation between the city and the broader territory as a mode and a way to address the question of urbanization. Specifically, the natural system and its processes are considered the carrier of design in all the various concepts that originated from it. What can we learn by studying these concepts in an analytical and synthetic way? Which design mechanisms can we borrow when dealing with deltaic urban landscape transformation?

These were among the questions which generated the review, adding to this, since the project was involved in processes of sites transformations, the following paragraph reviews several of its notions in order to shed light on their theoretical and visual legacy.

How is the subsurface represented in concepts like: 'field operations', 'machine landscape', 'drosscape', 'mat urbanism', 'thick infrastructure', 'constructed ground', 'synthetic surfaces'?

### 2.1.1 Field operations

The 'Field operations mode' by James Corner is about moving away from aesthetic design and categories and moving toward operational logic and strategic instrumentality, the processes. He calls for a focus on the agency of landscape (how it works and what it does) rather than on its simple appearance and a merging or crossing of the borders between technology (having the knowledge to understand the natural system and the implications of interventions) and urban design. Transdisciplinary collaboration should have a generalist approach and start with understanding the natural system together, before deciding on the spatial quality, technological necessities and what 'spatial technology' can bring. This should lead to a combined language, shared methods, unified concepts and integrated scales (Corner, 1999).

The Field Operations mind-set and way of thinking is visible also in a publication: *Taking Measures Across the American Landscape* (1996), an exploration of American types of landscapes through essays and map drawings by James Corner with aerial photos taken by Alex McLean.

The book investigates the American landscape through aerial photographs from the practical to the poetic and it suggests possible alternatives for reading sites as systems, with their palimpsest and forces. Here the act of notation, multiple medias applied on a 2D field turn into a moment of understanding of the spatio-temporal complexities of the urban landscape. Thus, the drawing becomes 'simultaneous representation of projection mechanisms' one that is able to represent and imagine the relations between planes, surfaces, objects and processes of transformations and off-site relations.

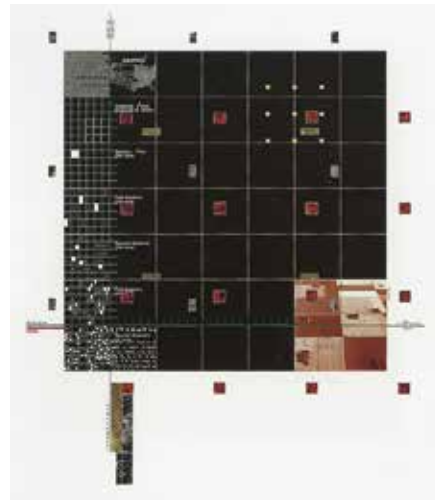


Fig 0.9. Taking measures across the american landscape.  
Corner and McLean 1994

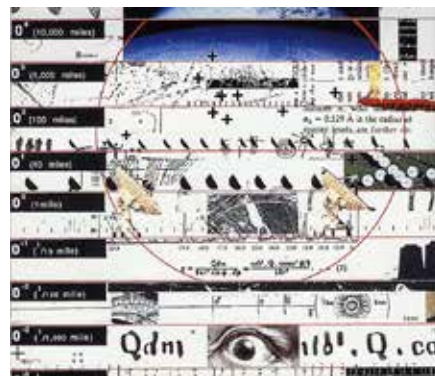


Fig 1.0. Taking measures across the american landscape.  
Corner and McLean 1994

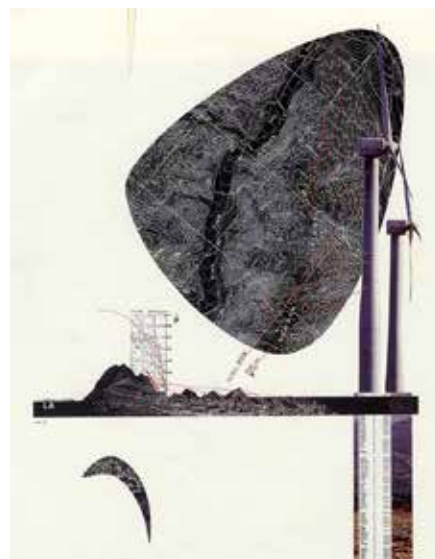


Fig 1.1. Taking measures across the american landscape.  
Corner and McLean 1994

### 2.1.2. Machinic landscape

The Machinic Landscape mode considers landscape as a cybernetic universe with its own laws (Mostafavi and Najle, 2003). The method applies dynamic systems in mapping to study the fluxes and processes that are inherent to the constant time-space evolution of the landscape. It contains gathering, decoding, synthesizing and processing information systematically to reach a design that accommodates change and indeterminacy. This approach puts data in the centre to steer infrastructure and ecological systems as ordering mechanism in urban design.

In the book *Landscape Urbanism: a manual for the Machinic Landscape* (Mohesen Mostafavi et al., 2003) landscape is seen as a performing system. A system functioning as software with its own operational logics. However, the idea itself of Machinic Landscape is not as defined as other design concepts emerged from the Landscape Urbanism discourse. It can be seen as a descriptive effort to show the intensification, or reprogramming of open spaces as Machines to support and generate the processes underpinning urbanization. Whether is solar or wind farming to supply cities with energy, or whether the landscape is seen as a machine by itself for its topographical and orographic characteristics, which makes it performing for hydropower purposes (Pevzner, 2015).

The research project builds also upon the Machinic Landscape paradigm through the idea of ecological performance in a combination with technical artefacts. Specifically, through the visualizations and projection of the 'machinic' aspects of air-land-water dynamics together with civil and engineering products. Eventually, a question rises, how will the Machinic Landscape change when restoration (landscape machine) and production (human-landscape machine) co-exist?



Fig 1.2: The machinic landscape of tulips. Der Spiegel 2008  
The figure describe how 'nature It's turned into a machine, detached from the natural cycles of time and geography, in other words, detached from itself, re-landscaped here to service a \$40 billion global flower industry.'

### 2.1.3 Drosscapes

Dross is a term first coined in 1995 by Lars Lerup, within his seminal essay 'Stim and Dross: Rethinking the Metropolis'. Lerup's comment that a city is a living organism or machine, an ecological envelope in which societal productivity and progression will inevitably produce waste and wasteful landscapes, or so called 'dross' (Lerup, 1995).

Building upon the notion of Dross, Alan Berger developed and expanded the term. He mainly focuses on the production of new visual and theoretical knowledge on the leftover spaces of urbanization, the so called wasteland, un-programmed, interstitial spaces, which can be seen as a natural by-product of urban development, also there is an attempt to describe vast horizontal spaces with impermeable surfaces (Cannatella et al., 2014)

The notion of Dross reflects a new contemporary condition of the urban machine, and drosscape is among others one of the most powerful concepts that depicts, describes and represents new spaces arising in the vast horizontal metropolis of the 21st century, fostered by more and more quick and cheap transportation systems (both for men and goods) (Berger, 2006)

The main difference between Lerups and Berger's idea of Dross is the positive attitude of the former which advocates for a simple two steps design methodology in order to plan and make use of these spaces for various means:

- 1) Use regional waste geographies and topical waste landscapes as the loci for future landscape design and planning activity.
- 2) Implement bottom-up advocacy processes, which will require inventiveness, entrepreneurialism and long-term environmental recovery.

With Berger, the concept of scale is developed according to a systemic point of view, naming it as a proper landscape category, in a way, characterized by its being unwanted and in wait.

Generally, the notion of dross acquires potential when seen in relation to a rising trend, i.e. shrinkage, abandonment and vacancy in post-industrial or decaying urban centres and open spaces. Their re-activation becomes a project in itself where the re-introduction of ecological dynamics and of ecosystem services becomes the main design strategy. Therefore, such areas must be rethought and re-designed paying particular attention to the relationships that they enable, and with the others components (sub-systems) that form the city.

Therefore, Drosscape reveals and describes a landscape defined by an endless matrix of built and open spaces along with the corridors and circulation systems, which connect them. From a projective point of view this matrix of leftover spaces can be transformed as an infrastructural backbone, i.e. a mix of planning, design strategies for possible landscape configuration that employs restoration, or reconstruction, of landscape elements in previously disturbed or fragmented landscapes, thus seeking opportunistic and innovative functions in association with urban infrastructures (Ahern, 2007).



Fig 1.3. CSX-Tilford Yard, Houston. Berger, 2006



Fig 1.4. Highway intersection. Berger, 2006



### 2.1.4 Mat urbanism

The notion of Mat that could be considered thick 2-D is first described by American Architect Stan Allen in 2002. It is Inspired by the Arab Kasbah, a typical city structure of arabic civilization defined by multiple buildings and voids next to each other forming a spatial complexity made of repetitive principles of composition (Oxman, 2002), according to Hashim Sarkis: *'Today Mats are appearing everywhere. We call them fields, grounds, carpets, and matrices. The mat answers to the recurring calls for efficiency in land use, indeterminacy in size and shape, flexibility in building use, and mixture in program. In the face of these challenges, the Mat claims to address a wide range of problems preoccupying contemporary architecture'* (Sarkis, 2001). Under this paradigm the concept of performance is one of the driving forces for a Landscape Urbanism concept that favors climatic comfort over aesthetic ideologies. It is inspired by the Arab Kasbah in the sense that it instigates a design strategy which can reconfigure processes of hybridization of forms and uses. The reconfiguration would have to start from a process of grafting and co-existence between different functions like in a Kasbah. The principle is not about literally making a Kasbah in being mixed and closed knit, but it should be a little more 'kasbahistic', by putting things together: and letting things penetrate into each other again. (Tuscano, 2005).

By studying it, not only there is an analogy with the concept of carpet, horizontality, dispersion and isotropy developed by Paola Vigano` in the project horizontal metropolis. Under this outlook, the Kasbah studied by Allen, with hybridity and co-existence of forms and functions can be linked to the description of various regional forms across the world, among others: the Veneto (citta' diffusa, i.e. diffused city) and Northern Belgium region which are defined by proximity of functions, where industry, agriculture, space for living and working merge into an isotropic territorial construction (Vigano`, 2016) .

Another important link with the Mat concept is the relation between the section and the plan. As the first focus has been on the planar dimension of such strategies, the section is equally important. The thick 2-D, as explained in his essays, reveals landscape performances and becomes an operational system with its own logic. For instance: " the work that the meadow or the forest performs: the processing of sunlight, air, or water: the enrichment and protection of the soil through the process of growth and decay, in mat configurations, section is not the product of stacking but of weaving,

warping, folding, oozing, interlacing or knotting together (Allen 2002).

By studying Mat concept, time and section appear to be strategic, descriptive and projective tools to understand the organizational logic of the natural system both in its spatial composition (horizontal) and process performances (vertical).

As we can draw from the article: Mat Urbanism:

The thick 2-d (Allen, 2001) the architect built upon a previous article by Allison Smithson in 1974, this research project, would like to advance and reflect the concept of Mat Urbanism in two ways, first with projective principles for a new script that consciously links subsurface infrastructures with surface qualities and secondly with new hierarchies and principles in the relation between the section (performance and process dimension) and the plan (composition and co-existence

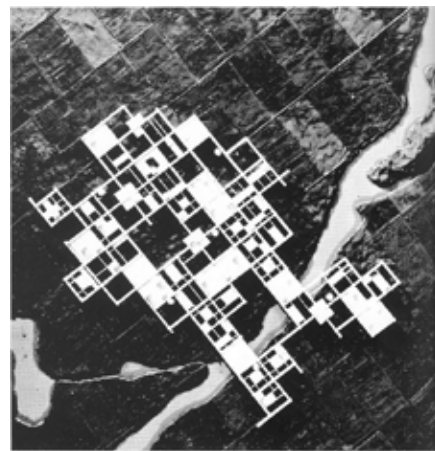


Fig 1.5. Agricultural city. Kurokawa, 1960



Fig 1.6. A vertical botanic garden. Allen, 2016

### 2.1.5 Thick infrastructure

The concept of Thick Infrastructure is related or somehow similar to the concept of Mat Urbanism. Both advocate for a more hybrid approach to infrastructures where material properties and programmatic symbiosis are revised as well as the question of its relationship with the city. Specifically, Thick Infrastructure put its emphasis on the section, to understand the geological, subsurface and surface condition as a unique space. The design of subsurface technology and its geology must enable a multifunctional program in its surface (spatial manifestation).

As we can draw from an article in the magazine 'Abitare' by Architect Weiss Manfredi (2016), it is important that infrastructures, as the civil engineering construction that supports the life of the city, incorporate cultural, ecological and recreational functions:

*'Infrastructural systems are the enduring forms of urban evolution, multiplying as cities grow and requiring expanding swaths of territory to accommodate requirements. As the very momentum of exchange incrementally overwhelms our urban landscapes, we wonder what new forms of public nature might emerge if highways, communication right-of-way, flood-resistant structures, railways, subway lines, and distribution grids were to become institutions of culture and recreation. Larger than life but part of it, infrastructure has an immediate presence; it shapes our environment and urban life in vital, authentic, and often messy ways. Tabula-rasa beginnings are rare for cities; hence, infrastructure, of both movement and culture, must evolve and activate pre-existing conditions. Highway, subway, utility lines, and tele-data networks have the capacity to serve and connect communities, define the static or fluid identity of an urban landscape, and unravel or re-stitch the increasingly fragmented fabric of our metropolitan world. The allure of this new public territory lies in its activation of a range of scales, its sectional opportunities for the simultaneous accommodation of movement and destination, and the hybrid programmatic potentials it affords.'* (Manfredi, 2016)

Weiss Manfredi among other designers and academics advocates for a new paradigm of infrastructures where the hard lines between architecture, civil engineering, urban and landscape planning and design would integrate into a more synthetic and innovative project for the urban landscape.

This contemporary thinking has been very much a spatial practice of the past centuries, especially in

examples of renaissance and pre-industrial cities, such as in the picture above, in the case of Ponte Vecchio in Florence and the wall of Otranto. Here the density of pre - automobile settlements required an efficient use of space, resulting in a multiplication of programs and pathways in a unique civil project. A revival of the design principles underlying this concept can be seen in recent projects for infrastructure and public space. The Big U in southern Manhattan by the Bjarke Ingels Group (BIG), for instance, proposes an intervention for the edge of an embankment between the bay and land with a construction that simultaneously links load bearing walls for flood protection, bioengineering and ecology, space for slow and fast mobility and a variety of recreational equipment and programs. Thus the project is able to accommodate social and ecological contingencies in space.

As we can draw from this brief summary of the 'thick infrastructure' concept, early examples of multifunctional and integrated infrastructure and environment design are seen a revival in new paradigms for 'post-industrial public work' as explained in the last example for the reconstruction of lower Manhattan by BIG. New abilities to pair programs will make investment more efficient and can create more interesting and complex design assignments.



Fig 1.7. Ponte vecchio in Florence. Fig 1.8. city walls of Otranto.



Fig 1.9. The BIG U project for southern Manhattan. BIG, 2014



### 2.1.6 Constructed ground

Constructed Ground is a general notion that appeared in various articles (Landscape Urbanism Reader, 2006; Scenario Journal, 2011-2012; World Landscape Architecture Magazine, 2011) and it is very much instrumental in the descriptive effort and projective ideas for territorial transformations. This simple notion is essential for its capacity to link engineering practices related to building site preparation and the different gradients of change of pristine fields or sites. It is also arguable that in the era of the Anthropocene every square meter of the earth is a constructed ground, being or having had, in a direct or indirect way, accommodated change that stems from the implications of human civilization (Rockstrom, 2009).

A clear example of a Constructed Ground which links subsurface engineering and surface programs is the Eastern Scheldt Storm surge barrier design by West 8 in the Netherlands, where technology and landscape are seen as unique integrated project which shape coastal bird migration, tide attenuation and recreational functions (Tepper, 2011). An important aspect of this project lies in its temporal dimension: the construction of the ground is staged in time. Management, cultivation and instigation of relationships become infrastructural in the sense that is the driving force not only shaping its ground but also its short – medium and long term relationships with exogenous flows. According to this point of view, Constructed Ground engages the complexity of material transformation on a hybrid framework between landscape architecture, urban design and architecture (Pollak, 2006).

Another important example of the notion of Constructed Ground can be found in the publication *Constructing the Landscape*, by Astrid Zimmermann (2009), a comprehensive manual for the construction of the public realm. The author shows the complexity in the construction of the urban landscape according to different disciplinary fields: from bioengineering, to soil mechanics, from structural foundation to materials in the public space. Soil properties and foundations seem to remain the basic and most important elements for construction of durable and resilient civic spaces in which there is a performative synergy between subsurface infrastructures and surface quality. Following this paradigm, thinking about the low lying state of the Netherlands is an extremely interesting example to show the seemingly banal complexity of a constructed ground. A state in which the reclaimed land, the polders, have undergone a process of biogeochemical transformation. That is to say, a gradual

change in material conditions, altitudinal dynamics, soil stability, the country could be described by the variety of civil, hydraulic, urban and landscape interventions that generated and underpinned conditions for life to prosper and for urban economies to thrive.

Constructing Ground calls for a new disciplinary synergies and the consequent redefinition on the way in which we build the surface and subsurface in order to accommodate occupation and urbanization strategies.

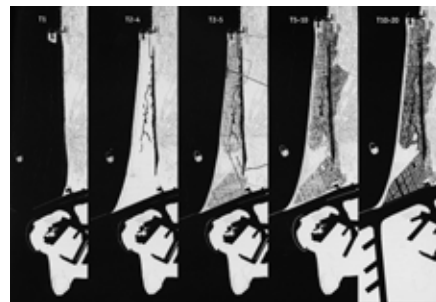


Fig 2.0. Eastern scheldt storm surge barrier. West 8, 1992

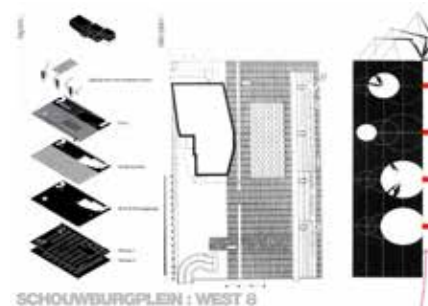


Fig 2.1. Schouwburgplein. West 8, 1997

### 2.1.7 Synthetic surfaces

The notion of Synthetic Surface appears in an essay in the *Landscape Urbanism Reader* (2006) written by landscape architect Pierre Belanger, which examines the seemingly banal aspect of 'one of the most important element which shaped our society': asphalt. This material is seen as the manifestation of the development of pathways and as a material synthesis of different surfaces. The article describes the processes generated by its construction, its landscape implications and relational consequences. The act of de-re-grading, de-sloping, and increase of stability through soil mechanics and building site preparation, contributed in the very physical transformation and alteration of the landscape, both surface and subsurface. More generally, when asphalt is laid out, it basically permitted the first interactions of people, trade and goods across vast regions and territories. The newly built circulation systems and conduits generated a series of tangible and intangible repercussions, for instance, urban development and capital accumulation (Lafleur, 2016).

The construction of these spatial elements has largely overlooked the material processes and topographies generated by it. In fact, natural elements like mud, marshes and wildlife were seen as obstacle to stability and speed and not made inclusive in the design cycles and management. Inclusion as elements of adaptation, mitigation and compensation could lead to internalizing the costs of the environment (natural capital) that is altered and replaced.

This discourse suggests that ongoing attention to the seemingly banal surface of asphalt is a crucial cultural task since it covers a vast amount of surfaces in the city. Once the only legacy in the construction of these systems, civil engineering will have to rethink its connection and synergies with design agencies in order to re-build integrated infrastructures and environment design. This is necessary because the externalization of environmental costs and benefits should be reintegrated under new forms of ecological infrastructure design inquiries.

Under this outlook, for instance, can asphalt and ecology co-exist in a new integrated infrastructural project? How can the urban section rebalance the human and the natural system, thus informing a better link between subsurface materials and surface manifestations? The project looks at ways in which different surfaces are informed and generated by the programming of what lies underneath, with the aim to reconstitute and shed light on possible configurations of

multi-programmatic fields.

Following this approach, history reveals some good practices of what is now considered to be central and crucial for an integration of different disciplinary fields in the infrastructural project. A prime example is the parkway system in Boston (1870) and Buffalo (1880) by the 'father of landscape architecture', Frederick Olmstead. These projects could be seen as the first example of integrated infrastructure and environment design, shaping at the same time the collective imaginary of the automobile landscape and the conservation of large pieces of habitat under the forms of linear forests (Desvigne, 2016). Thus it not only becomes a place of circulation, but it frames a series of open spaces, performative from a mobility, social and ecological perspective.

Interestingly enough, the landscape architect had a decisive role in the project that has been recognized to be a leading example of multifunctional infrastructure (Zaitzevsky, 1982). In the same way, by performing environmental services, social services and structuring new neighbourhood, the project is seen here as a precursor of a new urban infrastructural project.



Fig 2.2. Florida's turnpike. Florida Memory, 1958



Fig 2.3. Autostrada dei laghi public works. Varese press, 1924

## 2.1.8 Representation of concepts in drawing techniques

In the past 15 years these concepts under the prism of Landscape Urbanism allowed the discipline of landscape and urbanism to interact and 'feed' each other with potentials (Sordi, 2014). The review of Landscape Urbanism concepts provides an enormous stream of thoughts, tools, and instruments for designers and planners to rethink 21st century urbanization. They provide useful knowledge in how to first describe and then unfold the ecological agency over vast territories and small sites.

The urban plan, and planning documents in general should be innovative in such a way that they move away from deterministic models, and predictions of demographics and forms, on the contrary by embracing the non-linearity and uncertainty characterizing urban regions and sites, they must incorporate strategic interventions, multi-functionality, change over time, sequencing, process thinking, adaptive projects and ecological performance (Corner, 1994).

Thus, following up, in this research project another interpretation of Landscape Urbanism is proposed, as one that seeks (through design thinking) an integrated disciplinary approach that master the natural system and the ones that master the technology, and delivers shared benefits at multiple scales. Thus not only taking the operational logic of the natural system in itself as leading, but also together with the agency of the technological urban constructions that are already in place (Hooimeijer and Maring, 2017).

The question posed in this research was: How can the artefacts of the subsurface be included into concepts on urban development? (Hooimeijer, Lafleur and Trinh, 2017). The means to depict concepts like sketches, plans, sections and models, today expanded with an explosion in technology giving computer-aided drafting, photo-realistic rendering, and virtual reality. Despite these vast strides, however, the tools of representation are a blend of old and new – from techniques which have existed for centuries, to the technology of our century alone. The architectural sketch may be the first tool that every student comes into contact with in school, and possibly the most practical of them all. Fast and expressive, the sketch not only conveys the basic idea of spatial composition but also contains the individual style of the designer.

Producing plans and sections is a large part of the process of an urban project. Its greatest advantage

is that they present the urban tissue in specific proportions to enable the linking between scales. Also, urbanism should be considered interdisciplinary in essence and an essential method for knowledge brokerage in urban development projects is the reconnection of the plan with the section, or the horizontal and vertical dimensions to encompass all scales of the urban project. While the plan on the larger scale of the horizontal dimension is concerned with the strategic design of open spaces (surface network), the smaller scale of the vertical dimension (the section) is where the operational design of the technical construction takes place. The integration of the horizontal and vertical dimensions suggest possibilities (and best options) to link scales in a hybrid urban infrastructure, combining the strategic with the operational design.

Models, renders and virtual reality all escape the two-dimensionality of the sheet of paper. Models offer the possibility of observing, in general, the volumetric composition of the project from various points of view. Even though renders (or 3D visualizations) are two-dimensional compositions they usually are conceived from three dimensional digital models. They offer a realistic representation and are easy to use to see how interventions affect the natural and technical conditions. Virtual reality allows the observer to 'enter' into space and be part of it.

In order to be able to discuss the presence of the subsurface in the above described Landscape Urbanism concepts of 'machine landscape', 'field operations', 'constructed ground', 'mat urbanism', 'dross cape', 'thick infrastructure' and 'synthetic surfaces', the representation techniques of these concepts are checked. In table at page the subsurface is represented in the top layer, using the four categories of civil construction, energy, water and soil in which the subsurface elements are ordered. In the column the representation techniques are placed and for each concept checked. The analyses deliver insight in how well and in which technique the subsurface is represented.

The fact checking of the concepts gives a quick overview of which subsurface elements are well integrated and which elements are not. As could be expected from concepts that are part of the Landscape Urbanism discourse the element 'geomorphology and landscape diversity' of the soil category are represented

in all concepts in all the means of representation. The elements 'crop capacity' and 'ecological diversity' come in second with three of the concepts and are foremost represented by plans, sections and diagrams. The attention towards the fauna in the soil in 'living soil' is only looked at in two Landscape Urbanism concepts. In the category of civil constructions, the 'underground structures and foundations' are well represented although less in 3D. 'Cables and pipes' and 'basis for building' activities, are taken into respectively four and three concepts, and again mostly in plan and section. The other civil construction elements are underrepresented.

The water category is adequately demonstrated in all means of representation, except for the 3D model, which is also a fluid topic to draw. In the energy category there were no representations found. Besides the plan, the section is important to identify in vertical direction the confrontation of the different technical conditions, processes and projections (Bélanger, 2012). In that sense the Landscape Urbanism concepts all use

the sections but do not draw the human or engineered elements, and especially not the relation with these to the natural elements. The use of 3D, diagrams and sketches is a next step to be explored to become even more integrated in design concepts.

HOW \ WHAT		SOIL							CIVIL CONSTRUCTION					WATER			ENERGY		
		Healthy and clean soil	Resource minerals	Crop capacity	Living soil	Geomorphology Diversity landscape	Ecological diversity	Storage of materials	Cultural historical importance and archaeology	Unexploded ordnance (UXO)	Underground structures Foundations	Cables and pipes	Basis for building activities Stable ground	Water filtering soil	Water storing soil	Resource drinking-water	Aquifer Thermal Energy Storage (ATES)	Geothermal energy	Resource fossil energy
PLAN		●●	●	●●●	●●	●●●●●	●●●	●●●●	●●	●●	●●●●●	●●●●	●●●●	●●●●●	●●●●●	●●●			
SECTION		●●	●	●●●	●●	●●●●●	●●●	●●●●	●●●		●●●●●	●●●●	●●●●	●●●●●	●●●●●	●●●●			
3D	AXO			●●●	●	●●●●●		●●●	●		●●●●			●●●	●●●●				
	PERSP			●●●		●●●●●			●			●			●●●●				
	MODEL					●●●●●						●			●				
DIAGRAMS		●●		●●●	●●	●●●●●	●●●	●●●					●●●	●●●●	●●●●	●●			
PHOTOGRAPHY						●●●●●	●●●	●●●	●●		●●●●	●●●			●●●●				
SKETCHES					●	●●●●●			●●		●●●●●			●●●	●●●●				

- constructed ground
- mat urbanism
- drosscape
- thick infrastructure
- field operations
- machinic landscape
- Synthetic surface

Fig 2.4. Comparative table of representation medium and studied concept of 'Landscape Urbanism'. Hooimeijer, LaFleur, Trang Trinh 2016

## 2.2 Representation in domains

Even though not focused on representation for design, but for analyses, the various disciplinary fields in the subsurface also use the mean of representation. In order to gain insights on the visual legacy of these fields, here a visual essay is presented consisting of drawings and visualizations stemming from these different disciplinary fields.

In order to reach integrated disciplinary knowledge, the single disciplines are studied together with the visual references that they have produced. By doing so, both the spatial implications and the aesthetic language are studied. The interest is twofold, gaining knowledge on each disciplinary field by studying the representation medium and secondly in finding the overlaps, how things eventually 'shape the ground (subsurface – surface)'.  
Eventually, by studying the other disciplines, we are intertested in how processes of time, dynamics of biogeochemical interactions and flows axctually shape the ground.

### Soil



Fig 2.5. Land classification in Poland. Konecka, 1952



Fig 2.6. Exploratory soil map of Kenya.  
Eastern scheldt storm surge barrier. From: West 8, 1992

### Energy

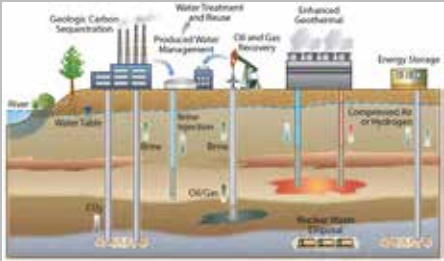


Fig 2.7. Subsurface Energy cycles. EESA, 2018

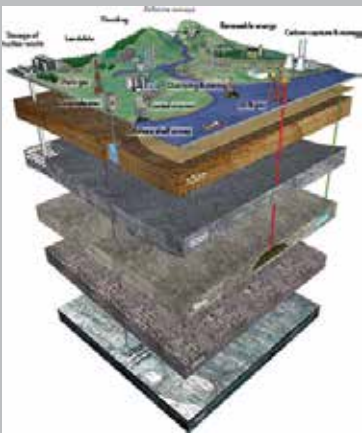


Fig 2.8. Geology and energy. British geological survey, 2017

### Archaeology

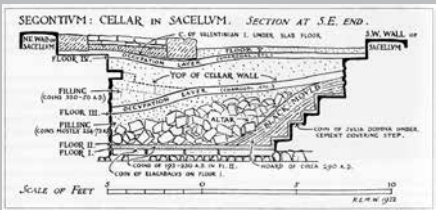


Fig 2.9. Roman fort in Wales, stratigraphy drawing.  
Wheeler, 1922

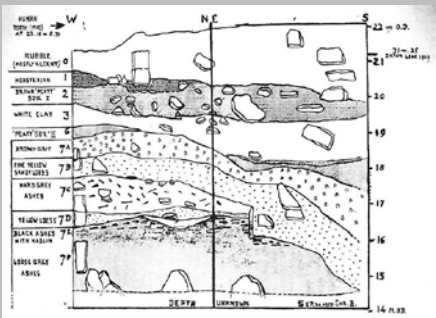


Fig 3.0. The coast of St. Brelade, longitudinal section. Burdo, 1956



Civil constructions

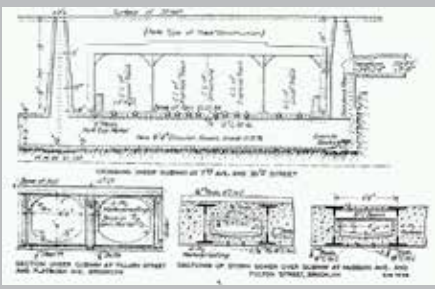


Fig 3.1. The New York Rapid Transit Railway Extensions. Engineering News, 1914

Ecology

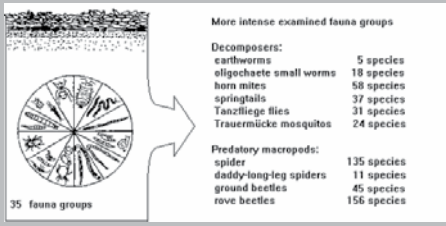


Fig 3.4. Soil fauna groups given a more intensive taxonomical examination. Weigmann, 1993

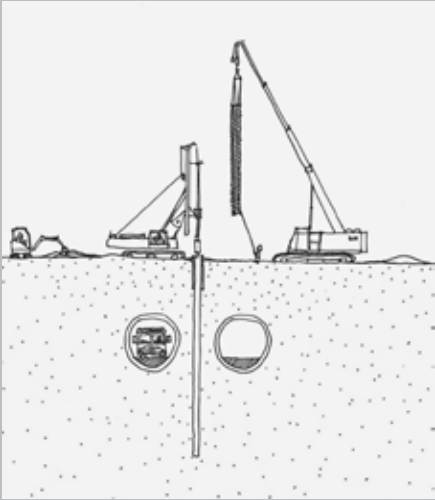


Fig 3.2. Foundation piles, drilling between the Metro Tunnels. Ware, 2014



Fig 3.5. Soil Fauna Diversity – Function, Soil Degradation, Biological Indices, Soil Restoration. Menta, 2012



Fig 3.3. The intersection of three underground railways. Skyscraper city, 2013



Fig 3.6. Microflora and fauna in soil. SOS - Arsenic, 2011

## Subsurface - Surface Representation

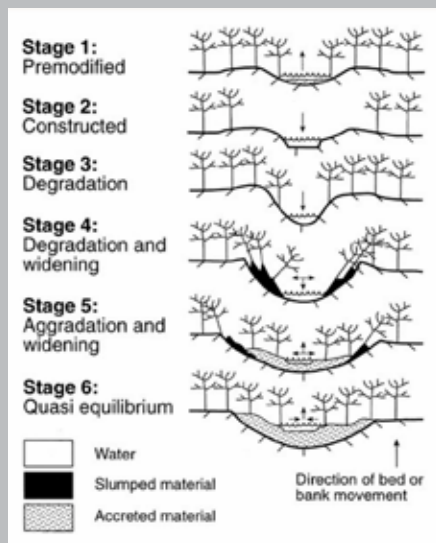


Fig 3.7. Stages of stream and floodplain evolution following channelization that occurred in western Tennessee streams around the 1900s. Hupp and Simon, 1991

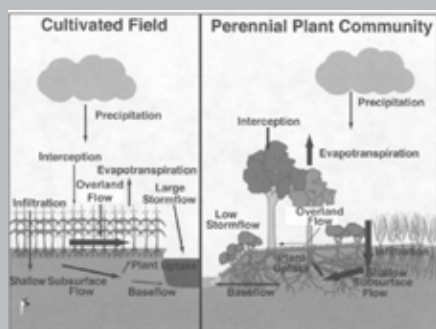


Fig 3.8. Differences in water movement in a non-tiled annual row-crop field and a perennial riparian forested buffer. American Society of Agronomy, 2000

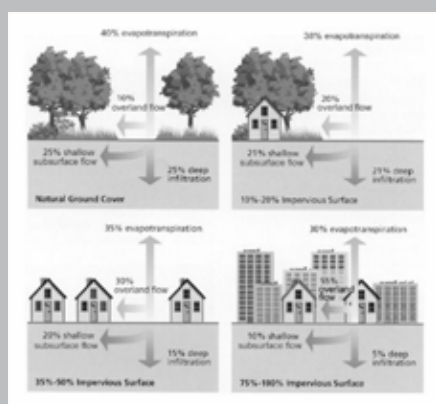


Fig 3.9. Relationship between impervious cover, shallow subsurface flow, deep infiltration, and overland flow. Federal Interagency Stream Restoration Working Group, 1998



Fig 4.0. Valley section. OPSYS, 2011

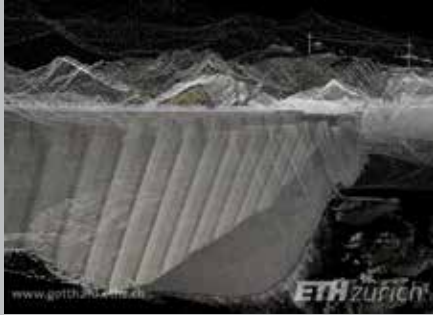


Fig 4.1. Gotthard landscape, the unexpected view. Girot, 2016

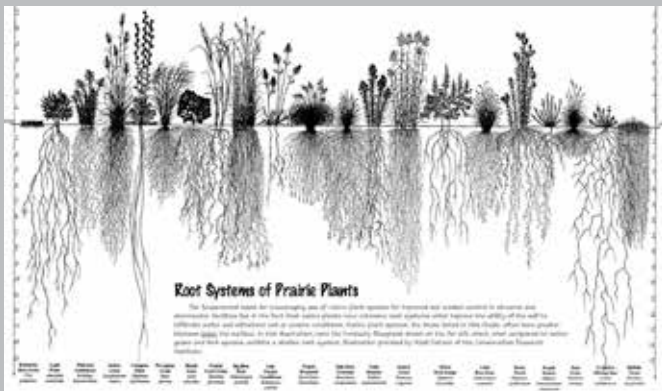


Fig 4.2. Root systems of prairie plants. Crumpler, 2013

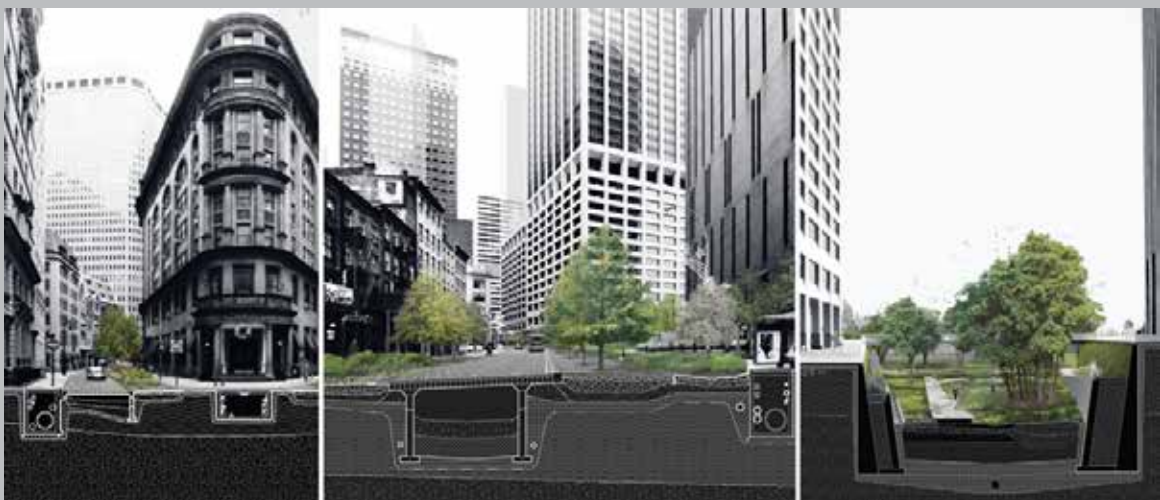


Fig 4.3. Rising currents NYC, street profile. DLAND Studio, 2010



## 2.3 Framing disciplines: Surface-subsurface space and relations

How to master the relation between surface and subsurface as an integrated project where both the natural system and the urban technological construction are taken into account? In order to do this, the project started with the aim to create an interdisciplinary scope. This is done through co-creation mechanism within the TU Delft community, and through interviews with experts at the municipality of Rotterdam in order to understand interactions in planning, design and engineering processes. Eventually is crucial to be able to visualize the implications on space and reflecting on the question of how to better synchronize their transformative agency in the context of low-lying delta areas.

### 2.3.1 Understanding of domains, disciplines and urban issues (elements of urbanism)

As 'elements of Urbanism' the various artefacts, which compose the urban landscape, should not be overlooked. If we want to gain more interesting outcome the process of hybridization of design and engineering disciplines should start with a conscious understanding of the various infrastructures which support and shape urban development.

To gain a better understanding of the relation between surface and subsurface, the System Exploration Environment and Subsurface (SEES) is used to show the domains within urban development and ordered the subsurface topics according to urban issues. This overview can be used as knowledge map and systems overview to encourage the view that both the surface and subsurface belong to a single space (Hooimeijer and Maring, 2013). This integrated perspective recognizes the interdependence of the techno-sphere and the bio-sphere – the constructed and natural systems – within the subsurface and sorts urban issues into four categories: civil constructions, water, energy and soil.

The SEES facilitates interdisciplinary working by providing an overview of the different fields of knowledge that involve the subsurface and displays their connection to surface planning and design. The framework is considered a 'performance landscape' that supports three tactical ingredients: the knowledge map, the system overview and knowledge brokerage between disciplines of different nature. It brings together different agents and enables distributed agencies to

adapt to the 'wickedness' of urban development. The ultimate aim is to identify opportunities in the synergy of different systems, and use that synergy to add to the general urban quality. During the design process, use of mapping should operationalize the subsurface information, making it possible to make natural conditions a priority and carefully balanced with the technical applications.

### 2.3.2 Subsurface categories and qualities

The subsurface layer of the SEES is built on the results of the project: Manual Planning with the Subsurface (<http://www.ruimtexmilieu.nl/>). In this project the qualities of the subsurface that support the surface were defined. These qualities were classified, in line with many ecosystem services studies, as having production, regulation, carrying and information qualities (Figure 4.4). This ecosystem-related view is not in line with a traditional spatial planning and design perspective as the categories of production, regulation, carrying and information are not within an urban developer's vocabulary and not part of contemporary urban issues (Hooimeijer and Tummers, 2017). For this reason, the SEES method has adopted the more familiar categories of civil constructions, energy, water and soil. In each category there are different subsurface qualities that are a knowledge field on their own. In order to get proper understanding of the relation between surface and subsurface these categories and qualities are elaborated on and described in the table at page 28-29, according to the following topics:

- Characteristics,
- Additional ambitions,
- Examples spatial appearance,
- Assignment starting from the expert,
- General Data online (for the Netherlands),
- Planning column: laws, regulations, policies.

In the research a better understanding of the different field and their ways of working was gained by holding interviews with the experts at the municipality of Rotterdam city, engineering department. The aim was to discover the level of interaction between different specialists, between designers and engineers and the management and time of interaction behind the process of territorial transformations.

Most of the specialist were found in a working condition of 'stability and control' over their disciplines with few interactions with other disciplinary fields. The table in the next pages are an attempt to show in a comprehensive way the implications that each knowledge field has on various spatial, jurisdictional and procedural field.





















SUBSURFACE / SUBSOIL	CIVIL CONSTRUCTIONS					ENERGY			WATER			SUBSURFACE						SUBSURFACE / SUBSOIL
LAYERS	archaeology	explosives	underground building	cables and pipes	carrying capacity	ATES (aquifer thermal energy)	geothermal energy	fossil energy resources	water filtering capacity	water storage capacity	drinking water resources	clean soil	subsoil life / crop capacity	geomorphological landscape type	ecological diversity	sand/clay/gravel resources	subsurface storage	LAYERS
PEOPLE																		PEOPLE social structure (neighbourhood typology) social behaviour labour productivity labour capital
METABOLISM																		METABOLISM energy / food water waste air (building) material products
BUILDINGS																		BUILDINGS offices housing utility culture
PUBLIC SPACE																		PUBLIC SPACE living environment culture nature agriculture
INFRA STRUCTURE																		INFRA STRUCTURE mobility network
SUBSURFACE																		SUBSURFACE subsurface subsoil water energy civil constructions
SUBSURFACE																		SUBSURFACE

shallow  
shallow and water layer  
water layer  
deep > 500 meter

Fig 4.4. SEES, System Exploration Environment and Subsurface table. Hooimeijer and Maring, 2017

## Subsurface Layers: Toward an interdisciplinary approach

The subsurface layers table aims at showing the relationship between the various subsurface layers and a series of spatial, legal and general characteristics of them. Thus doing the study helps in the issue and objective of interdisciplinary knowledge brokerage.

	WATER	Characteristics	Additional ambitions	Examples spatial appearance
	water filtering soil and water quality regulation	Important properties related to the water filtration capacity of soil are: soil permeability, amount of organic matter, soil ecology, subsurface structure. The subsurface has a certain resilience to filter and purify water. With the use of unpaved surfaces, grass and gardens, etc.; to infiltrate the water and filter before it enters the open water system.	<ul style="list-style-type: none"> <li>• Avoid sealing and pollution in infiltration areas</li> <li>• Avoid compaction and clogging of soil. If possible use (stimulated) natural degradation of contaminants</li> </ul>	Bioswales, helophyte filters, bioretention cells, raingardens, retention and detention basins
	subsurface water storage & water level regulation	By facilitating underground water storage capacity creates protection from pluvial floods and natural salination. Regulating groundwater levels is related to subsidence and peat oxidation. Limiting paved surfaces can facilitate groundwater replenishment and storage capacity.	<ul style="list-style-type: none"> <li>• Take into account the water storage capacity from the beginning of the planning process (water test).</li> <li>• Promote water storage capacity of the soil according triad: retention, storage and disposal.</li> <li>• Search for functions that can be combined with water storage.</li> <li>• Encourage absorbency of the soil.</li> </ul>	permeable pavements, open soil: agriculture, grass, meadow, wetland, forest, opens spaces; open water
	supply of drinking water/fresh water	Aquifers are a sources of water and are located on different depths. Competing water sources between drinking water, agricultural water use, water for industrial use and water used for cooling. Should be protected from pollution and lack of replenishment.	<ul style="list-style-type: none"> <li>• Avoid damaging destinations / activities inlet of infiltration areas.</li> <li>• Smart spatial planning saves drinking water.</li> <li>• Incorporate drinking water from the beginning of the planning process (water test).</li> </ul>	Nature reserve, no urban or recreational functions
	Energy	Characteristics	Additional ambitions	Examples spatial appearance
	thermal storage (WKO)	Thermal storage requires are open systems in aquifers. Aspects that should be considered are: sufficient permeability soil, freshwater and saltwater boundaries of ground water, the presence of contaminants, presence of protected areas (such as protected drinking water areas), the demand for heating/cooling in the area. Pay attention to piercing of sealing layers and for mutual interference of adjacent thermal storage systems.	<ul style="list-style-type: none"> <li>• Integrate into (existing) city heating systems.</li> <li>• District / city energy plan development.</li> <li>• Licensing with the Groundwater Act through the authority of the Province administration.</li> <li>• Innovate through combinations of ground water remediation.</li> </ul>	Above ground footprint of a thermal storage tank
	supply of fossil fuels	Significance depends on the quantity and accessibility of the fossil fuels. Concern is drilling through layers, the water from high depths (brine water) is very salty.	<ul style="list-style-type: none"> <li>• Limit the nuisance for surface activities.</li> </ul>	Oil extraction pump jack
	geothermal energy	Feasibility of geothermal energy depends on depth, permeability, demand and available surface space for extraction. Pay attention to piercing of sealing layers. Costs of drilling is very high, while there is no 100% success rate.	<ul style="list-style-type: none"> <li>• Density of buildings in areas suitable for geothermal energy production, because it is only economically attractive at high heat demand (horticulture, industrial, high urban area).</li> </ul>	When drilling the area should be set up safely, it requires space. Thereafter, part of that space will be occupied by a production unit. Maintenance of the drilling hole and subsurface equipment also requires space.
	Soil	Characteristics	Additional ambitions	Examples spatial appearance
	clean soil	Severity of pollution depends on the type of pollution source, type of pollution and surface activity in the area. Pollution can be both mobile and immobile, which depends from the ease of movement of the groundwater and type of soil and type of pollution.	<ul style="list-style-type: none"> <li>• Search for coordination between spatial features and clean soil.</li> <li>• Have the humane and oncological risks taken into account.</li> </ul>	Basis for public spaces, parks and in the case of pollution combine underground construction (with the remediation), whether or not in combination with large scale construction above ground.
	availability mineral resources	Management of mineral resources is another way cities manifest them self in space through the continues alteration of sand and soil in the city. Both receiving it through sedimentation and altering it through construction, extraction and maintenance. Many different stakeholders, public and private have interests in reusing this precious material. Transporting it and re-using it closely. Using soil according to the quality and type, provides opportunities for soil upcycling. Organic soils, like peat, are important for gardens, parks, etc.	<ul style="list-style-type: none"> <li>• Use of local mineral resources and limit transportation.</li> </ul>	Provides inspiration for materialization of public spaces and buildings The soil management has a clear spatial goal: peat/clay for public gardens, clay/sand for sound barriers, sand for contraction and heightening of roads.
	crop production capacity	Concerns the chemical, physical and biological soil fertility, natural vegetation of the region, characteristic flora and fauna, degree of nutrient levels and ability to retain or supply nutrients important for the agricultural activity. Excess inputs of nutrients may also disturb soil ecology. Can conflict with other subsurface infrastructures.	<ul style="list-style-type: none"> <li>• Target only after nature objectives that are achievable with the current soil conditions</li> <li>• Appropriate land use by changing production.</li> <li>• Impoverishment in nature.</li> </ul>	Urban agriculture, school gardens, allotments.
	living soil	10 to 20cm of the top layer is the most active part in the soil ecosystem services. It is often polluted. A more divers soil ecology provides larger capacity for soil resilience. Maintenance of cables and pipes underneath parks interferes with the organic layer and ecological performance. Living soil and healthy soil generate and stimulate healthy ecosystems in terms of biodiversity. Ecological performance of the soil forms the basis for the ecosystem above ground.	<ul style="list-style-type: none"> <li>• Use biological soil quality references in planning nature.</li> <li>• Develop region-biodiversity.</li> </ul>	Nature and compounds thereof on urban scale, on lower scale natural banks, ecological design by greenery and water.
	diversity landscape image	Diversity landscape image is related to surface water. Type of landscapes and structures in the landscape. Maintaining of certain landscape features can also be counterproductive. Current standards for organic soil per tree is 7m3, but depending on the tree this may not be enough. For parks and gardens the standard is a top layer of 30 cm of organic soil.	<ul style="list-style-type: none"> <li>• Use methods and techniques that make quality of the landscape negotiable.</li> </ul>	Connect with site preparation to the character of the landscape and allow it to determine the vegetation.
	geomorphological diversity	The structure of the subsurface and soil formation processes such as peat formation, sedimentation, erosion. Slow processes, thus the inclusion of these is difficult to fit into spatial plans. The upscaling from the data, especially in the question of soil and ecology to larger territorial dynamics.	<ul style="list-style-type: none"> <li>• Develop the landscape by preserving and strengthening the characteristics.</li> </ul>	Utilize diversity in the soil for diversity in cityscape image.
	ecological diversity	The ecological performance is strongly related to the presence of ecological diversity. Ecological performance has many indirect benefits to healthy living conditions. The presence of birds other fauna are indicators of healthy ecological biodiversity.	<ul style="list-style-type: none"> <li>• Utilize ecological transitions for nature development.</li> <li>• Make plans for nature with the subsurface.</li> <li>• Manageable strategy of two networks for structural challenges.</li> <li>• Balance of nature and soil properties in a systematic way according to the ecotypes approach.</li> </ul>	Main structure of green and water.
	CIVIL CONSTRUCTION	Characteristics	additional ambitions	Examples spatial appearance
	basis for construction activities	Basis for construction activities is to be determined by soil structure, such as peat layers in the upper middle of soil and load bearing layers. An increase of the load on the ground causes a compression of the soil. this will consequently increase the bearing capacity, but will also decrease the water handling capacity. Groundwater reductions for construction activities may cause subsidence.	<ul style="list-style-type: none"> <li>• Do not build on weak soils.</li> <li>• Build on poorer soil demands according to building regulations and more expensive facilities if necessary for structural safety.</li> </ul>	Method of site preparation as a basis for urban design.
	stable subsurface	Prevents erosion and thus vulnerability from water and wind erosion. Compensation for lack of stability (e.g. vegetation) is dependent on the subsurface structure and soil types in the area.	<ul style="list-style-type: none"> <li>• Build on stable locations to save costs.</li> <li>• Use unstable locations for lightweight constructions or functions such as practical, public spaces, sport etc.</li> </ul>	Method of site preparation as a basis for urban design, zoning of green areas.
	underground construction	Underground construction can cause a disturbance of the groundwater flow. This may cause seepage and the raising or lowering of groundwater level. Various measures for construction might be necessary for reinforcing subsurface.	<ul style="list-style-type: none"> <li>• Infrastructure (high) metropolitan areas.</li> <li>• Shopping and companies in (high) metropolitan areas.</li> <li>• Laying of cables and pipelines must be reported to Cables and Pipelines Information Centre (KLIC).</li> </ul>	Parking underground, fewer cars on streets, takes in space above ground.
	storage for substances	Subsurface stability should be taken into account before the storage of substances is considered. Proper geological investigation of the layers will be necessary and extra attention to leaks when drilling of sealing layers.	<ul style="list-style-type: none"> <li>• Storing CO2 in production areas (inter alia industrial areas).</li> <li>• Solids storage in salt caverns serving soil stability</li> </ul>	No spatial impact
	sewerage, cables and pipes	Cables and Pipes are found everywhere in the Netherlands and documentation is often incomplete. For large objects such as tunnels geotechnical surveys are needed. Note groundwater flows underground objects may be an obstruction.	<ul style="list-style-type: none"> <li>• Cables and pipes in a multi-utility duct.</li> <li>• Place C &amp; P as much as possible under or alongside existing (above ground) networks.</li> <li>• Cables and pipes should be taken into account with the topsoil functions, such as planting trees</li> </ul>	Constitutes a restricting condition for the topsoil because it determines where development can and cannot take place, where open land and trees can and cannot be placed.
	cultural & heritage and archaeological values	Cultural & Heritage and archaeological values concerns the characteristics of the landscape coupled with cultural activities and the underground and partly aboveground remnants of ancient times. Inclusion of archeological values should be kept situational depending on the likelihood of existing structures of objects. Attention is required for changes in groundwater levels or quality as it may affect archaeological objects.	<ul style="list-style-type: none"> <li>• Historical usage, design and construction visible in spatial planning (action program space and culture).</li> <li>• Follow the phased plan archeology.</li> <li>• Use of available maps</li> <li>• Take note of inspiring examples</li> </ul>	Existing qualities of an area that can give substance to the new features, use, main, public space design and construction.
	unexploded ordnance	The presence of unexploded ordnance is based on historical data (including photos of bombing) information about possible unexploded ordnance can be retrieved. If there is a significant risk for the presence of unexploded ordnance, then this should be included in planning process. Vibrations pose risk if they are present.	<ul style="list-style-type: none"> <li>• Remove unexploded ordnance if this can be incorporated in the project.</li> </ul>	Decisive for construction pile driving and deep excavations.

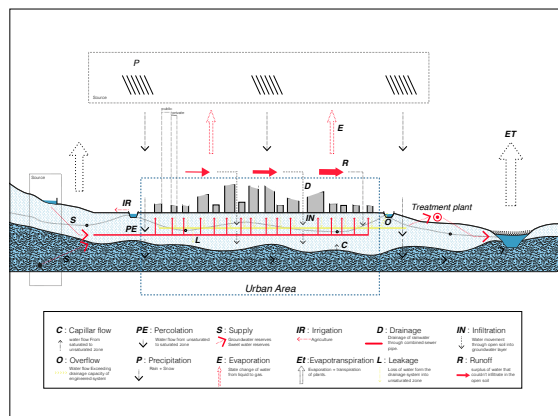
Assignment starting from the expert	General national data subsurface	Planning column: Laws, regulations, policies
How do we include the private space in the water infiltration and quality assignment.	<a href="http://www.atlasnatuurrijkkipitaal.nl">www.atlasnatuurrijkkipitaal.nl</a> <a href="http://www.ruimtexmilieu.nl">www.ruimtexmilieu.nl</a> <a href="http://www.geologievanederland.nl">www.geologievanederland.nl</a> <a href="http://www.clo.nl">www.clo.nl</a> <a href="http://nederland.risicokaart.nl">nederland.risicokaart.nl</a>	EU: Water Framework Directive Urban Wastewater Directive Ground Water Directive
Interventions in private space due to low maintenance with soil subsidence. Depending on the desired surface qualities the water management solutions can be chosen accordingly.	Different waterboards have a climate atlas: <a href="https://rijnland.klimaatatlas.net">https://rijnland.klimaatatlas.net</a> , <a href="https://wddelta.klimaatatlas.net">https://wddelta.klimaatatlas.net</a> . The websites of these water boards are offering much more information.	NATIONAL: Water Act National Water Plan Environmental Management Act Safety Qualification Primary Defence
Protecting drinking water supplies from pollutant.		REGIONAL/LOCAL: Regional Water Plan Water Plan Water Level Decree waterschaplegger Local waste-water plan
Assignment starting from the expert	National data	Planning column: Laws, regulations, policies
Advancement of the energy transition.	<a href="http://www.wklotool.nl">www.wklotool.nl</a> <a href="http://www.stiog.nl">www.stiog.nl</a> <a href="http://www.thermogis.nl">www.thermogis.nl</a> <a href="http://www.dinoloket.nl">www.dinoloket.nl</a>	EU: European Energy Strategy Plan (2013) Energy Technologies and Innovation (2013)
Governmental regulation and policy plan of the subsurface energy potential.		
Advancement of the energy transition.		NATIONAL: Nuclear Energy Law: regulates ministerial competences for storage of radio-active waste; SER energy agreement (2013) Strategy on Shale Gas (expected 2015)
		REGIONAL/LOCAL: IPO agreement geothermal Heat Plan
Assignment starting from the expert	National data	Planning column: Laws, regulations, policies
Think at different scale in planning for soil remediation. Due to the reactive role they often limited to the project site with no larger vision. In the process of remediation of an area, what remains fix and what changes. A question of design for the long and short term (process based design).	<a href="http://www.bodemloket.nl">www.bodemloket.nl</a> <a href="http://www.dinoloket.nl">www.dinoloket.nl</a> <a href="http://maps.bodemdata.nl">maps.bodemdata.nl</a>	EU: Directive on Waste, Directive on Landfill of Waste, European Soil Strategy, NATIONAL: Mines Act, Soil Protection Act (1987), STRONG (National Spatial Planning Strategy for the subsurface), Excavation Act Information System Soil, Environmental Management Act Soil Policy Letter (2003), Soil Convent, Nature Protection Act, REGIONAL/LOCAL: Soil Vision/Soil Ladder soil, Remediation,
How can we re-use the surplus of soil types coming from the alteration of the delta territory in landscape and urban design. How can we project the metabolism of soil as an urban landscape infrastructure, creating conditions for ecological and human occupation?	<a href="http://www.deltastoffenonline.nl">www.deltastoffenonline.nl</a>	
How can we have a map of urban farming, taking into consideration what has to be avoided and the material requirements? How would you facilitate the production of organic soil for crop production (urban farming) in the city from the public sector?		
Include the soil ecology and a diversified remediation (is more effective) and the design of new nature based solutions for contaminated sites.		
Can we design a fixed space in the subsurface. For ecology to grow in time? Designing for co-habitation and coexistence human and natural processes? What if the bats were are clients?		
How can you work with the natural processes, in a time based perspective, to create synergies with human needs? (reintroducing the special dynamics of the delta)	<a href="http://landschapnederland.nl">landschapnederland.nl</a> <a href="http://www.natura2000.nl">www.natura2000.nl</a> <a href="http://maps.bodemdata.nl">maps.bodemdata.nl</a>	
Include the ecological performance as an asset for the livability of a neighborhood.	<a href="http://www.geologievanederland.nl">www.geologievanederland.nl</a>	
Assignment starting from the expert	National data	Planning column: Laws, regulations, policies
Optimize the site allocations of constructions early in the planning process depending on the carrying capacity of the area to limit costs.		NATIONAL: External Safety ordinance: obligation to register risk with dangerous material.
Optimize the site allocations of constructions early in the planning process depending on the soil stability of the area to limit costs.		LOCAL: Environmental Management Act sewer regulations Local regulations considering cables and pipes in general.
Limit the necessity for underground constructions.	<a href="http://ez.maps.arcgis.com/apps/MapSeries/index.html?appid=9f695bf837249a886209ca026e">http://ez.maps.arcgis.com/apps/MapSeries/index.html?appid=9f695bf837249a886209ca026e</a>	EU: European Convention on the Protection of the Archaeological Heritage (1992) NATIONAL: Archaeological Heritage Management Act Monuments and Historic Buildings Act
		REGIONAL/LOCAL: Provincial Research Agenda Archaeology Policy Culturel Heritage; Programme Heritage
Take into account the lifecycles of cables and pipes in the planning process for efficiency.	<a href="http://www.kadaster.nl/nic-wion">www.kadaster.nl/nic-wion</a>	LOCAL: Beleids- en beheerplan opsporen en ruimen Niet Gesprongen Explosieven uit de Tweede Wereldoorlog.
Include archaeological finding for the benefit of the historical identity of the area.	<a href="http://www.archeologienederland.nl">www.archeologienederland.nl</a>	

### 2.3.3 Interdisciplinary by mapping

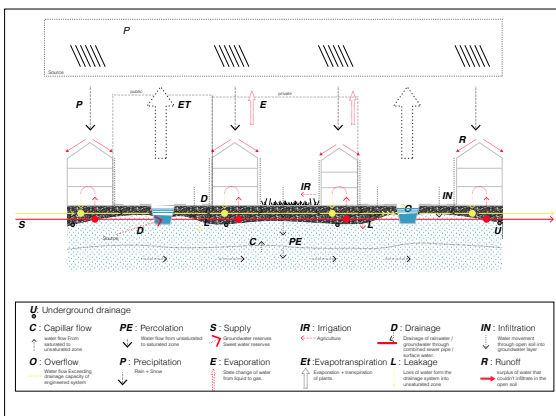
In order to reach a truly interdisciplinary approach there is a need for a 'common language' and understanding of each other's disciplinary concepts. To support this process, the idea of interdisciplinary knowledge acquisition through mapping is here showcased. As one example of the work delivered, the mapping starts from a diagrammatic representation of a flow or technology (in this case water) received by the experts in the

field (civil engineering department at TU Delft) and it represent at various scales (city, neighbourhood and household) spatial implications, both on surface and on the subsurface. More specifically, the subsurface and surface, are here conceived as one united space. Not only the water cycles in the territory is visualized but also the multitudes of artefacts and human technology that are part of this cycle. Thus the complexity and

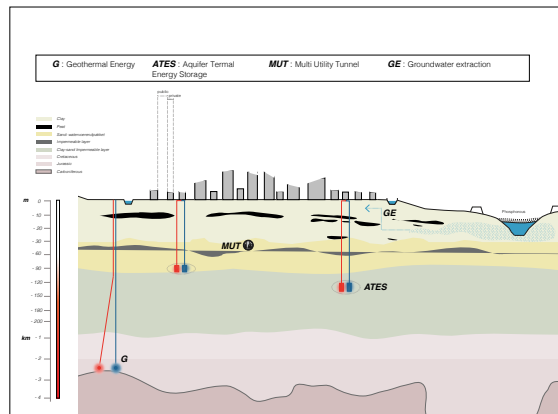
**City scale: Watermanagement and Drainage system**



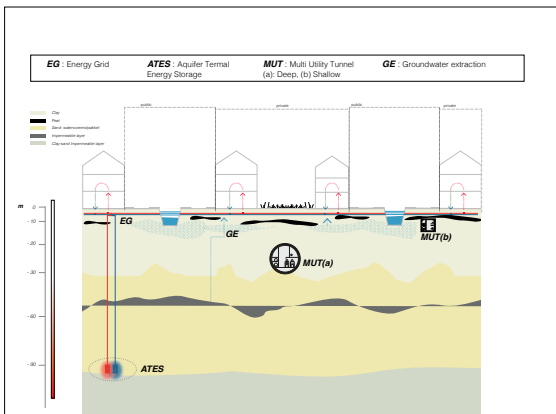
**Neighbourhood scale: Watermanagement and Drainage system**



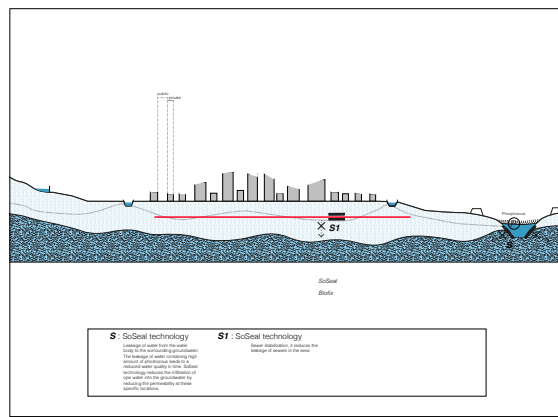
**City scale: Underground space technology**



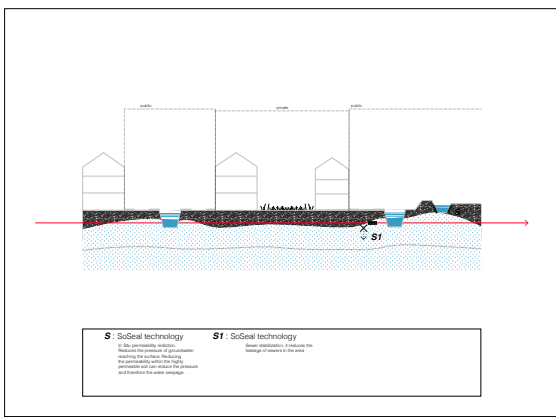
**Neighbourhood scale: Underground space technology**



**City scale: Biogeocivil subsurface engineering for soil improvement**

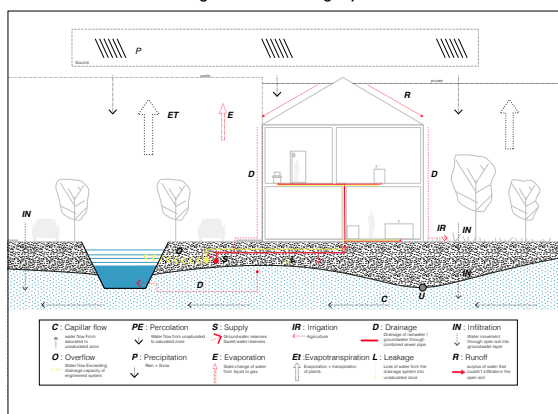


**Neighbourhood scale: Biogeocivil subsurface engineering for soil improvement**

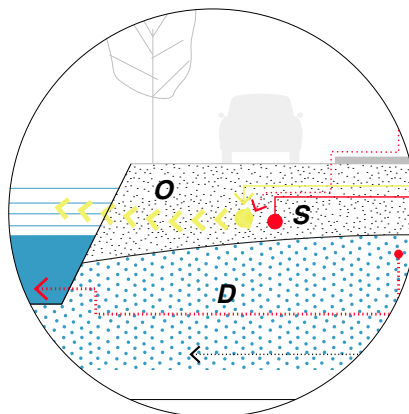


hybrid legacy of the water system together with technology, landscape, urbanization and public works is highlighted (Hooimeijer, Bacchin and LaFleur, 2016).

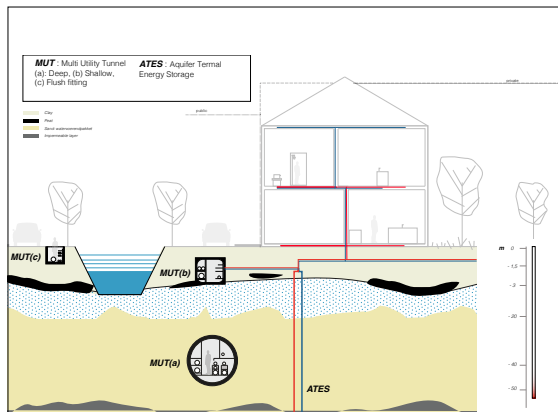
**Household scale: Watermanagement and Drainage system**



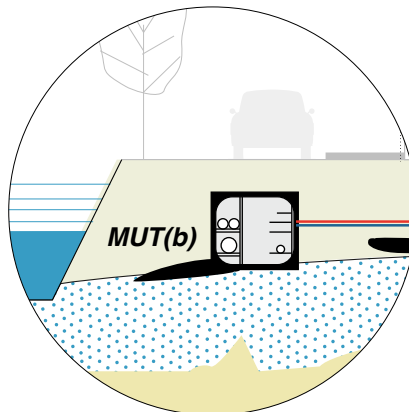
**Zoom In: Watermanagement and Drainage system**



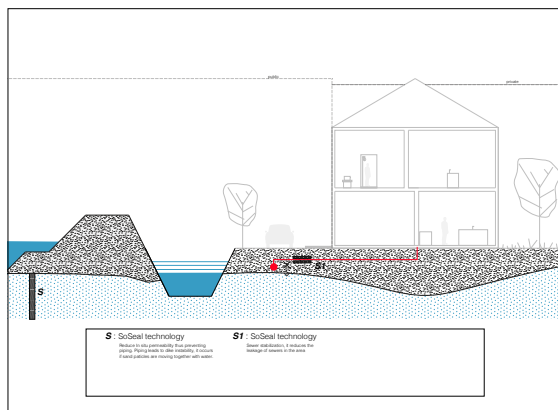
**Household scale: Underground space technology**



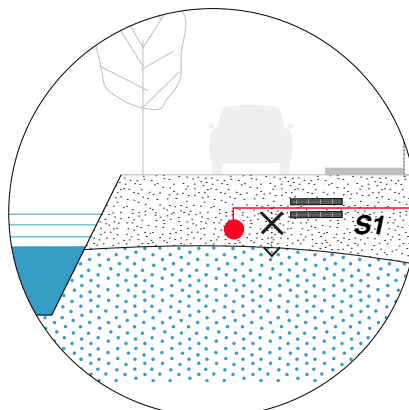
**Zoom In: Underground space technology**



**Household scale: Biogeocivil subsurface engineering for soil improvement**



**Zoom In: Biogeocivil subsurface engineering for soil improvement**



### 2.3.4 Interdisciplinary by research

In order to integrate subsurface artefacts that now in research and practice are segregated, the first phase of the project brought together different specialists from: water management, building site preparations, urban drainage, bio-geo-civil engineering, underground space technology and urbanism.

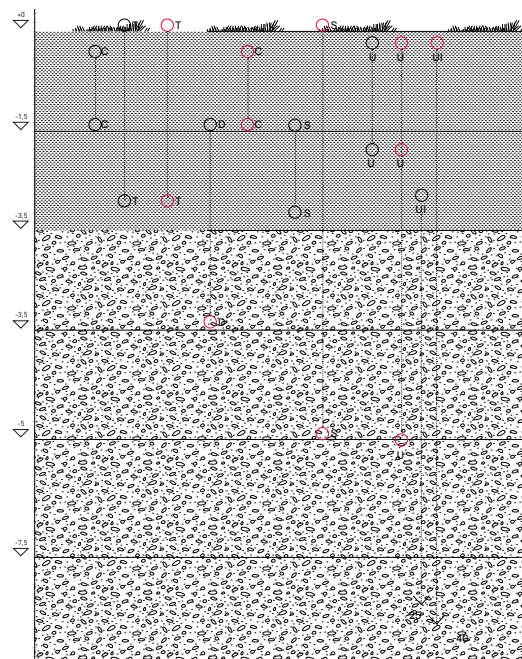
The main question of the research is: How can the different technological artefacts in the subsurface be synchronized offering more space and adding to a better urban quality?

Thus the focus was on the potential future synergies between these fields and their contribution to urban quality. From the interaction with the specialists and the specific inputs, regarding the future of their disciplines, New Synergies emerged with interesting potential consequences with the field of urban-landscape planning and design.

Especially regarding the 'Surface Materialization' of previously hidden systems calls for ways in which the project and the disciplines are integrated and designed for mutual benefits.

#### Subsurface Matrix

Present	○	Future	○
<b>Technologies:</b>			
Utilities	○ U	Underground infrastructure	○ UI
Drains	○ D	Trenches	○ T
Cables	○ C	Sewer systems:	○ S



The results of this inventory were presented in a first multidisciplinary workshop where possible synergies and reciprocities between the technologies and the

relation to (future) urban quality were identified. These ideas and research questions were then evaluated in relation to future scenarios (climate change and urbanization) by urban planners and designers. In a second workshop, these scenarios were then discussed within the multidisciplinary group of experts of the subsurface and urban development aiming at the establishment of a common research agenda.

To create a synergistic approach in which a hybrid thinking add values beyond the multidisciplinary input, a different type of teamwork is required.

The interdisciplinary aims at creating synergies between aspects of theory, method, and process leading to an integrated approach across the different fields. The DIMI context is the ideal ground for experimental try-out and evaluation of team development in an interdisciplinary context composed by different engineering profiles.

This process had been coupled with scenario making exercise and had a broader inquisitive character, the method has been set up according to Van den Dobbelsteen et al. (2006), which explains the relation between the principles of forecasting, backtracking and backcasting - shown in the figure below. In short they can be defined:

- Forecasting means 'to estimate the consequences of current developments and our own interventions on long-term effects'.
  - Backtracking means to base solutions 'on historical circumstances at the time when there still was a sustainable equilibrium.'
  - Backcasting means 'to describe a desired future state at a certain point in time and to translate this state into strategies and measures that we need to develop now.'
- The diagram here below shows, conceptually, the process of the research, starting from technologies, understanding their relation and implications in space, and eventually building a vision in which the deployment of technologies are related to socioeconomic dynamics. In this sense the diagram wants to show the rising complexity of the research process as an outcome of this explorative method.

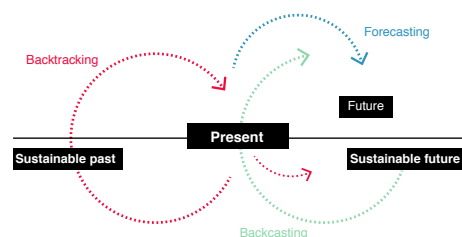


Fig 4.5. Concept of Backcasting, forecasting.  
Van Dobbelsteen, 2006. Adapted by author



As visualized here below, this scenario is characterized by densifying cities, progressing climate change, and an increase in financial resources. These conditions have been translated in a spatial vision in order to reconsider new phases of potential infrastructural deployment. It follows two major issues that offer opportunities: 1) the need to conceive 'vertical strategies' for the integration, synchronization and co-existence of uses (live, work, leisure, production) and infrastructures (green, blue, grey);

2) the need to redirect financial (research) investments and regulatory mechanisms towards technological, environmental and socio-cultural policies. Since urbanization and better financial means will increasingly rise in this scenario, higher pressures are expected on resources and on the management of flows needed to sustain the city. In addition, interdependencies between the city and its hinterland have to be rethought at a larger scale.

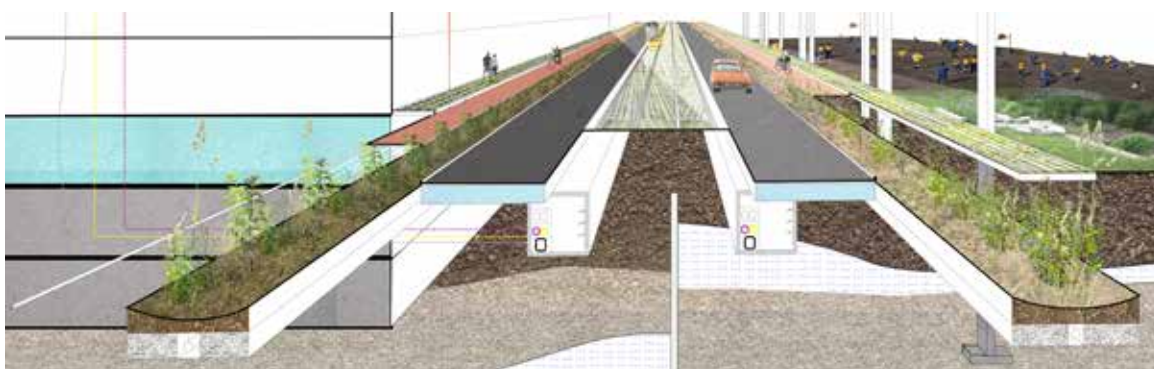


Fig 4.6. Scenarios for densification in Rotterdam.  
Hooimeijer, Bacchin, LaFleur, 2016

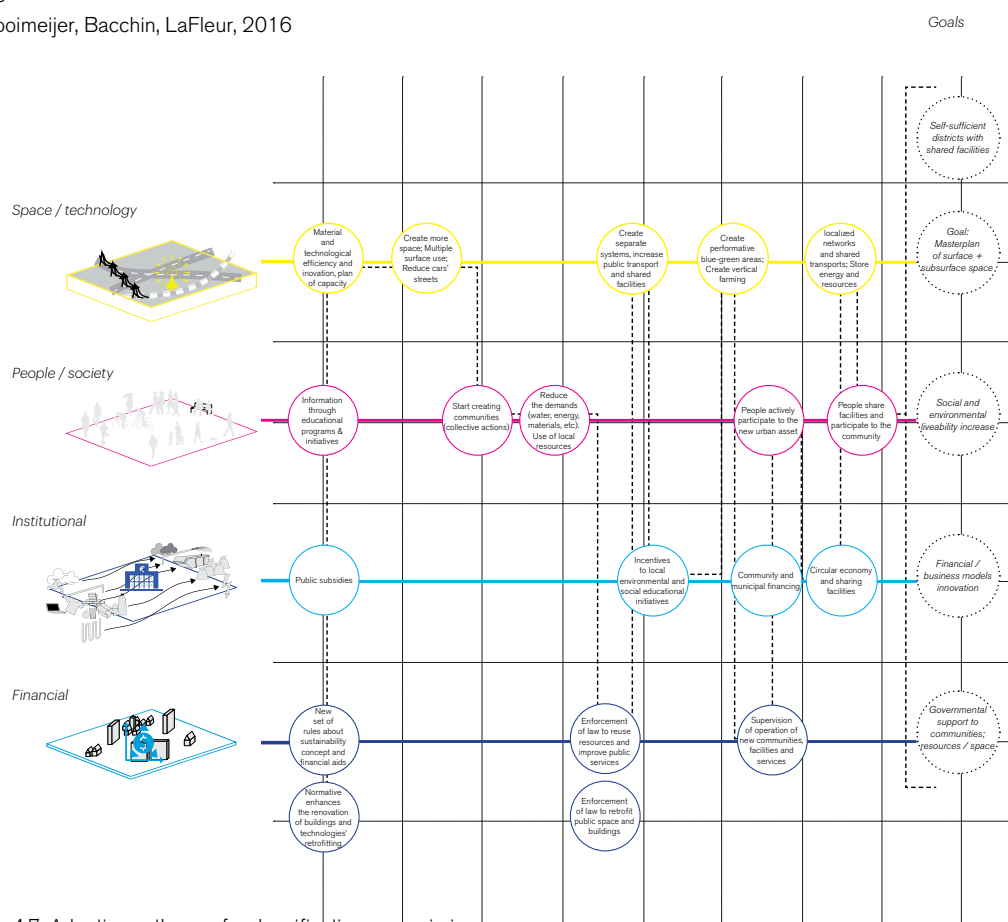


Fig 4.7. Adaptive pathways for densification scenario in Rotterdam. Hooimeijer, Bacchin, LaFleur, 2016



### Subsurface matrix vs. scenarios

This matrix offers an overview of the applied research methods, the steps and the perspective in the project. It shows how the initial technologies are connected to spatial interventions, if they are interdependent amongst each other, how they offer opportunities and constraints, what is the impact on urban management, and finally their contribution to the three scenarios. The matrix also gives insight into the relevance of the four engineering profiles. It shows that the constraints are particularly relevant for the contextual engineer, while urban management pertains to the systems integrator. The technology, dependency on other technologies, and space applications tend to belong to the realm of the specialist.

The explorative method of this project has brought forward insights and design methods for the urban renewal of (delta) metropolises where resilient, durable (subsurface) infrastructure is carefully balanced with parameters of the natural system. The question 'how can the different natural and engineered elements in the subsurface be synchronized offering more space and adding to a better urban quality?' is answered by taking procedural steps from technology (the knowledge of) to the design of public spaces and the main urban structures. In each step, the translation from engineering language to the language of the urban designer (and vice-versa) is done by producing an informative and useful overview in how to transmit the natural and engineered elements directly to urban quality. This approach of de-coding the engineering language and re-assembling it with a spatial (subsurface – surface) approach, evokes proper understanding of how to connect urban qualities (urban design) and performance (engineering).

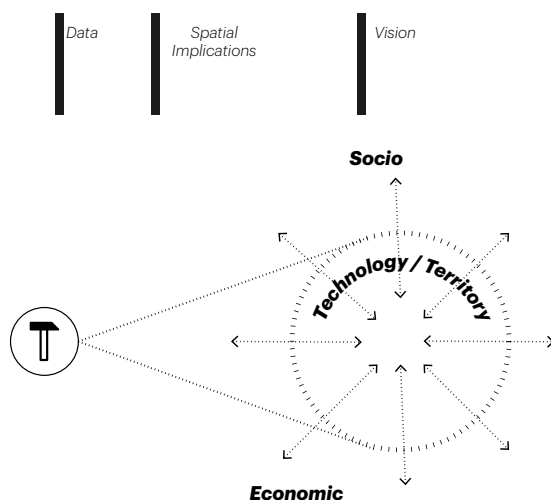


Fig 4.8. Research process, from technology to territory.  
Hooimeijer, Bacchin, LaFleur, 2016

	TECHNOLOGY	DEPENDENCY ON OTHER TECHNOLOGIES	OPPORTUNITIES
<b>Soil improvement</b>	SCC – Soil carrying capacity (BioGroutt)	UST: carrying capacity to support infrastructures	UWM: managing the groundwater table (recharge)  Sewer: flexible pipes
	SP – Soil permeability reduction (SoSEAL)	UWM: groundwater flows  UWM: water quality	
	QS – Quality of soil GRO (field not investigated in the project)		UST: excavation  UWM: water quality
<b>Urban Drainage (Sewer)</b>	<ul style="list-style-type: none"> <li>- Sink disposal: Organic waste; flexible pipes (more capacity; heat-energy recovery from pipes)</li> <li>- Source separation: Urine/feces (Yellow/grey/ black water) separation to recover nutrients</li> </ul>	UWM: Separate system + water quality  QS - Quality of soil	UST utilities  UWM: balancing the capacity of the sewer system (unload the network)  SCC
<b>UWM (Urban Water management)</b>	<ul style="list-style-type: none"> <li>- Smart piping</li> <li>- Infiltration crates</li> <li>- Helophyte filters / Constructed Wet Lands (water quality)</li> <li>- Underground buildings</li> <li>- Nature based solutions</li> </ul>	- Quality of soil  Sewer systems  UST: groundwater	UST utilities  Underground buildings can offer storage  Sewer: flexible pipes  SP
<b>Building-site preparation</b>	<ul style="list-style-type: none"> <li>- Partial-filling technique</li> <li>- Nature based solutions</li> <li>- New architectural typologies</li> </ul>		
<b>UST (Underground space technology)</b>	Multi Utility tunnel	Soil improvement and UWM: UST deals with soil quality, soil carrying capacity and water flows (groundwater)	Multi-functionality  SCC
<b>Values</b>			

SPACE APPLICATION (RELATION TO SPACE)	URBAN MANAGEMENT	CONSTRAINTS	PP: PUBLIC/ PRIVATE	Warm shrinking	Steam shrinking	Warm densification	Steam densification
<ul style="list-style-type: none"> <li>- Allows for urban nature (Relief)</li> <li>- Improves functionality (Robustness)</li> <li>- Determines functions</li> <li>- If it is good quality → green spaces (Design with nature)</li> </ul>	<ul style="list-style-type: none"> <li>- New maintenance plan</li> <li>- No applied sand</li> <li>- Maintenance of dikes</li> <li>- Quality control programming</li> <li>- Maintenance</li> <li>- Connection to pipe system</li> <li>- Trade off water &amp; public space system</li> <li>- Trade off function &amp; remediation</li> <li>- Excavation management</li> </ul>	<ul style="list-style-type: none"> <li>- Irreversible?</li> <li>- Time</li> <li>- Governance (urban programming)</li> <li>- Legal</li> <li>- Financial</li> <li>- Technology up-take (social acceptance and adaptation)</li> <li>- People behavior</li> </ul> <p>Extra for QS:</p> <ul style="list-style-type: none"> <li>- Cost/profit balance</li> <li>- Health</li> </ul>	<p>Improve PP S/XL relation</p> <p>Improve PP S/XL relation</p> <p>Public</p>	Smart soils for water units	Smart soils for water units	Smart soils reduce maintenance and includes nature	
Quantity of space and material functionality	<ul style="list-style-type: none"> <li>- Waste/sewer community</li> <li>- Sewer planning</li> <li>- Improve system flexibility and material</li> <li>- More systems lead to more space occupied, thus more maintenance is required</li> <li>- More waste utilities involved</li> <li>- No more sand</li> </ul>	<ul style="list-style-type: none"> <li>- Health</li> <li>- Depreciation</li> <li>- Governance (urban programming)</li> <li>- Legal</li> <li>- Financial</li> <li>- Technology up-take (social acceptance and adaptation)</li> <li>- People behavior</li> </ul>	<ul style="list-style-type: none"> <li>- Relation S/XL connections (small/big scale)</li> </ul>	Micro treatment plant	Sink disposal with flexible pipes Source separation		Sink disposal with flexible pipes Source separation
<ul style="list-style-type: none"> <li>- Main infrastructure</li> <li>- Design of surface and materials</li> <li>- Use of surface water</li> <li>- Programming (water quantity and quality) + public space</li> </ul>	<ul style="list-style-type: none"> <li>- Water quality (rules)</li> <li>- System of water bodies or flows</li> <li>- Water communities (water boards and polders community)</li> </ul>	<ul style="list-style-type: none"> <li>- Health</li> <li>- Soil sealing</li> <li>- Maintenance</li> <li>- Governance (urban programming)</li> <li>- Legal</li> <li>- Financial</li> <li>- Technology up-take (social acceptance and adaptation)</li> <li>- People behavior</li> </ul>	<ul style="list-style-type: none"> <li>- Relation S/XL groundwater</li> <li>- Intermediate scale QS</li> </ul>	Nature based solutions Harvest water Partial filling	Nature based solutions Green roofs facades Partial filling new foundations	Green roofs Infiltration crates No filling for maintenance, nature based solutions	Green roofs Smart piping Infiltration crates No filling New building typology
<ul style="list-style-type: none"> <li>- Multifunctional land use (public)</li> <li>- Mobility improvement (private)</li> <li>- Maintenance improvement</li> </ul>	<ul style="list-style-type: none"> <li>- Smart pipe management</li> <li>- Street maintenance is about efficiency, flexibility, costs, logistics</li> <li>- Underground space buildings, trade off old/new foundations</li> <li>- Excavate polluted soil</li> </ul>	<ul style="list-style-type: none"> <li>- Risk with excavation</li> <li>- Governance (urban programming)</li> <li>- Legal</li> <li>- Financial</li> <li>- Technology up-take (social acceptance and adaptation)</li> <li>- People behavior</li> </ul>	Community of owners Clustering in smart pipes PP knowledge relation			Trade off with suburbs that will be decentralized, inner city MUT Urban district heating	Underground water storage MUT (deep) Urban district heating
				<b>Affordability</b> Biodiversity Flexibility Livelihood <b>Appropriateness</b> Efficiency Collaboration PP Awareness	Affordability Biodiversity Flexibility Livelihood <b>Appropriateness</b> Efficiency Collaboration PP <b>Awareness</b>	Affordability Biodiversity Flexibility Livelihood <b>Appropriateness</b> Efficiency <b>Collaboration PP</b> Awareness	Affordability Biodiversity Flexibility Livelihood Appropriateness <b>Efficiency</b> <b>Collaboration PP</b> <b>Awareness</b>

Fig 4.9. Tables showing the relation between subsurface matrix and scenarios. Hooimeijer, Bacchin, LaFleur, 2016

The Intelligent Subsurface project is building on an earlier project involving TU Delft and Deltares (Hooimeijer and Maring, 2013) - Design with the Subsurface, in which the System Exploration Environment and Subsurface (SEES) and the Subsurface Potential Map were developed. The Subsurface Potential Map is a map in which the data has been translated into thematic sub-surface information under the categories of civil construction, water, energy and soil / ecology.

In this research the subsurface potential map is being refined and contextualized in the form of a Technical Profile, in which more scales are represented with a shared precise legend that annotates static or solid and process items. The aim here is to frame the field as a complex imbroglio of different natural-human artefacts and dynamics. Following this approach, this chapter introduces various methods that were used in the process that helped to shape the infrastructural and environmental question through drawing and mapping inquiries.

### 3.1 Technical profile and the legend

The Technical Profile is a systematic representation of all the subsurface artefacts in plan and section and on several scales. It offers the base for an imagination of an integrated project in which the artefacts in their static or dynamic state can be used to design for.

The challenge is to draw all the different subsurface artefacts in such a way that relationships between and with the subsurface become clear. This will support better understanding and decision making on interventions and desired effects. Moreover, some topics also should be considered on the larger scale, such as water, energy and ecology, and artefacts such as cables and pipes and ecology also require representation on the architectural scale. The exact drawing of the subsurface, or the technical profile, has been tested

on two cases. Moreover, the technical profile is seen as a moment of investigation, of subjective and comprehensive mapping where the relation in time between natural and human dynamics are equally important to their precise manifestation in space. As a drawing technique it simultaneously cuts the ground (2-D) at different altitudes permitting a synchronic representation of surface and subsurface objects.

Therefore, it both serves as a descriptive and reading tool of the territorial palimpsest and the interactions between elements. In addition to this, it receives the potential (data and space) as well as prepares and stages the 'ground' for an imagination of it. As an example of the descriptive legacy, and features of such tool, a more precise description of it is given in the 'Agency of the cross section' paragraph in which the technical profile is 'de-composed' and described.

The legend of the Technical Profile follows the layers of the System Explorer Environment and Subsurface. The legend items in the left column are static or fixed and in the right column the processes or dynamic elements are visualized. Just like the Water State Map, the legend is introduced and explained in more general terms in the right top corner of the drawing. Here also elements that have not been drawn are explained because they occur over the whole area.

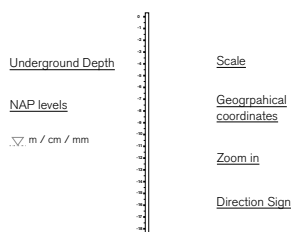
The legend and the technical profile have been tested and used in two cases where knowledge brokerage and design process were instigated. In the following two pages the technical profiles of Rotterdam Bloemhof-Zuid, and Leiden Station area are shown.

The legend is also regarded as a pure communication tool, where the different terminologies are made clear along with their visual component. The definition of a common language through visual methods are regarded as one the pre-requisite for a successful interdisciplinary research project (Ahern et al., 2006)

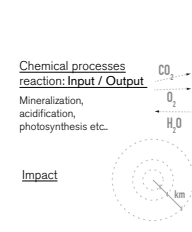
*"As design professionals practicing in the twenty-first century, we must reduce the energy demands of our designs, increase efficiencies, and integrate renewable energy. But beyond these planet-saving technical measures, we must ensure that new and revived urban areas are still places that celebrates the intrinsic qualities of a site: landscape urbanism has the potential to bring out the hidden, the unknown and the delightful for those who inhabit these places. These abilities and processes will make landscape urbanism an ethos that appeals to professionals and people beyond the field."* (Gray, 2006)

	Solid \ static conditions	Processes		Solid \ static conditions	Processes
<b>Metabolism</b>		Energy Waste Food Air Water Material Soil	<b>Energy</b>	Fossil Fuel Energy Geothermal Energy ATES (Aquifer Thermal Energy)	Electricity Heat
<b>Buildings</b>	Footprint Rooftop orientation Monument	Programmatic change	<b>Water</b>	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 Water Nuisance
<b>Public space</b>	Open soil Grass Low medium vegetation High vegetation	Biota Flows Growth / succession	<b>Soil / ecology</b>	Sand Silt Peat Mulch Gravel Clay Humus clean soil Bedrock Polluted soil Macro map Main green structure Secondary green	Subsidence mm/year Oxydization Crop Capacity Rhizosphere processes Contaminants Subsoil Life (microorganism)
<b>Infrastructure</b>	Asphalt Permeable pavement Road Public transport	Movement - flows			
<b>Civil constructions</b>	Underground Building Utilities: Cables and Pipes Archaeology Explosives Dike	Partial filling Site Grading Integral filling Combined Utilities Sewer Age			

#### Cartographic indication



#### Metabolic / flows



#### Metereological

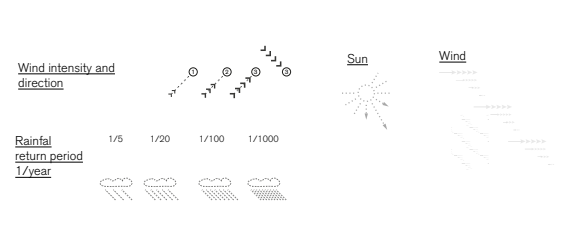


Fig 5.0. The legend as a base for mapping and projecting subsurface surface projects. Hooimeijer and LaFleur, 2018

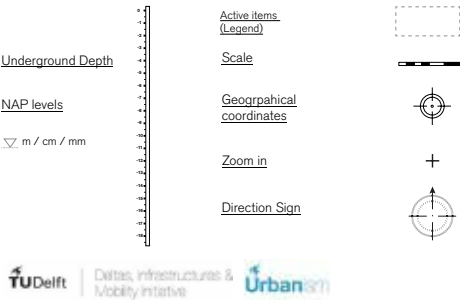
# Technical Profile

## Rotterdam Bloemhof Zuid

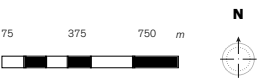
**Authors:**  
dr. F.L. Hooimeijer  
ir. Filippo Lafleur

**Drawings:**  
ir. Filippo Lafleur  
Jesse Dobbels  
Enzo Yap

Cartographic indication



### Macro scale: Territorial condition



#### Infrastructures



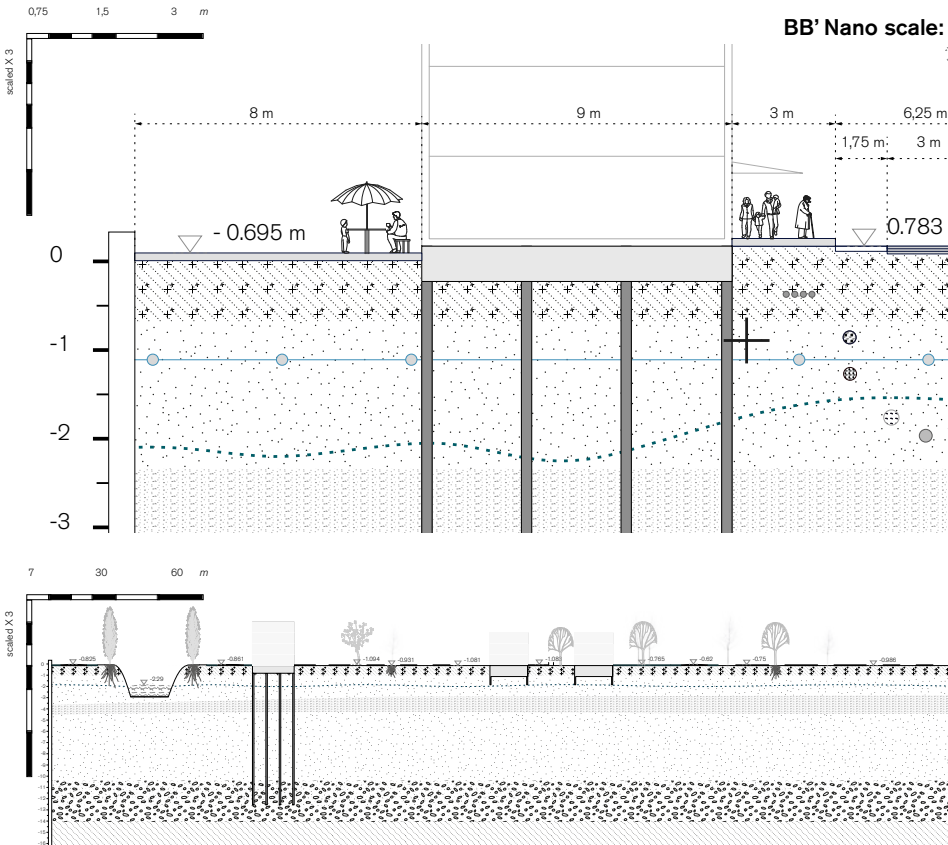
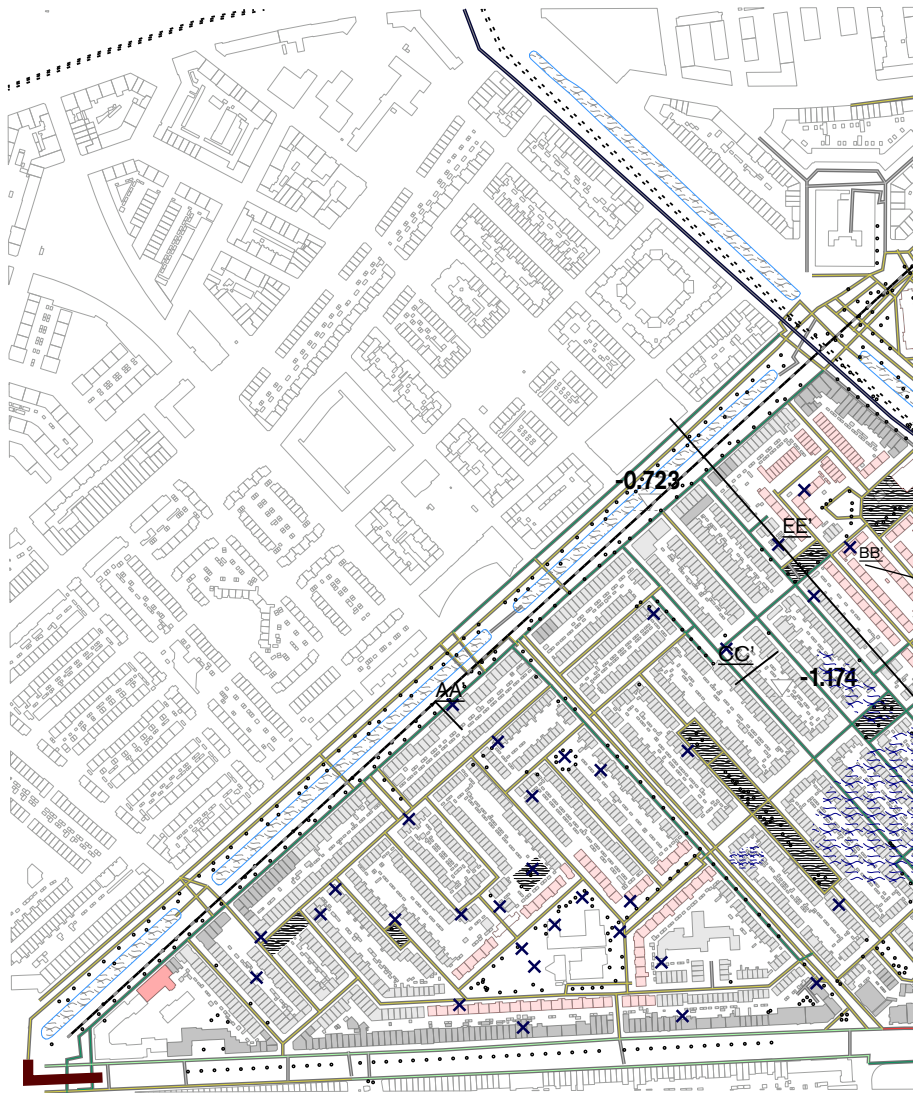
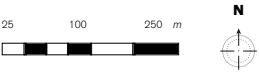
#### Water



#### Landscape structure

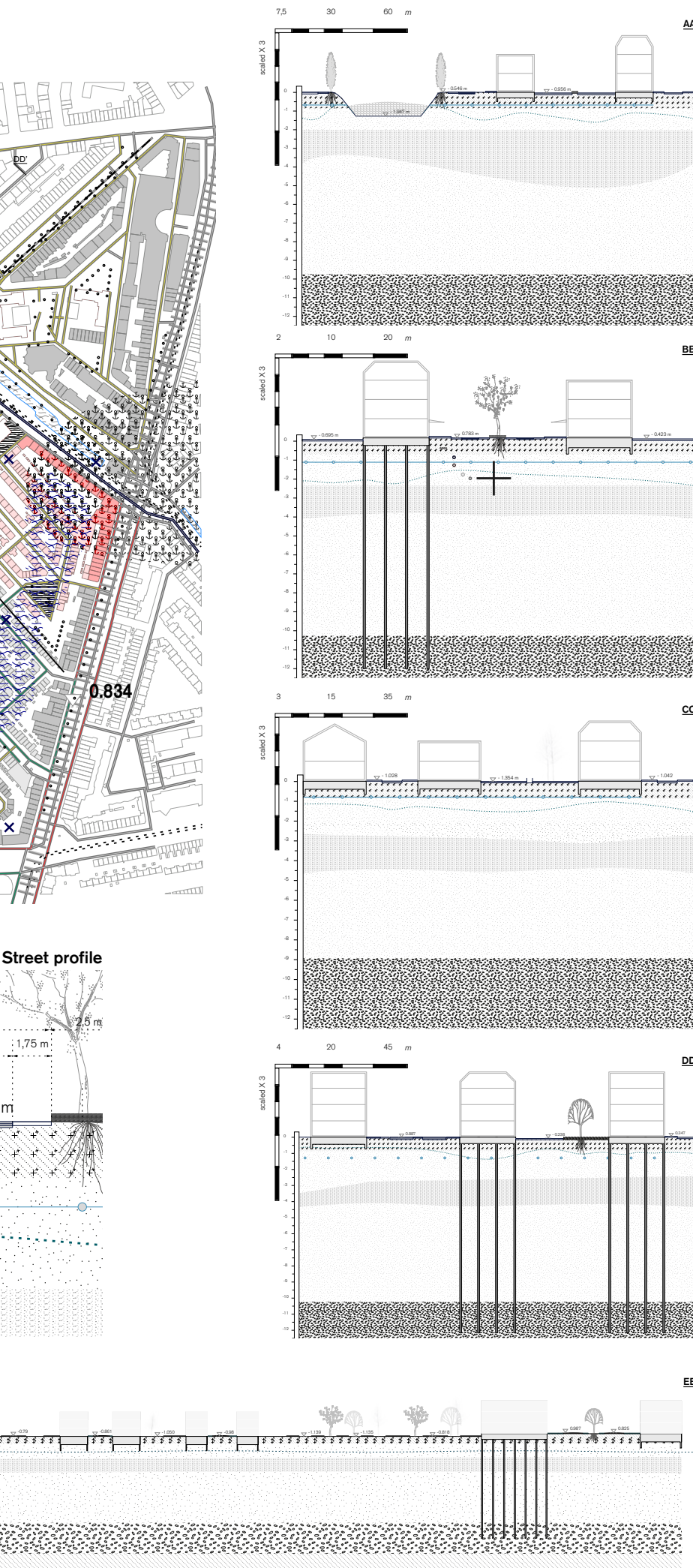


### Meso scale: Plan, site investigation





## Micro scale: Technical section



## 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". <i>Delevens, 2015</i>
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 and other factors. <i>Encyclopedia Britannica, 2008</i> 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 groundwater level.

### Static and dynamic conditions

	Solid \ static conditions	Processes
<b>People</b>		
<b>Metabolism</b>		<div>Energy</div> <div>Water</div> <div>Waste</div> <div>Material</div> <div>Food</div> <div>Soil</div> <div>Air</div>
<b>Buildings</b>	<div>Footprint</div> <div>Rooftop orientation</div> <div>Monument</div>	<div>Programmatic change</div>
<b>Public space</b>	<div>Open soil</div> <div>Grass</div> <div>Low medium vegetation</div> <div>High vegetation</div>	<div>Biota Flows</div> <div>Growth / succession</div>
<b>Infrastructure</b>	<div>Asphalt</div> <div>Permeable pavement</div> <div>Road</div> <div>Public transport</div>	<div>Movement - flows</div>
<b>Civil constructions</b>	<div>Underground Building</div> <div>Utilities: Cables and Pipes</div> <div>Archaeology</div> <div>Explosives</div> <div>Dike</div>	<div>Partial filling</div> <div>Site Grading</div> <div>Integral filling</div> <div>Combined Utilities</div> <div>Sewer Age</div>
<b>Energy</b>	<div>Fossil Fuel Energy</div> <div>Geothermal Energy</div> <div>ATES (Aquifer Thermal Energy)</div>	<div>Electricity</div> <div>Heat</div>
<b>Water</b>	<div>GroundWater</div> <div>Drinking water resources</div> <div>Open Water</div> <div>Rain</div> <div>Underground drainage</div> <div>Macro map</div>	<div>Rainfall return period: 1/year</div> <div>Euthrophication</div> <div>Infiltration</div> <div>Runoff</div> <div>Drainage</div> <div>Evapotranspiration</div> <div>Water Nuisance</div>
<b>Soil / ecology</b>	<div>Sand</div> <div>Silt</div> <div>Peat</div> <div>Mulch</div> <div>Gravel</div> <div>Clay</div> <div>Humus</div> <div>clean soil</div> <div>Bedrock</div> <div>Polluted soil</div> <div>Macro map</div>	<div>Height difference</div> <div>Trees</div> <div>Oxidization</div> <div>Crop Capacity</div> <div>Rhizosphere processes</div> <div>Contaminants</div> <div>Subsoil Life (microorganism)</div>



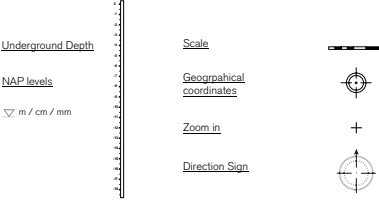
# Technical Profile

Leiden

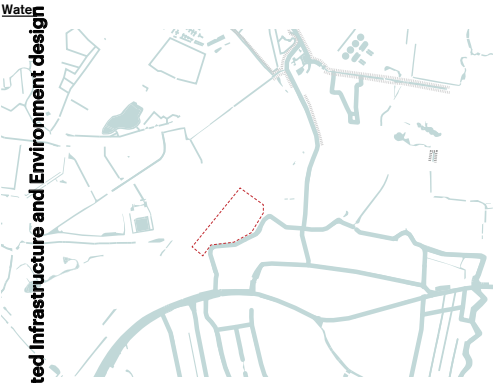
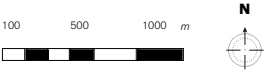
**Authors:**  
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**Drawings:**  
ir. Filippo Lafleur  
Jesse Dobbelsteen  
Enzo Yap

Cartographic indication



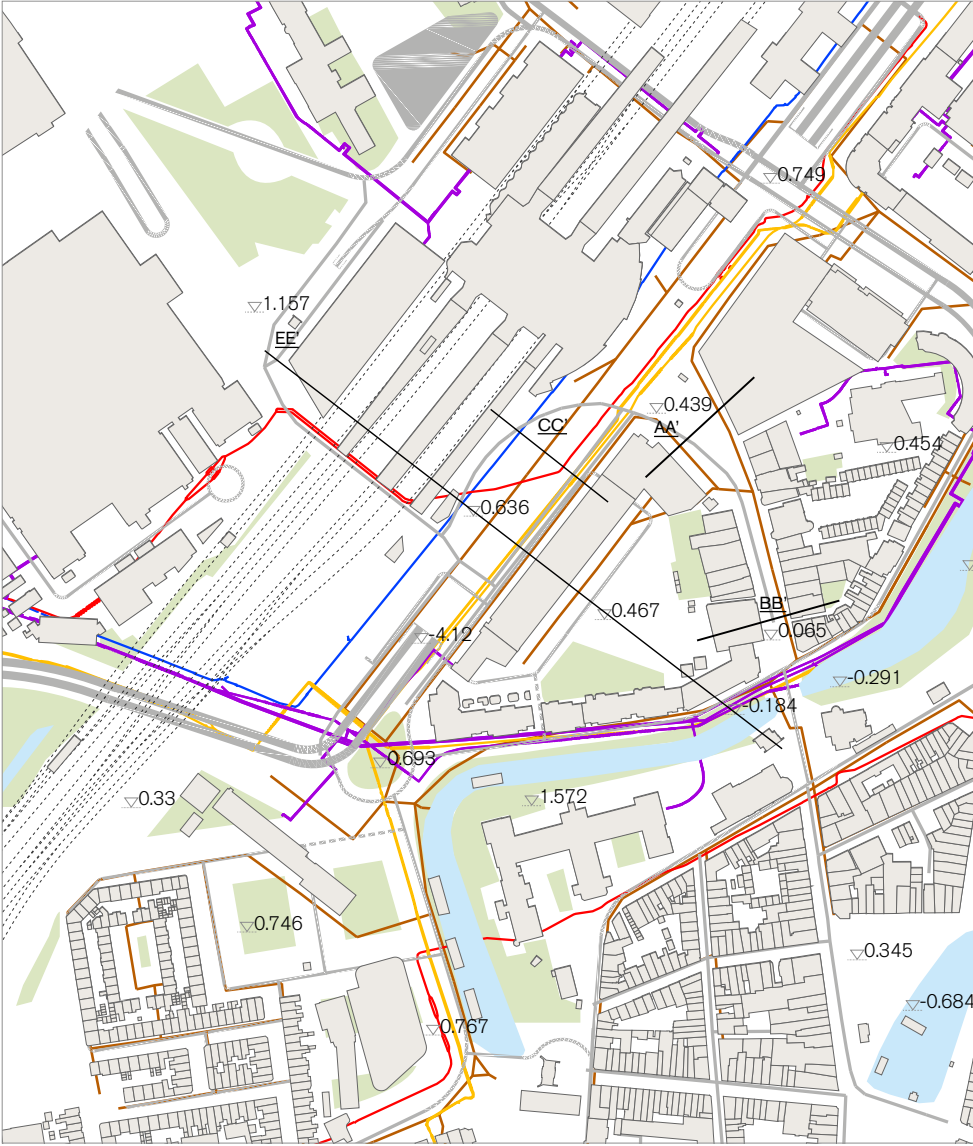
## Macro scale: Territorial condition



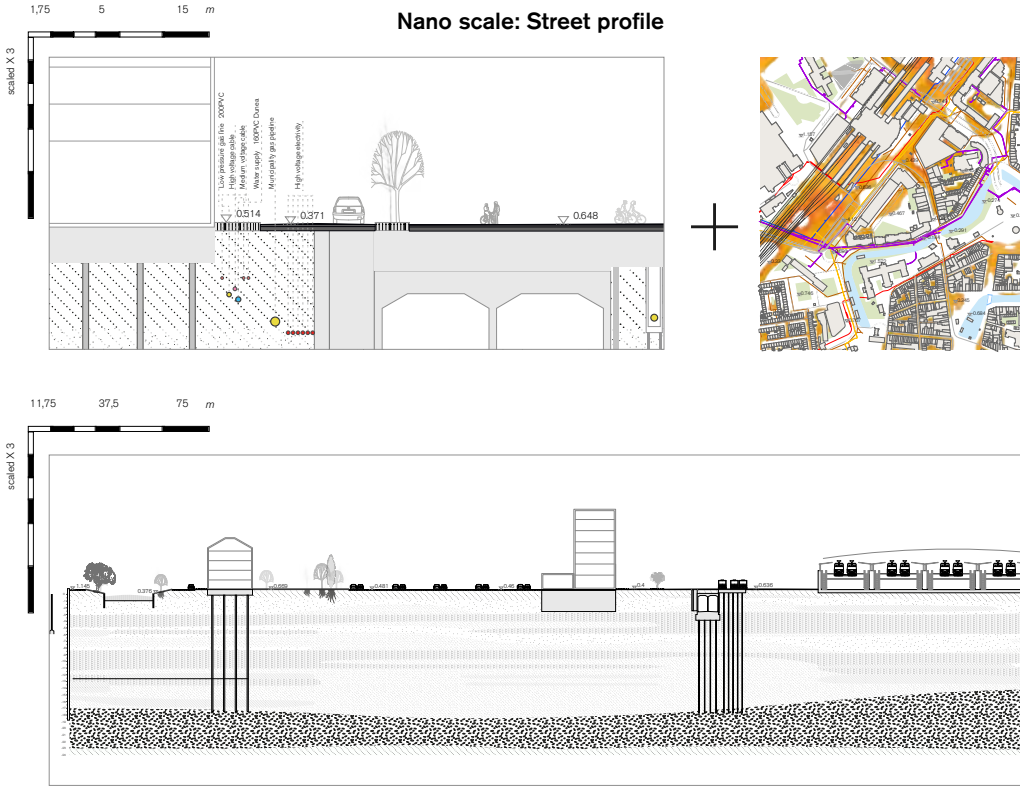
## Land scape structure

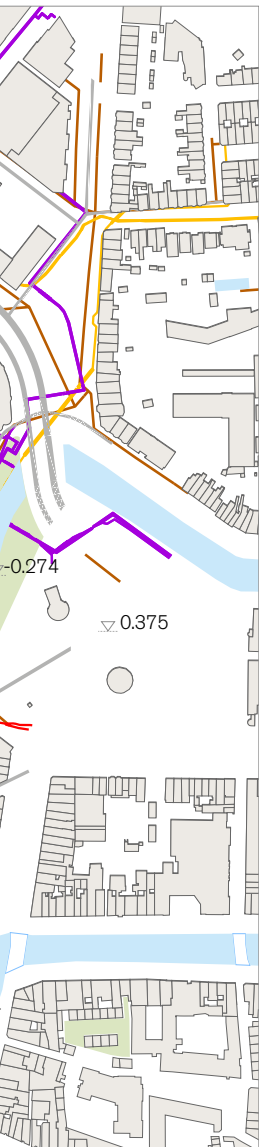


## Meso scale: Plan, site investigation

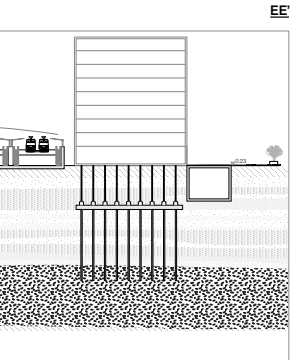
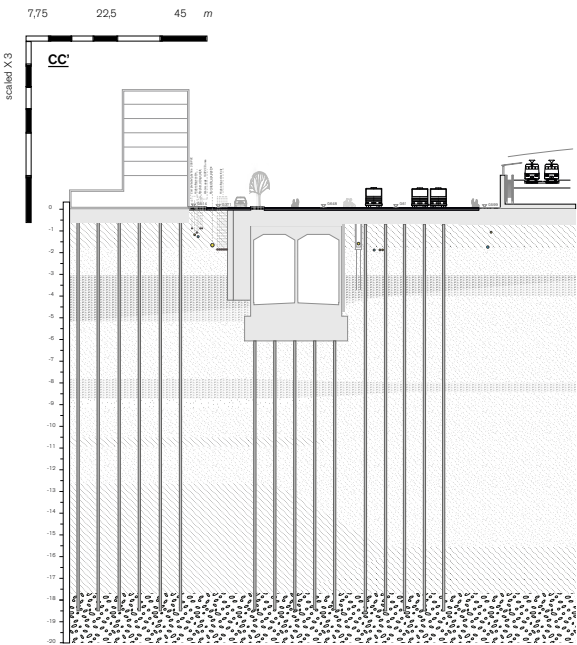
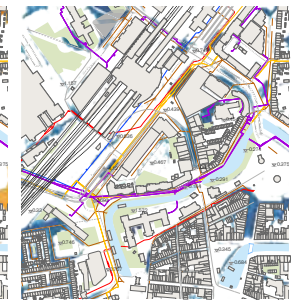
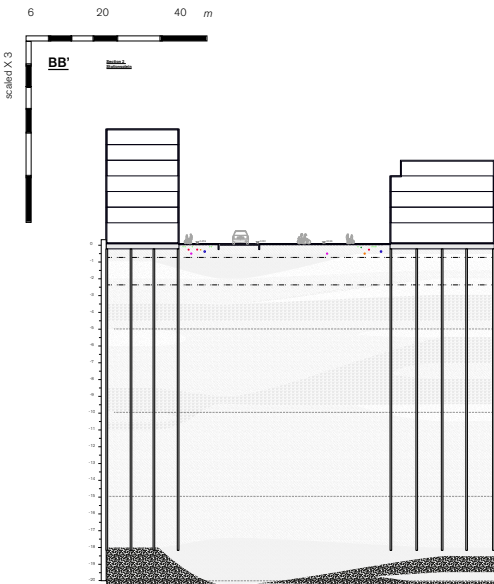
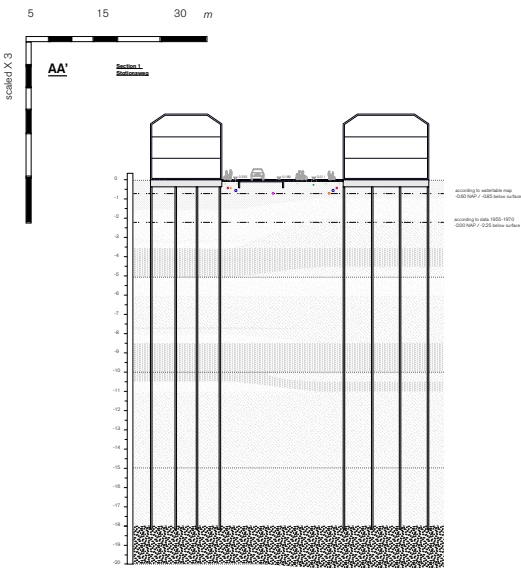


## Nano scale: Street profile





Micro scale: Technical Section,



Conditions present in the area

Water Nuisance		Water management problems in the area. The gradient of blue shows the intensity of water nuisances in the case of a heavy rainfall. In this case rainwater overloads the sewer, causing the so called Combined sewer overflow.
Wooden \ steel piles		All the buildings are built on wooden / steel or concrete piles foundations. As shown in the sections, the piles reach down to minus twelve, minus fourteen meters depth, where a more stable sand layer is found.
Urban Heat Island		Urban Heat Island refers to the process in which cities and hard surfaces raise up the temperature of cities both during night and during the day. The station area is where this phenomenon occurs more often due to the lack of open soil and vegetation.
Archaeology		Medium to high probability of archaeology.

Static and dynamic conditions

	Solid \ static conditions	Processes
People		
Metabolism		<div>Energy</div> <div>Waste</div> <div>Food</div> <div>Air</div> <div>Water</div> <div>Material</div> <div>Soil</div>
Buildings	<div>Footprint</div> <div>Rooftop orientation</div> <div>Monument</div>	<div>Programmatic change</div>
Public space	<div>Open soil</div> <div>Grass</div> <div>Low medium vegetation</div> <div>High vegetation</div>	<div>Biota Flows</div> <div>Growth / succession</div>
Infrastructure	<div>Asphalt</div> <div>Permeable pavement</div> <div>Road</div> <div>Public transport</div>	<div>Movement - flows</div>
Civil constructions	<div>Underground Building</div> <div>Utilities: Cables and Pipes</div> <div>Archaeology</div> <div>Explosives</div> <div>Dike</div>	<div>Partial filling</div> <div>Site Grading</div> <div>Integral filling</div> <div>Combined Utilities</div> <div>Sewer Age</div> <div>&lt;= 25</div> <div>26 - 40</div> <div>41-50</div> <div>&gt;50</div>
Energy	<div>Fossil Fuel Energy</div> <div>Geothermal Energy</div> <div>ATES (Aquifer Thermal Energy)</div>	<div>Electricity</div> <div>Heat</div>
Water	<div>GroundWater</div> <div>Drinking water resources</div> <div>Open Water</div> <div>Rain</div> <div>Underground drainage</div> <div>Macro map</div> <div>Water Input/output</div> <div>Connection</div> <div>Water level district</div>	<div>Rainfall return period: 1/year</div> <div>Euthrophication</div> <div>Infiltration</div> <div>Runoff</div> <div>Drainage</div> <div>Evapotranspiration</div>
Soil / ecology	<div>Sand</div> <div>Silt</div> <div>Peat</div> <div>Mulch</div> <div>Gravel</div> <div>Clay</div> <div>Humus</div> <div>clean soil</div> <div>Bedrock</div> <div>Polluted soil</div> <div>Height difference</div> <div>Trees</div>	<div>Subsidence mm/year</div> <div>Oxydization</div> <div>Crop Capacity</div> <div>Rhizosphere processes</div> <div>Contaminants</div> <div>Subsoil Life (microorganism)</div>

### 3.2 The agency of the section

The key for interdisciplinary working and an essential method for knowledge brokerage in urban development projects is the reconnection of the horizontal and vertical dimensions to encompass all scales of the urban project. While the larger scale of the horizontal dimension is concerned with the strategic design of open spaces (surface network), the smaller scale of the vertical dimension (the section) is where the operational design of the technical construction takes place. The integration and hierarchies between the horizontal and vertical dimensions suggest possibilities to link scales for an integrated infrastructure and environment design, combining the strategic with the operational design. Specifically regarding the vertical dimension, the cross section is the representation of the third dimension of the city and connects the understanding of plan with urban systems. Adding to the 'building block of a common language', or the legend, the purpose of the section is to investigate, construct narratives of spatio-temporal changes and increase cross-disciplinary exchanges by design. Bélanger (2010), addresses the relationship between the horizontal and vertical dimensions in the following extract:

*'In contrast to the specificity of planometric forms of representation [the horizontal], the section provides a much more flexible means of communication, prototyping change across a large scale. [...]*

*For these reasons, sectional strategies have become the privileged interface between the complexity of the subsurface below [...] and the banality of the surface above'[...]. Small and often minuscule changes of surface profiles in cross-section can have pronounced effects across vast distances when seen from above, or experienced from the ground'.*

Therefore, the cross section is fundamental for two reasons. First, it permits the drawing and understanding of subsurface, geological and artificial, conditions together with surface and atmospheric ones. It simultaneously becomes a tool of discovery in a way that it finds and draw relationships between air, land and water dynamic as hybrid infrastructural systems across vast terrains. Secondly, for urban designers it is also a tool of measurement, to determine accurate dimensions (Desinimi et al. 2016).

Geologists, among others, make use of the cross section for geological properties, describing the material conditions of what occurs below surface as an outcome of long range spatio-temporal processes. The representation of these layers in colours are internationally the same: However, these sections do not take into account the whole artificial system of urban and landscape transformation which occurred on the surface throughout the years as well as the interactions between the two.

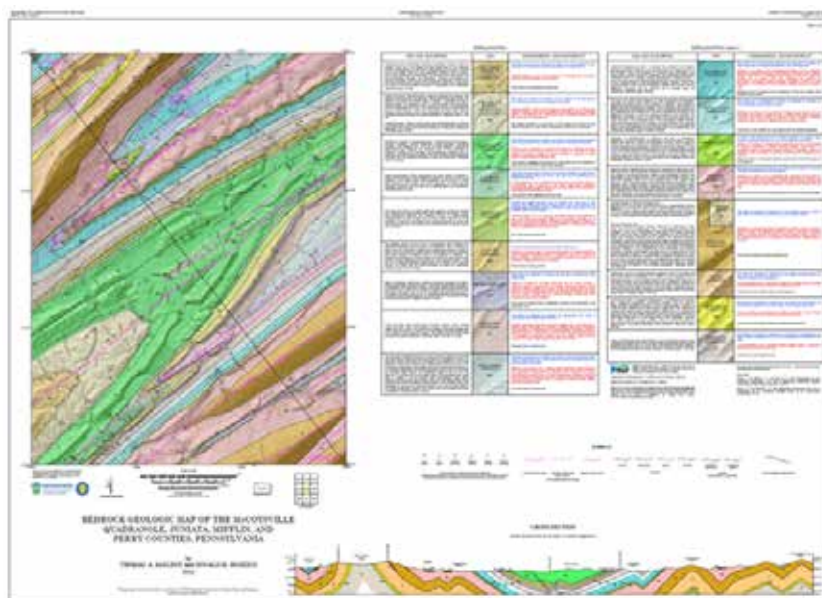


Fig 5.1. Bedrock Geologic map. McElroy, 2011



### 3.2.1. The sections of Von Humboldt and Geddes

An early innovation in how the section is deployed for descriptive purposes, with a rising complex and integrated thinking comes from the work of German geographer, naturalist and explorer Alexander von Humboldt, 1845. In his work, the section becomes the main tool to describe a material condition (surface) of the earth in relation to climatic variables (altitudes, latitudes and longitudes) and geological properties (subsurface materials). In his wonderful taxonomies, the series of sections showing subsurface, surface and vegetative properties make a unique contribution in how we understand the planet today as well as in how we can deploy 'sectional' thinking and strategies.

visualize the concept of 'city - region' as a complex model which combines geological data and mineral condition of the soil, physical geographies, patterns of occupation and the interrelation between them.

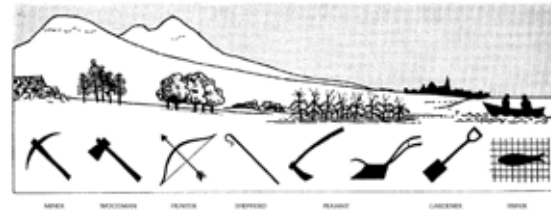


Fig 5.2. Valley section. Patrick Geddes, 1909

Following the same innovative approach (survey and relational thinking), the cross section is used in 1909 by Scottish biologist Patrick Geddes, the father of ecological design and bioregionalism (Wahl, 2017). Geddes published the idea of the valley section to

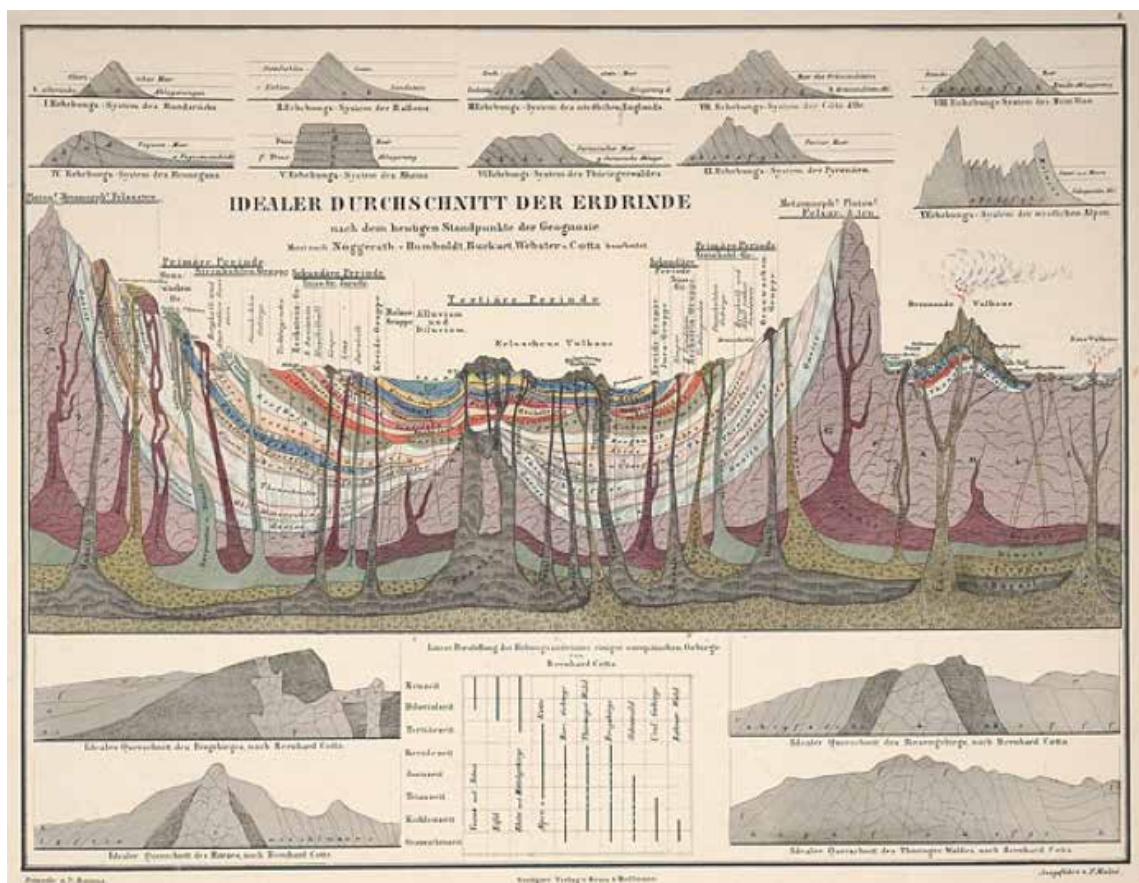


Fig 5.3. Ideal section of the earth, Kosmos. Alexander Von Humbolt, 1845

When studied across vast terrains the section allows for a multiple relational reading of the territory, a one in which culture, nature, occupation and industry are strictly related to the topographical, atmospheric and geological features of the territory.

On the other hand, sections by urbanist are often used to:

- Frame the difference between public and private,
- Frame the relation between build up space and open space,
- Describe dimensions of street profiles,
- Describe public space design,
- Measure and show construction drawings.

Although the subsurface is represented, in the Coolsingel drawing of West 8 (2014) the details and level of interaction with other disciplines remain less developed and explored.

As a counter mechanism, the cross section in the research is taken as a strategic method to describe, understand and analyse the hybrid subsurface-surface condition of the fields to exploit potential symbiosis and synergies. Indeed, this tool allowed for a synthetic reading of its 'thickened ground' blending together the artificial, the natural, the geological and the temporal dynamics (mostly related to the water and carbon cycle).



Fig 5.4. Coolsingel Rotterdam, West 8, 2014



Fig 5.5. Cross section showing altitudes of urbanization  
OPSYS, 2016

*From 10,000 meters below the sea, to 35,000 kilometres in orbit above the surface of the earth, the infrastructure that supports urban life has reached unimaginable extents below ground, in the water, and across outer space. Re-tracing the conventional contours of the cities we live in and the spaces we travel through, this diagram illustrates the range of depths and dimensions that we have reached and explored over the course of the past 3,000 to 5,000 years of human history. Organized through different depths and elevations, the elements mapped out here pro-pose a different projection of the infrastructures that not only support everyday life, but also the environments generate it. While attention is traditionally given to the plans of urban civilization and top views of human history, this schematic cross-section view of the world opens a lens on the planet as an urban projection, pattern and process of overlapping change across different layers and level of space, in time. Belanger (2016)*





*"If a Deep Urbanism is a reading of the city as a complex system composed of interconnected layers of social and biogeochemical processes, then the deep section is its primary graphic device for communicating a synthetic view. The deep section is an essential representational tool in expressing and addressing design challenges holistically—allowing varied processes to become visible and be explored relationally, rather than analytically. The deep section breaks away from reliance on the visual and apparent—creating space for the visualization of the processes of urban nature more readily than do plans and perspectives. The deep section also brings infrastructure, hidden both underground and in plain sight, to the forefront, expanding our understanding of the pre-conditions of projects and the boundaries of our interventions..."*

47

*A deep section approach might overlay information of below-ground dynamics in order to express the connections or synergies between aspects of maintenance activities (i.e. both the pruning of plants above ground and the addition of soil amendments, microorganisms or subsurface irrigation)...*

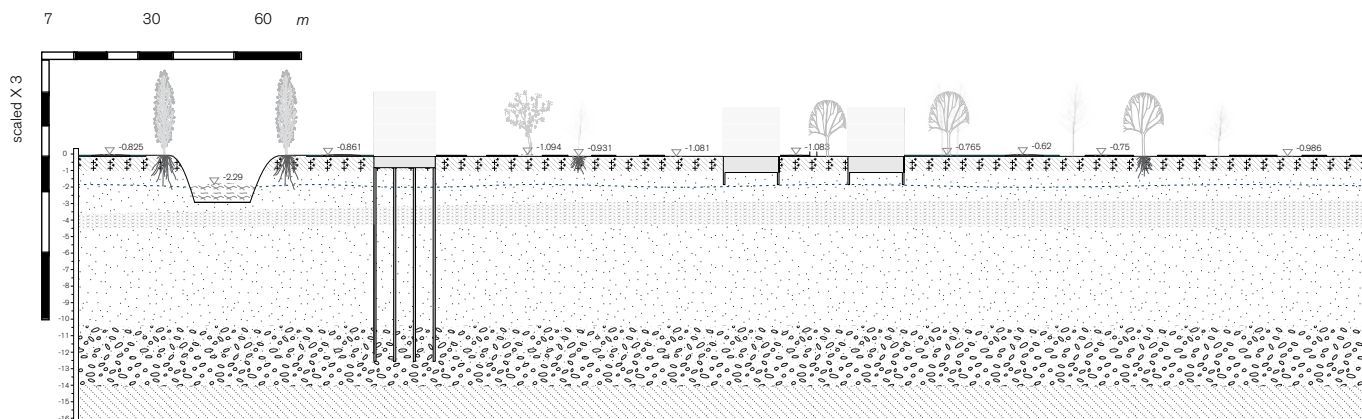
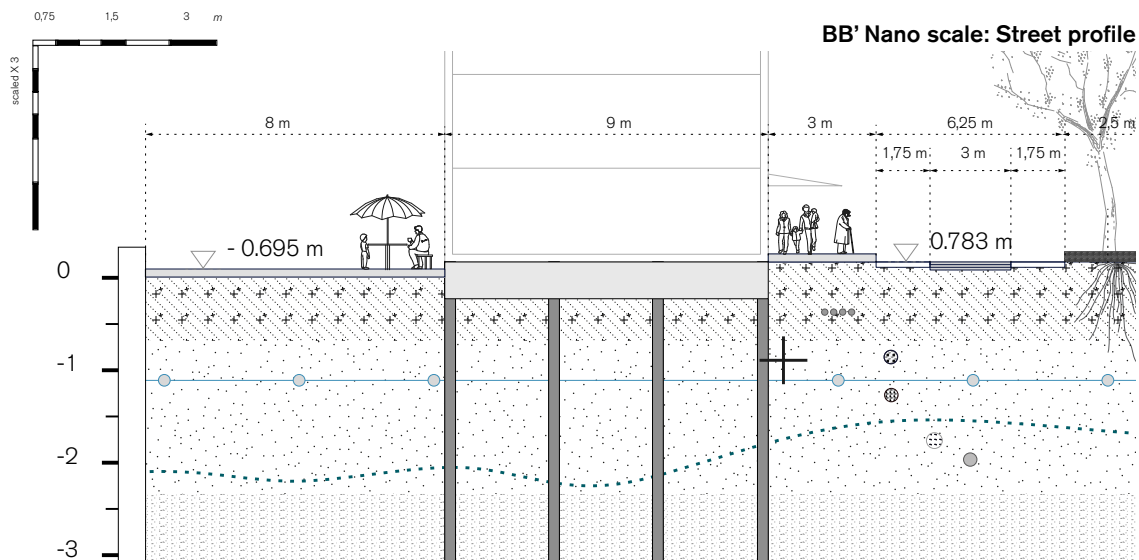
*Able to be drawn quickly and early in the design process, sections offer a powerful generative, communicative and analytical tool. The deep section designates a physical space in which a project's unknowns, goals and constraints can be drawn and tested. The "deep section" holds out promise as the graphic platform for convening the interdisciplinary conversation necessary to solve the complex and layered challenges of contemporary urban landscape projects within a medium that is native to landscape architecture."*

### 3.3 Mapping Bloemhof-Zuid Rotterdam

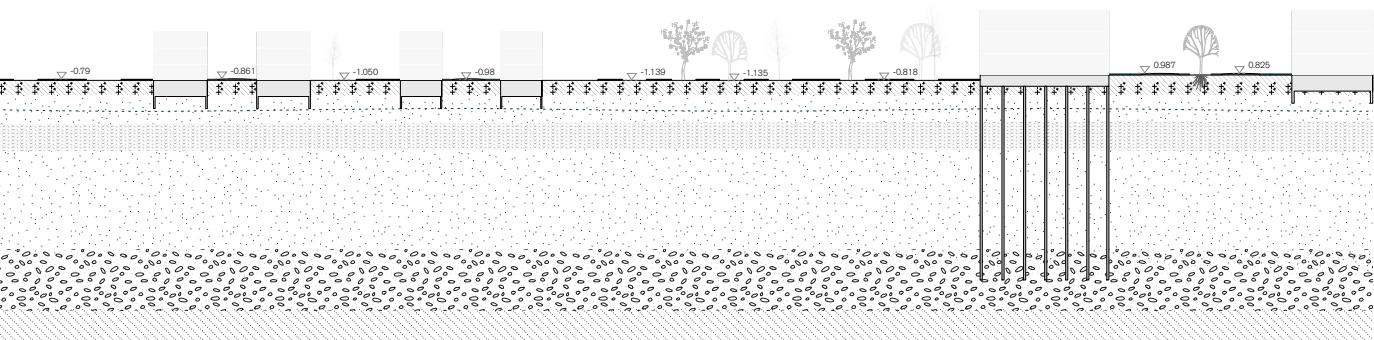
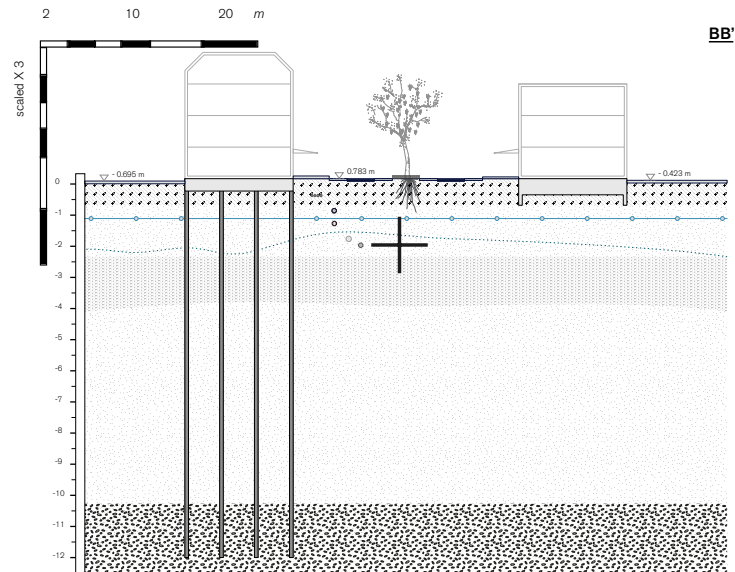
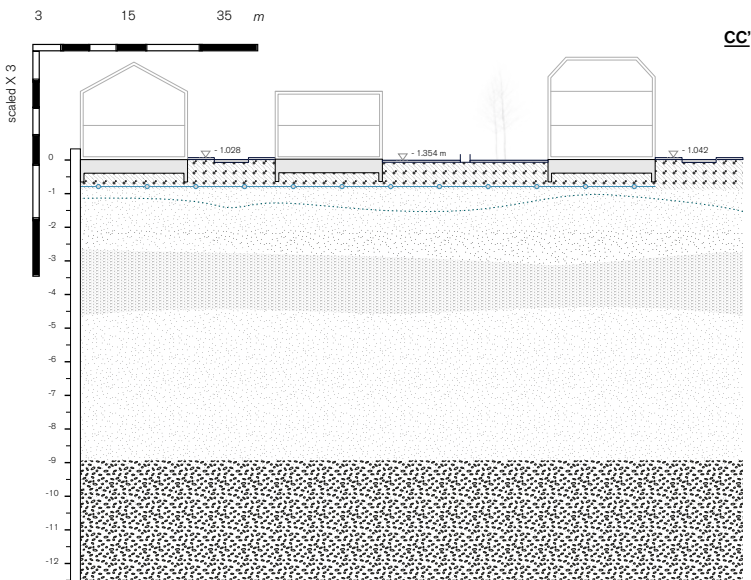
The series of sections show the representation of natural, artificial, surface and subsurface artefacts and elements in Rotterdam Bloemhof-Zuid. The TU Delft team was engaged as part of the design process with the aim to help the design office, the municipality and the housing corporation (developers) to fine tune strategies of transformation according to the visual and procedural findings.

The section here allowed for a better understanding of the site condition but most of all of the interactions in time, which have led to specific surface qualities and

subsurface criticalities. The drawings underpinned the relation between different temporalities of incremental changes and transformation of the surface, with the consequences of diminishing ecological performances, triggering soft soil's oxidation. As a matter of fact, the main problem in the area is related to water nuisance and especially the subsidence of the ground that is causing millions of euros of damages. Finally, it allowed revealing intangible physical dynamics that happened in time as a consequence of dynamic interdependences between the natural and the human system (Hooimeijer and LaFleur 2018).



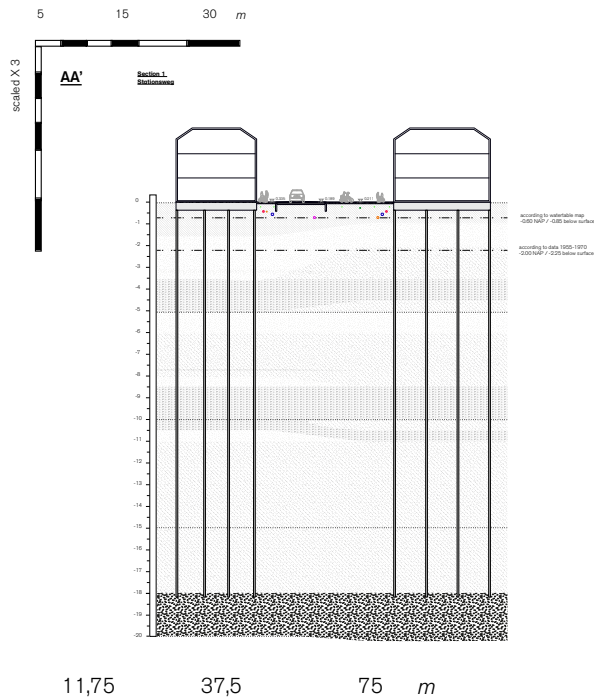
Sections:  
Framing Rotterdam Bloemhof-Zuid



### 3.4 Mapping station area Leiden

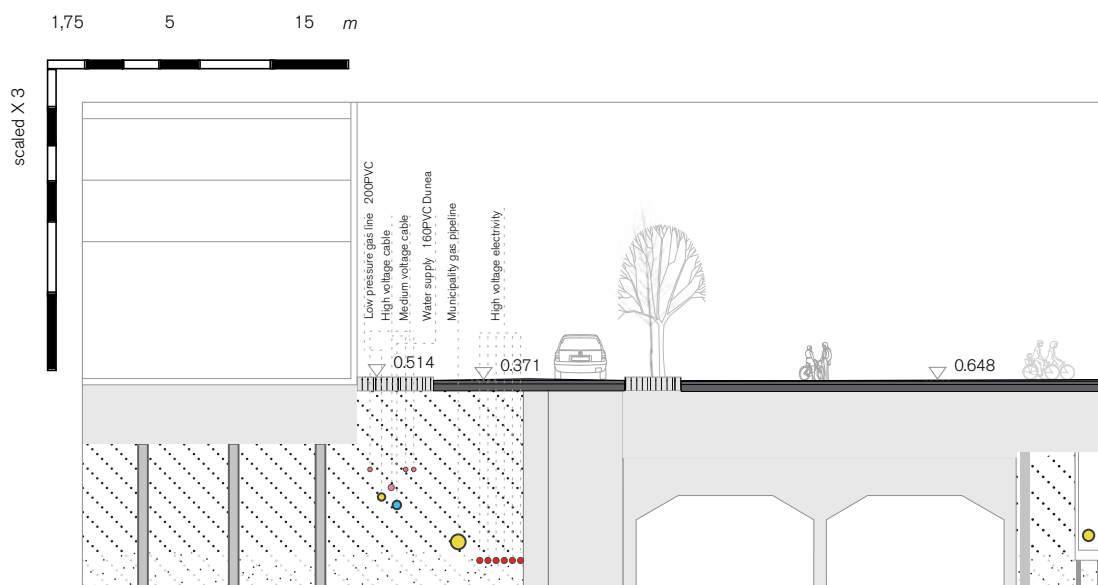
Following the same procedure, the TU Delft team also helped in the making of the Leiden Central Station area development. In the first phase of the projects the drawings served as a mechanism to understand the complex and 'constructed nature' of the site. Here the sections represent the 'thick ground' of the area

as an 'underground urbanism of civil constructions' together with the transformed geology of its soil layers. Furthermore, since the project also aimed at substituting the energy network, the systems of cables and pipes are accurately drawn in the smaller scale (Hooimeijer and LaFleur 2018).



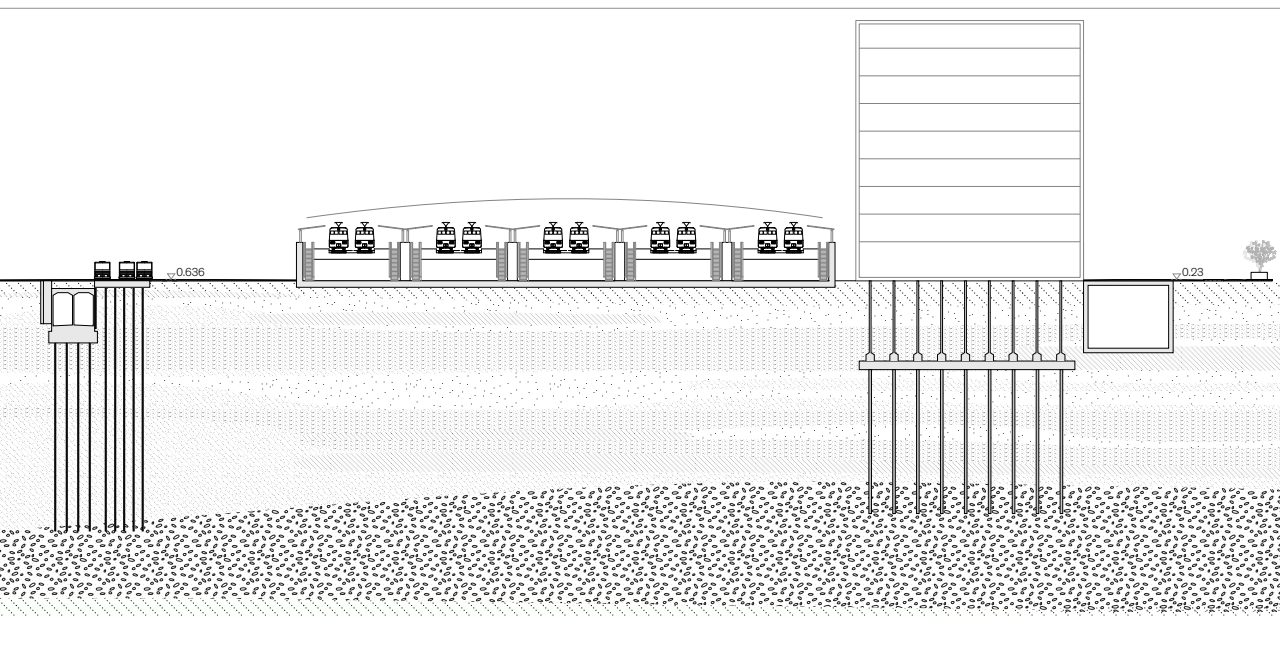
Sections:

Framing Leiden station area



51

**EE'**







The case of Amsterdam is an interesting example in order to understand the process of territorialisation (appropriation, transformation and inhabitation) of deltaic regions. Here specifically the case is instrumental to understand the legacy of water management inside the dikes in which managing groundwater levels is a primary task. The cross section is used as a method of historical reconstruction in which the natural and the artificial systems and their interdependencies are investigated. As previously mentioned, to truly understand the 'contemporary' condition, the diachronic approach shows the different processes of change regarding the interplays between land - water and the urban construction project. The section thus permits to reveal the changing interdependencies, varying altitudes and the synchronization of biological civil - hydraulic and spatial change. It permits a basic infrastructural reading of the territory, in which infrastructure is seen as the set of systems which permits and generate urban life and economy.

As a matter of fact, the analogy of the Netherlands as a hydraulic machine is represented in the next pages (56-59) with a sequence of drawings, which shed light on the continuous process of pumping and drainage of water in soft soils generating a stable ground for human occupation to thrive.

The area investigated lies just north of Vondelpark, the biggest urban park in the centre of Amsterdam, and is considered nowadays as one of the most expensive areas to live, with real estate values at an average price of 7.000 euros per square meters. Given this real estate market condition private owners together with building developers have recently started an expansion of underground basements thus altering the soft and fragile condition of subsurface and surface dynamics even more.

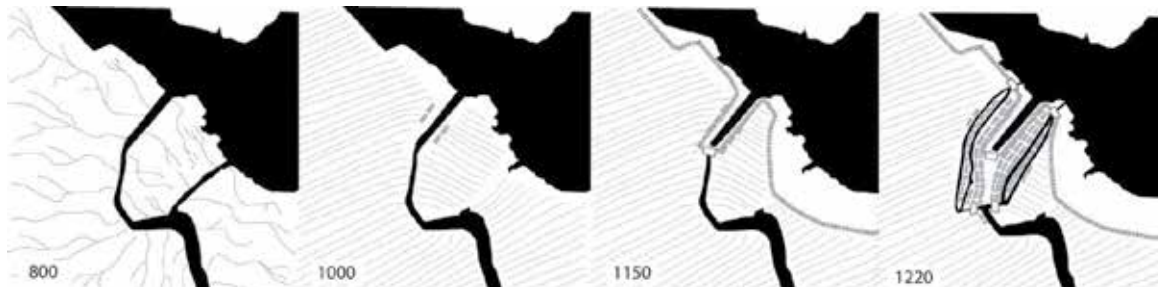


Fig 5.6. Amsterdam early days Urban landscape and settlement evolution. Hooimeijer, 2014

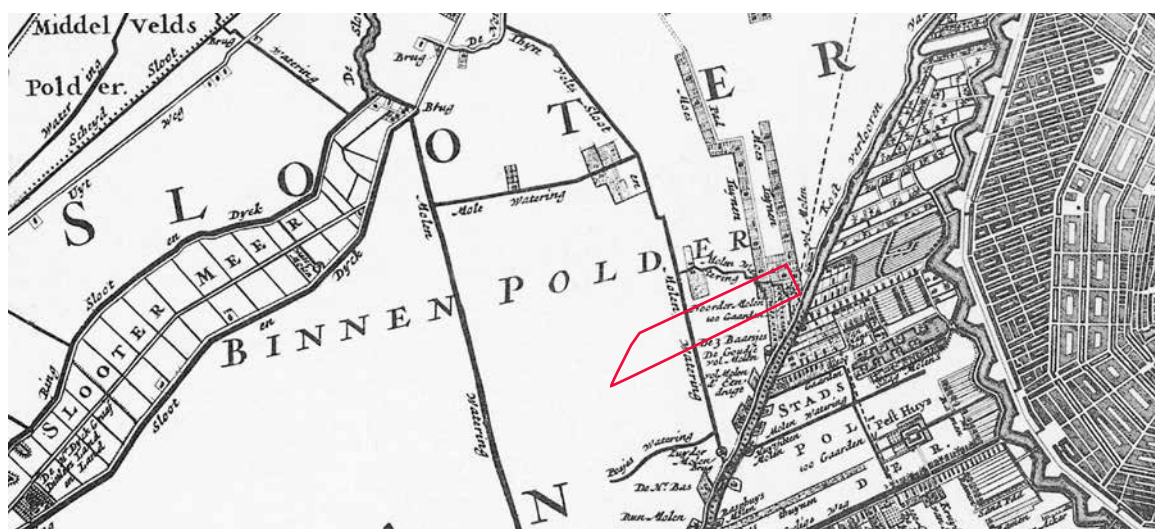
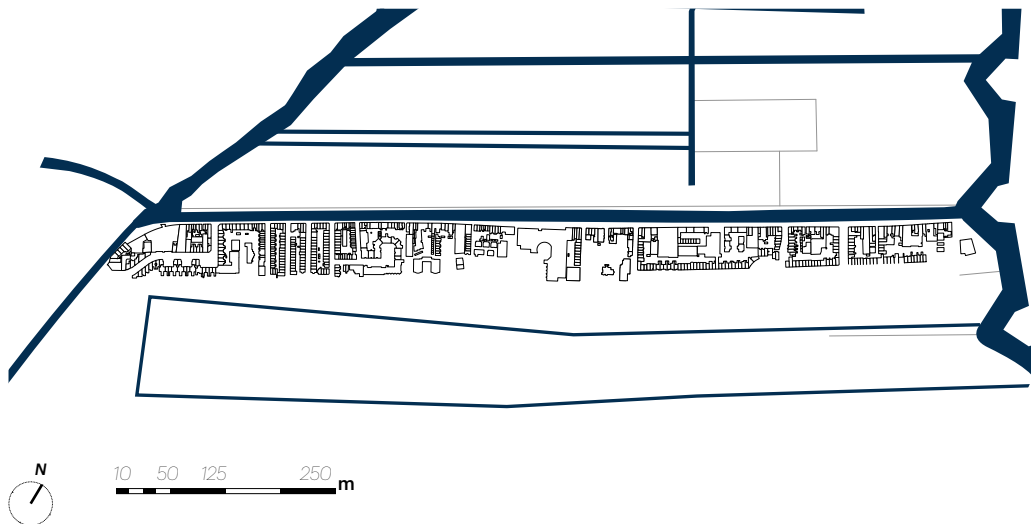


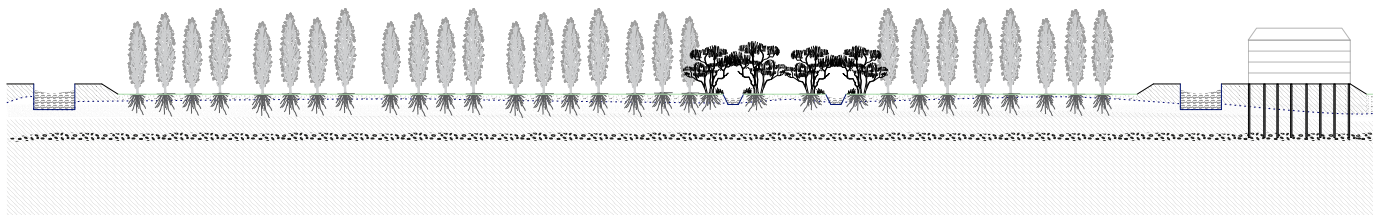
Fig 5.7. Amsterdam historical map and site plan overlaid. Adapted from Author based on Drogenham, 1770

Plan of water and drainage system, as the fundamental public work preparing the land for urban and landscape development. The plans and sections show the relation between the construction of the drainage system and the flow of water. Plan and processes dynamics are seen as inseparable part of the understanding of the territory.

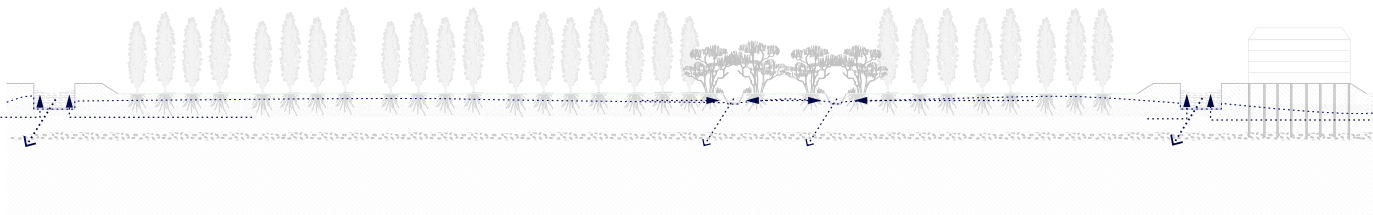


54

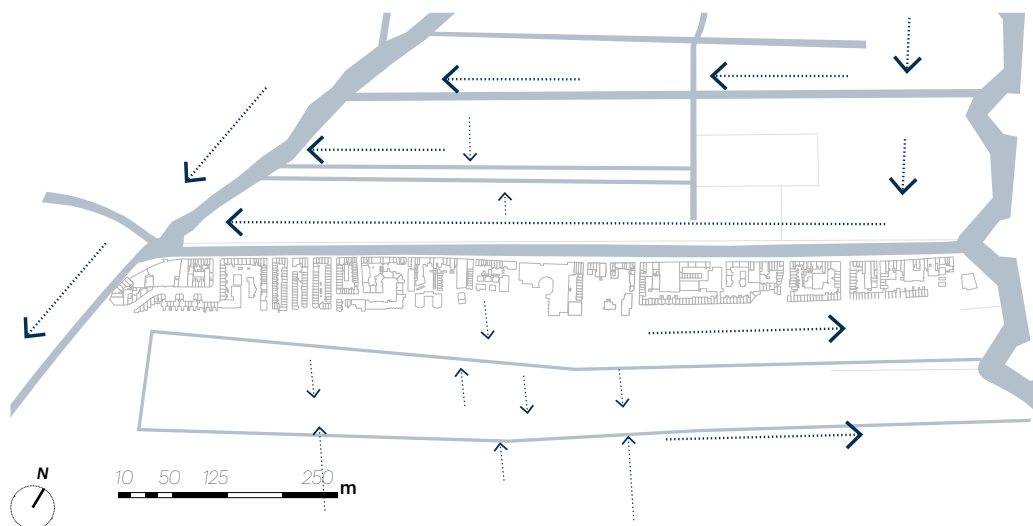
Plan of the construction of the water system as part of land reclamation in the south west of Amsterdam historical core



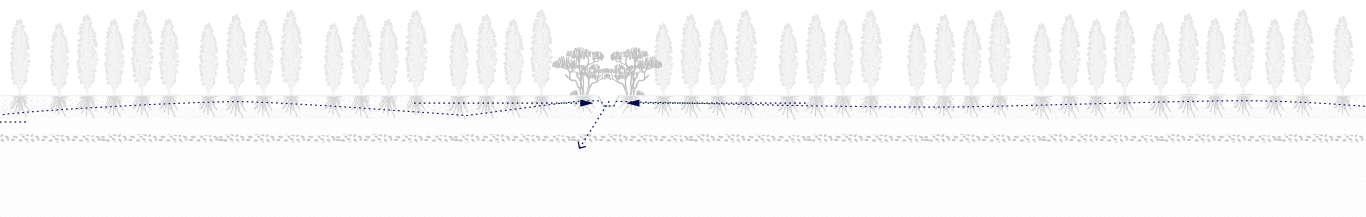
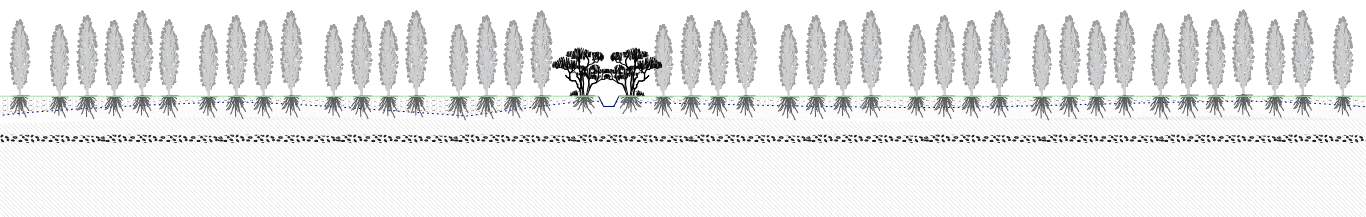
Section of the construction of the water system. Building site preparation, foundations, vegetation and infrastructure are thus mapped as a unique socio-technical space



The section is here used to overlay process dynamics related to the continuous functioning of the water system. Groundwater drainage, groundwater level and discharge channels



Plan of the water dynamics of groundwater and open water drainage. Pumping draining and discharging are thus overlaid with the plan



### 3.6.1 The making of constructed ground

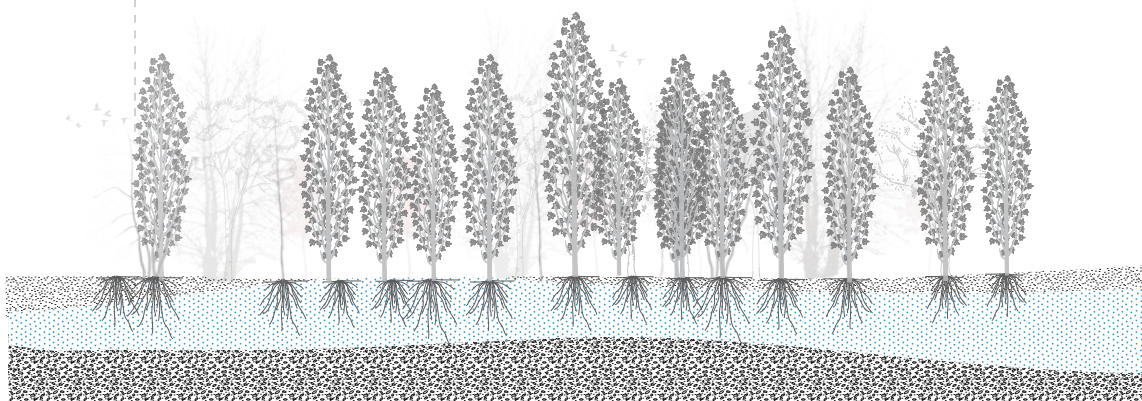
Drawing sequences of change allows for an understanding of the transitions in 'land - water composition'. The site can be 'read' from the viewpoint of the water system in which the groundwater and open water are one unit that is altered by drainage, pumping and soil transformation. The original landscape of peat and clay is covered with sand and sealed with streets and buildings: the new typology of 'constructed ground'.

The incremental process of Inhabitation, i.e. Territorialization, LaFleur (2016) is mapped through the dynamics of change of water. It conceives the urbanization process from its fundamental act, the one of constructing the ground in which the most fundamental operation has been the movement of water from the ground (subsurface) to open water (surface) through an early integration of planning, design and civil, hydraulic engineering. This incremental degree of change is visualized in a simplified way in the diagrams under each section, where a speculation on the gradients are visualized to make the reading of the drawing easier.

56



Poplar trees / wetland



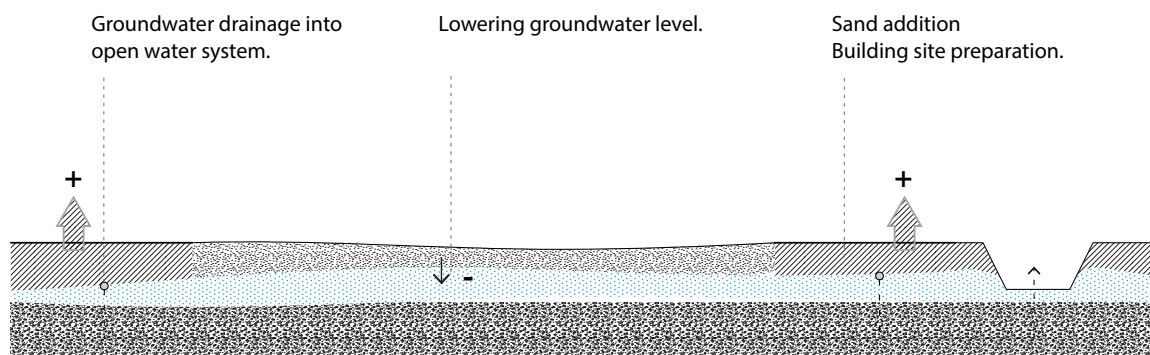
Water in the ground 100 %





First level alteration:

- Draining the ground,
- Building site preparation, sand addition,
- Preparing the ground, levelling.



Water in the ground 75 %



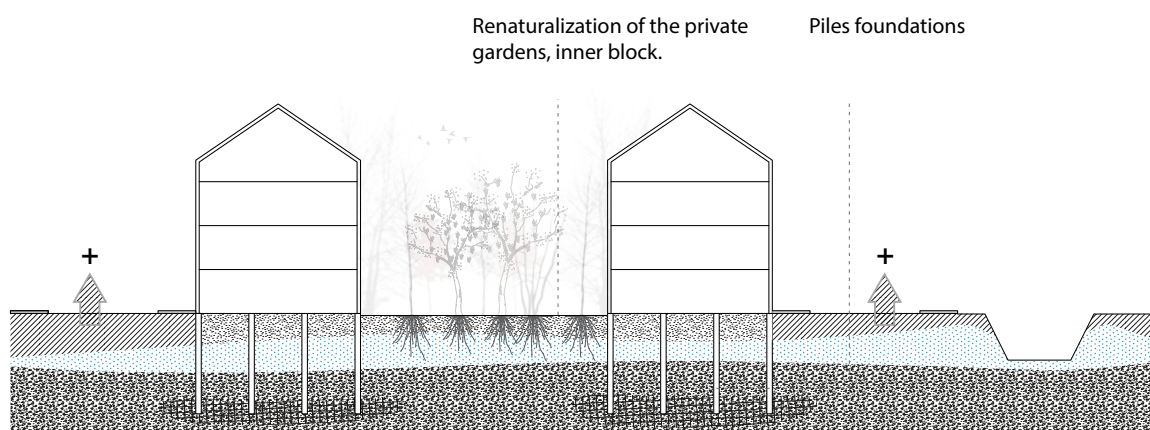
Open water 25 %



57

Second level alteration:

- Underground construction: pile foundation,
- Soil sealing,
- Sand addition as maintenance (Street heightening).



Water in the ground 75 %



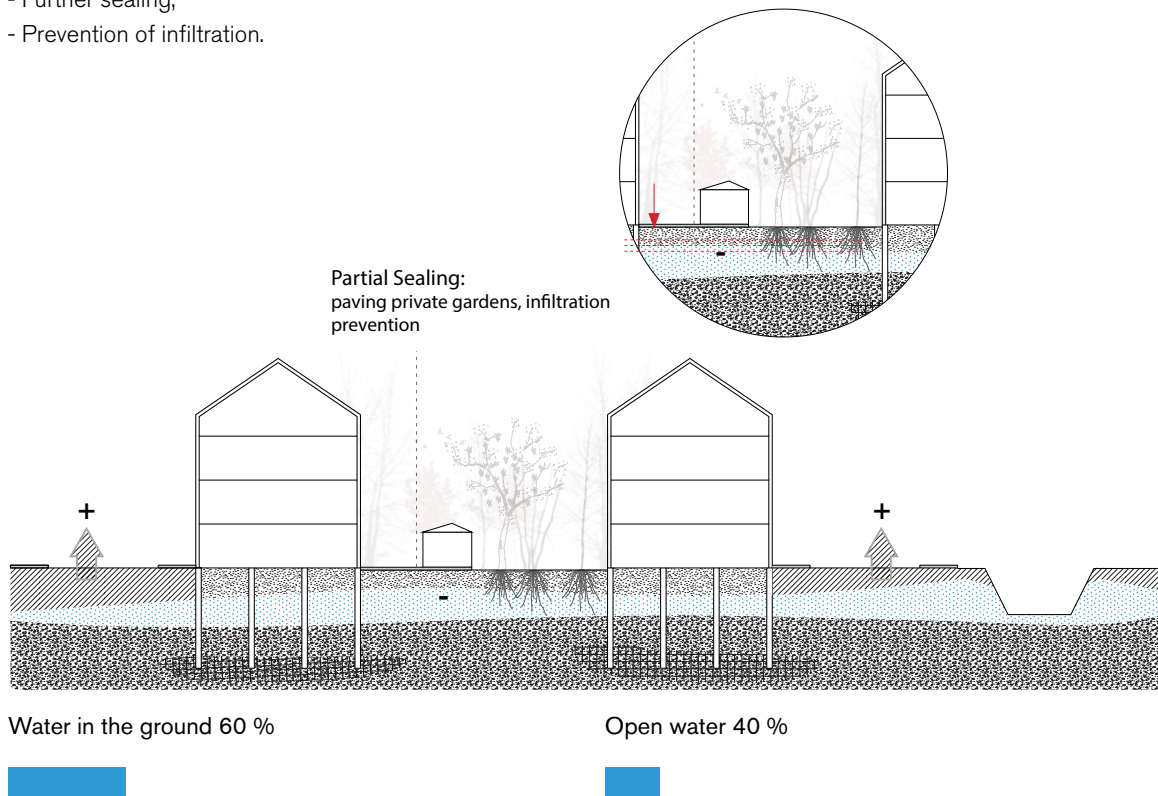
Open water 25 %





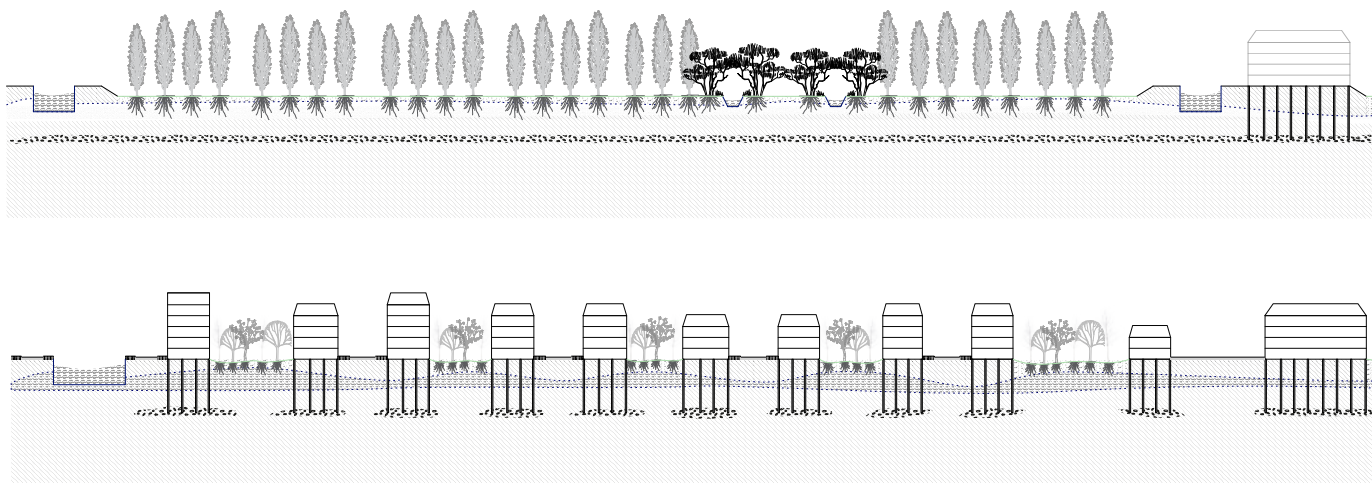
Third level alteration:

- Further sealing,
- Prevention of infiltration.



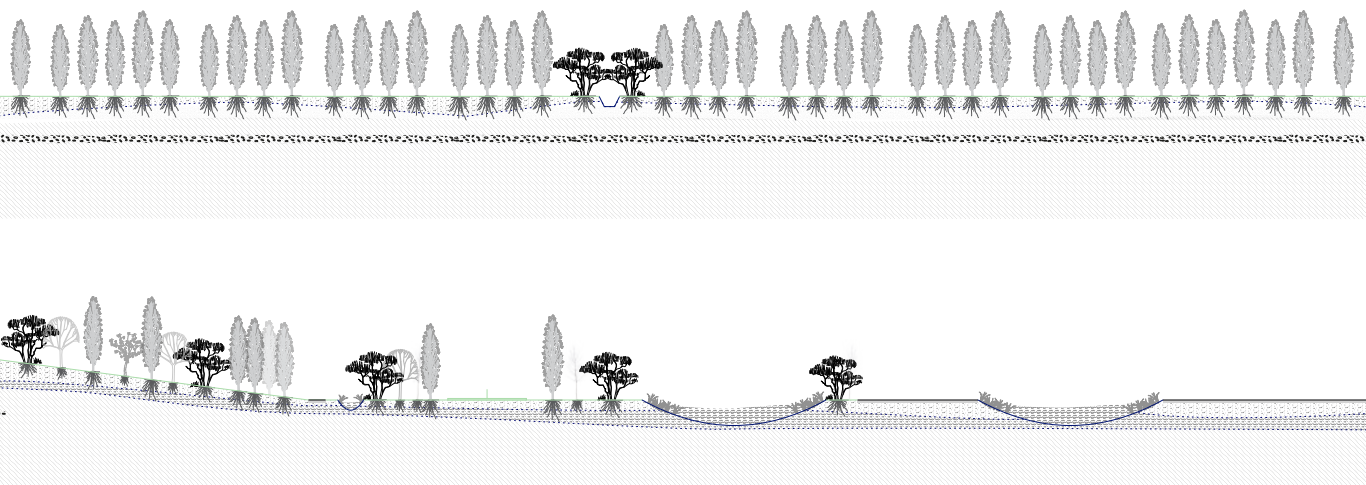
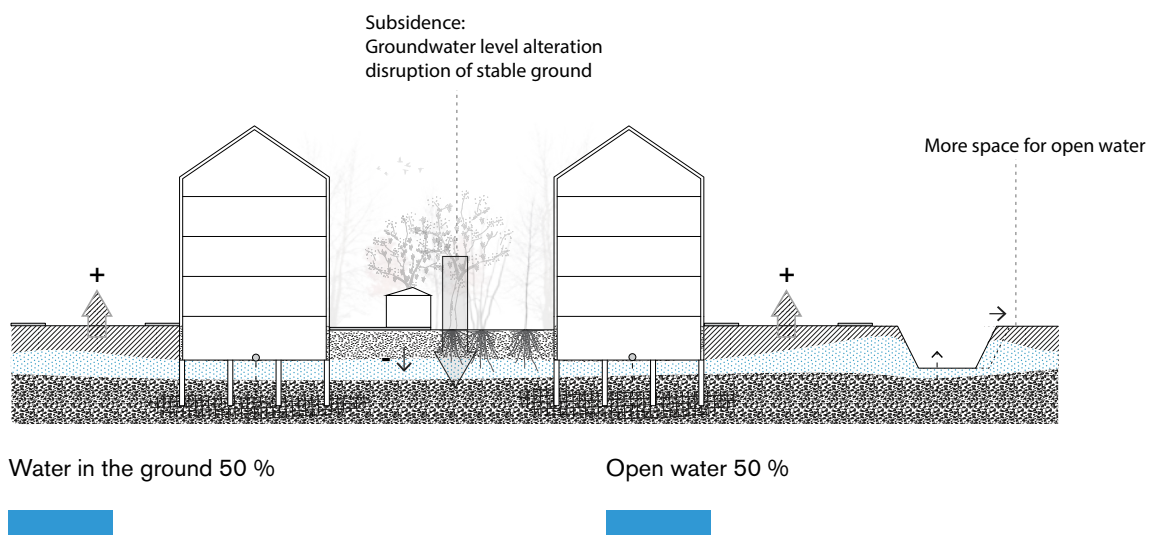
58

The sections here below show the making of the 'constructed ground' in section, with the comparison between before situation (above) and after, contemporary situation (below).



Fourth level alteration:

- Pumping / draining the ground,
- Groundwater regime disruption,
- Subsiding.



The final chapter of this publication, under the framework, 'drawing the subsurface', takes a provocative and projective step in order to showcase possible drawing and mapping techniques that are able to consciously link the subsurface in urban development and at the same time reach a balanced and dynamic integration of infrastructure and environment design. The term 'projection' implies an 'estimate or forecast of a future situation based on a study of present trends' (Oxford Dictionary); thus, the word projection implies the possibility of a future project. More than the orthographic representation as an architectural tool, the word projection here implies both an alternative but also the hidden processes attached to it that can be projected in the same visualization. Therefore, the agency of projection entails a relational connotation, as a visualization technique, it makes possible to show sequences of transformations and to reveal often unseen dynamics. Moreover, overlaying, scripting and scenarios becomes ways in which 'the projection unfolds' - which means ways in which it manifests itself through prototypes, principles and options in space allowing the advancement of integrated infrastructure and environment design.

In this chapter the research results of the projects in Rotterdam and Leiden are presented with the focus on the use of provocative scenario's and projections in interdisciplinary setting as well as the central focus on how to draw the technical conditions for a site in projective manner.

#### 4.1 Use of provocative scenarios: Bloemhof-Zuid

The current state and situation is the starting point of a projective scenario. It extrapolates current trends and build future images. The construction of a projective scenario can also be named as forecasting. For instance, developing estimation on future populations are based on forecasting. (Geurs & van Wee, 2004) On the other hand, prospective scenarios start at a possible or desired situation in the future. This future is usually described by goals and targets which are set and established by assumed events between the current and future situation. The construction of a prospective scenario can also be named as backcasting. Backcasting holds the capability to highlight

discrepancies between the current and desired future and can incorporate large and even disruptive changes. (Geurs & van Wee, 2004)

The project proposed two scenarios for Bloemhof-Zuid as a way to stimulate knowledge brokerage and interdisciplinary co-creation. Specifically, two provocative driven scenarios were developed for the site, starting from the spatial investigation that was translated into the technical profile (see page 38 - 41). Both scenarios are provocative in the sense that they propose to deal with subsidence without adding sand to the area (as is usually done) and by stimulating a new constructed ecological system as the main strategy of urbanization. This approach is done by taking into account the long term environmental processes and technological interventions to try to foster interdisciplinary integration. An important aspect is to show and visualize the synergies and strategies in which design and engineering disciplines co-develop. This exercise is also taken as a way to explain how knowledge integration works to the professionals at the municipality, as well as external professionals taking part in the process of urban (re)development. Functioning both as process support and provocative projections, the series of drawings describe integrated strategies related to the designed symbiosis between water, soil and civil construction technologies. The idea is to follow a performative logic, related to the integration of seemingly separate disciplines, rather than aesthetic reasoning or orthographic compositions, following landscape urbanism principles (Hooimeijer, LaFleur, 2018).

#### 4.1.1 Polder in the polder scenario

Building on the strong legacy of water and civil-hydraulic engineering integration in spatial development in the Netherlands, the scenario proposes a 'Polder in the Polder' scenario in which a new water unit is created within the subsiding area. The new circular structure of water drainage, or in Dutch 'singel', becomes the main infrastructural and performative strategy as a way to accommodate and manage the subsidence on the smaller scale as well as to manage storm water runoff and groundwater drainage, nevertheless it aims at

guiding the urban-landscape composition and future programs.

With the following drawings, several strategies related to the integration of infrastructures and environment design and the space-time relation is explained.



Site plan of the proposed 'polder in the polder' scenario. The main performative and spatial strategy is materialized through a water loop which at the same time is able to perform hydrologically as well as structuring occupation and infrastructural patterns.

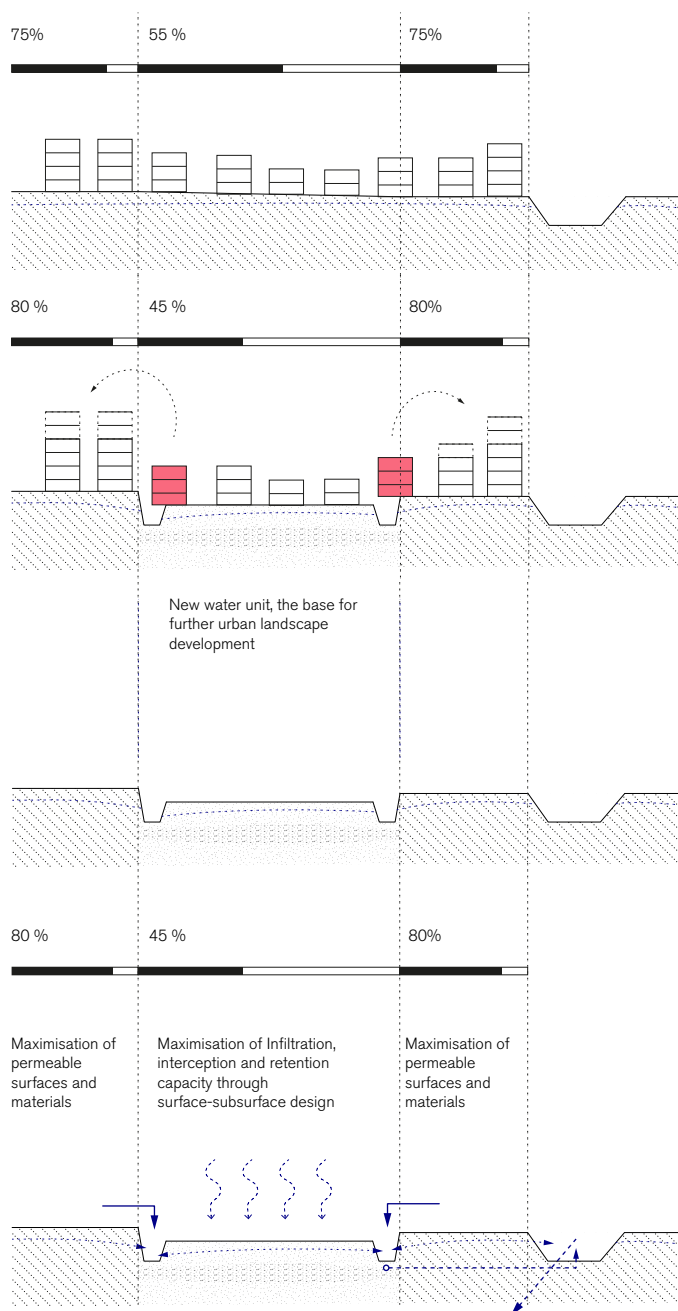
#### Legend

	Primary road
	Secondary and tertiary road
	Circulation systems (no cars)
	Water structure
	Stable ground
	Design with Subsidence
	Green structure

## Urban landscape development principle

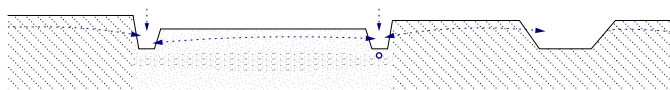
The section is instrumental to show the main spatial development strategy with an interdisciplinary outlook; it takes the functioning of the natural system as an opportunity to integrate various geo-civil-hydraulic engineering choices. The new infrastructural framework enhances the performance of the natural-artificial system according to the different intensities of rainfall patterns. The series of drawings show the new shape of the profile that is able to accommodate contingencies related to the natural system and material properties.

The natural systems, and the unpredictable events that are embedded in its functioning, ask for an infrastructural framework that is designed to be flexible, i.e. that is able to accommodate change related to shifting intensities of rainfall patterns and groundwater drainage. Material properties are the bio-geo-chemical components of the infrastructural framework, mostly related to soil condition, and are drawn in relation to their natural performance and temporal dynamics. The section (shape of the profile) is firstly coupled

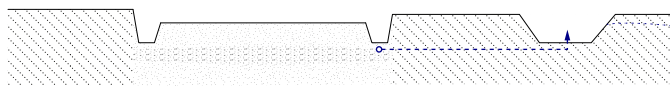


with the main technical construction in the area and secondly it shows the synergies with subsurface – surface environmental properties. Thus, it visualizes a sequence of transformations that are related to the movement of buildings, technologies and soil properties with the aim to achieve an integrated infrastructure and environment strategy.

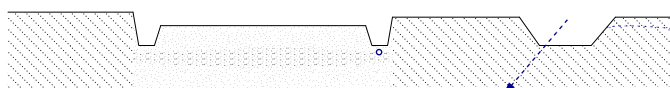
### Water management principles



T1= Groundwater management in the polder

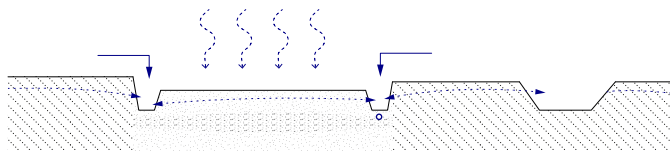


T2= Discharge to boezem level with a pump



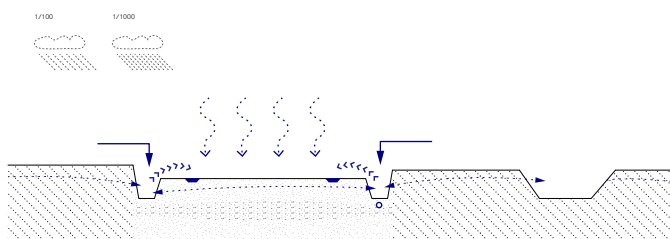
T3= discharge from boezem to larger water system (river)

### Processes



Water processes in space: drainage, runoff and infiltration

### Excedence



Water processes in space: drainage, runoff, infiltration and designed excedence



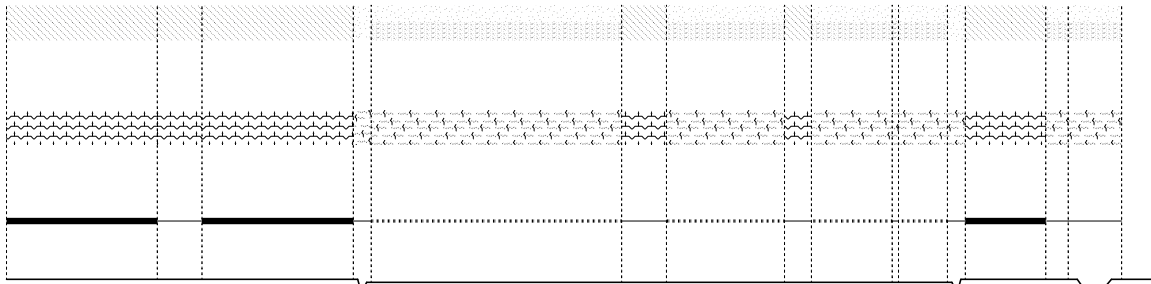
## Integrated Infrastructure and Environment design strategies: Projecting Constructed ground

In these drawings the new sectional profile is related to its structural and functional zones (surface qualities and potential program), subsurface materials (building site preparation), and artificial durable structures (civil engineering strategy). The restoration of a high groundwater table is coupled with the decision to opt for slabs foundations. In this example we can see how spatial, programmatic, and technological dynamics and choice were balanced and synchronized according to a temporal and spatial strategy.

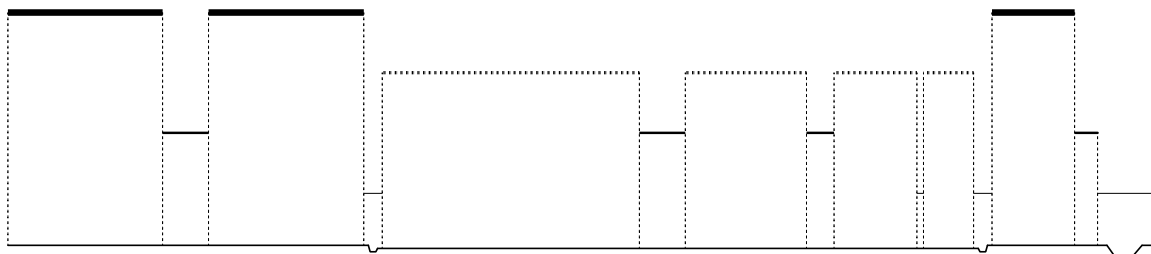
The drawings could be read as a single entity (as it's in the cover) starting with the abstraction of buildings foundation (on slab) and making a series of relations

in regards to the distribution of properties and functions. Thus, the interrelations between a purely physical / spatial object that is static (the section) are intertwined with intensities of movements, stability and subsidence, subsurface bioengineering, and circulation features. Under this frame of reasoning, functions were specifically decided, however the aim of this visualization is also a one in which the most suitable program (surface manifestation) can be revealed.

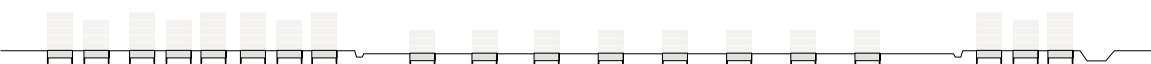
### Building site preparation



### Structural and functional zones



### Civil engineering strategy



Subsurface soil deployment

Soil temporal dynamic: filling and subsidence

Corridor and patches differentiation

Hard stable ground

Soft soil urbanizations

Main corridors

Ecological corridors

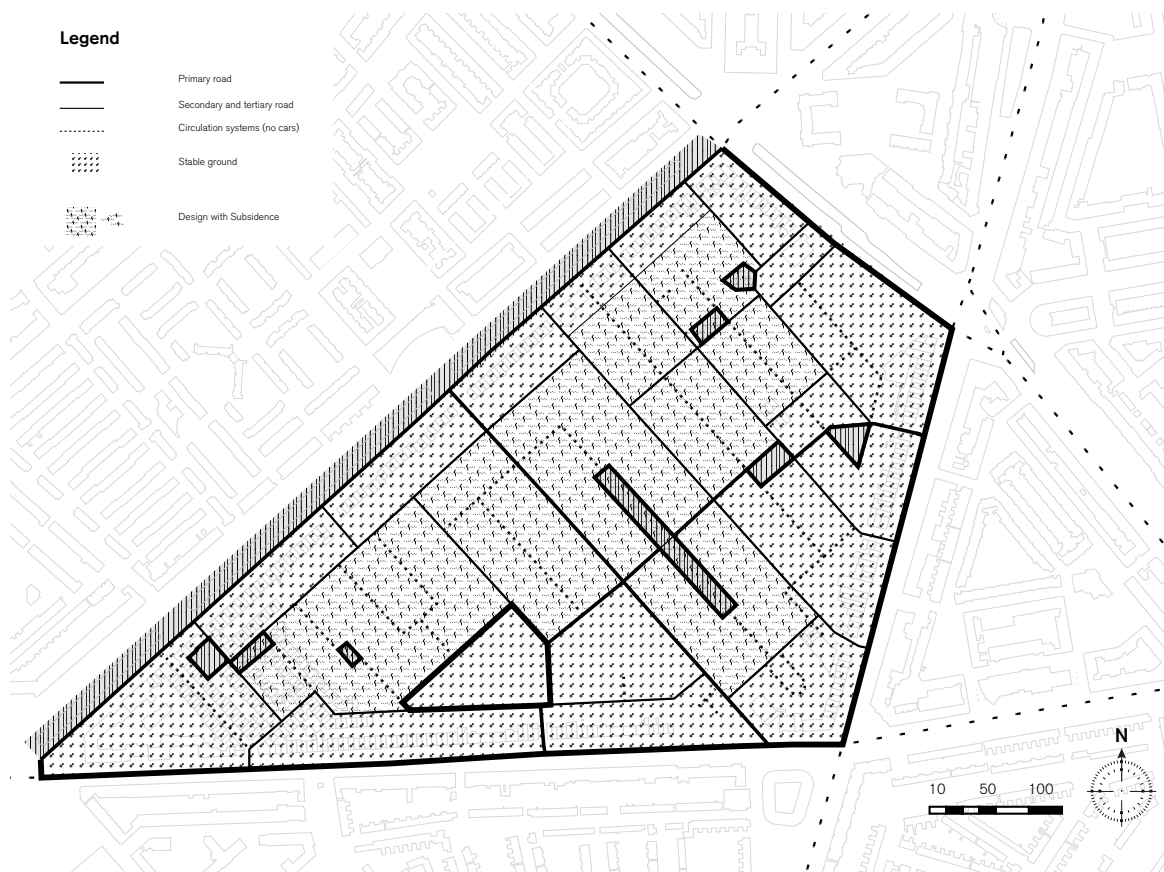
Slab Foundations

#### 4.1.2 Extreme scenario

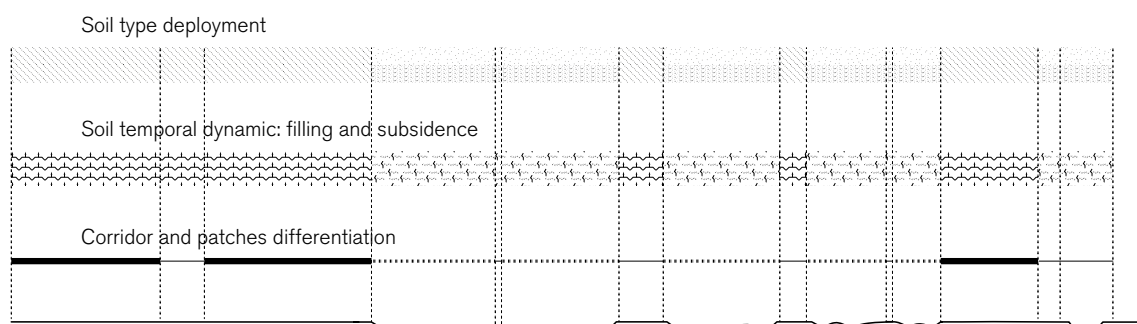
The second scenario deals with the acceptance of subsidence in another extreme approach which is aiming for the restoration of a wet landscape coupled with building back all housing on piles with deep foundation (12-14 meters). As a counter proposal to the previous one (which is a new designed 'extreme' polder), here the strategy aims at creating new natural topographies that resemble a natural wetland coupled with hard, fixed elements that support and generate human occupation. Therefore, the distinction between high dynamic (subject to high degree of change in time) and low dynamic (human occupation pattern) becomes the main strategy of urbanization that undertakes co-existence between systems as its main scope.

Again, this extreme condition is presented in a workshop at the municipality, in order to reflect on the possible implications, strengths, weaknesses, threats and opportunities as well as on the synergies, conflicts between disciplinary fields in the search for co-existence and mutual benefits.

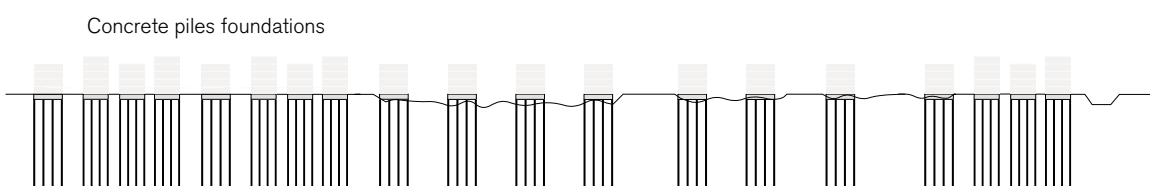
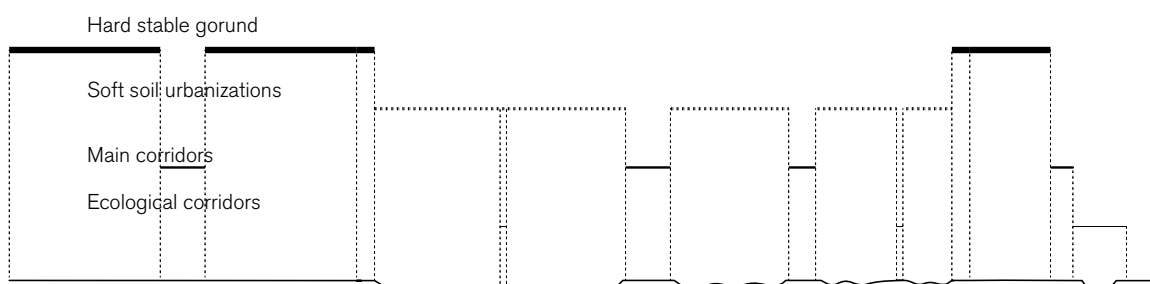
Following the previous scenario, the series of drawings, on page 67, aims at creating relations between a new spatial framework, and the disciplinary fields involved in the full life cycle of territorial transformations. It shows how the different disciplinary fields are synchronized in a unique socio-technical space under the form of a new integrated infrastructure and environment project.



Site plan of the proposed 'extreme' scenario. The main performative and spatial strategy is materialized through the choice of leaving an unstable, yet ecologically performing, ground coupled with piles foundation. Thus reaching a dynamic balance between stability and dynamics of the human and natural system.



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## 4.2 The agency of the section

As an essential tool for interdisciplinarity in urban development projects, the reconnection of the horizontal and vertical dimensions is here used to link scales in a hybrid urban water infrastructure, combining the strategic with the operational design.

Until the Industrial Revolution, this integration was a strong part of the Dutch practice of urban development (Hooimeijer, 2014). The making of Dutch polder cities, as Burke emphasizes, is not a matter of architecture alone, but primarily a visionary way of dealing with the hydrological demands of the wet territory: 'the poorest natural resources . . . constant danger' of urbanization that is undertaken with 'qualities of courage and tenacity, ingenuity and faith' as demonstrated in the Dutch landscape and cities (Burke, 1956). The planning of the expansion of Alkmaar in the sixteenth century already incorporated an integrated technical plan due to the literal vertical issue of stepping of the original dry core of the city centre and expanding in the lower lying, wet and soft soil conditions around the city. It represents the Fine Dutch Tradition, in which urban plans are made using the parameters of natural systems and efficiently link the hydrological cycle, soil and subsurface conditions with technology and urban development opportunities (Hooimeijer, 2014).

The representation of the vertical dimension is key to this integration of the technical domain into the planning and design realm.

Thus, the section becomes a tool of knowledge brokerage and should be a conscious product during the development of urban development strategies and tactics for climate adaptive cities. A strategy is considered a plan of action (or planning) designed to achieve a long-term goal under conditions of uncertainty. Tactics on the other hand, are considered to be short-term actions (or design) that form part of a strategy and are based on agreement and certainties (Bryson and Delbecq, 1979). The inclusion of tactics within strategy via the section could be seen as connecting time and space. As a projection into the future that accepts uncertainties while at the same time defines and agrees on short-term actions for working towards the projected future. Carlisle and Pevzner (2012) propose 'sequential sections' in which multiple sectional cuts express the narrative across space or time. In *Anchoring the Edge* in Mumbai's Maidans the sequel, the section is used to represent specific spatial conditions in each individual section, while the entire progression of section cuts maps flows and relationships.

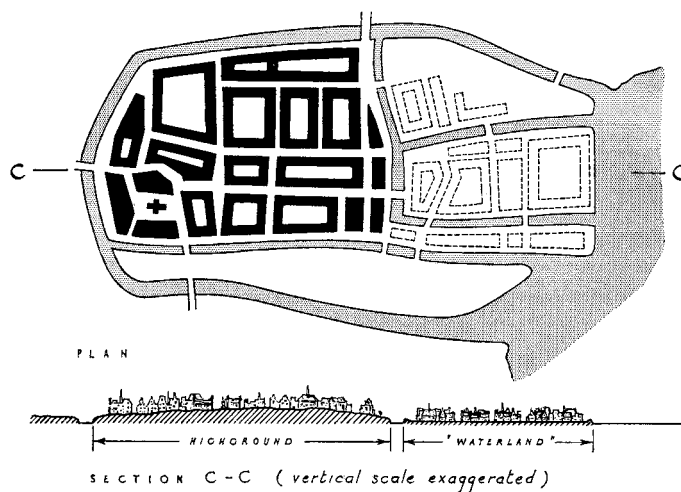


Fig 5.8. Alkmaar in the sixteenth century. Burke, 1956

For water projects in particular, the section not only acts as an interface between strategic planning and tactical design, but also plays a role in the following: confronting of the larger and smaller water systems, of fresh and saline water, of the natural and artificial water systems and of surface and subsurface infrastructure.

The section enables to define the relation between form, performance and the question of flexibility in the planning and design process. Adaptation in time (flexibility) is recognized to be one of the main challenges to plan and design in an era of uncertainty (Bacchin, 2015) thus the concept and the relation between framework (fixed) and content (flexible) becomes crucial. Can we think of ways in which design creates various spatial 'elements', some of them are fixed in time and space and some of them are subject to change, i.e. a sort of designed flexibility? Can we program these relationships in a project?

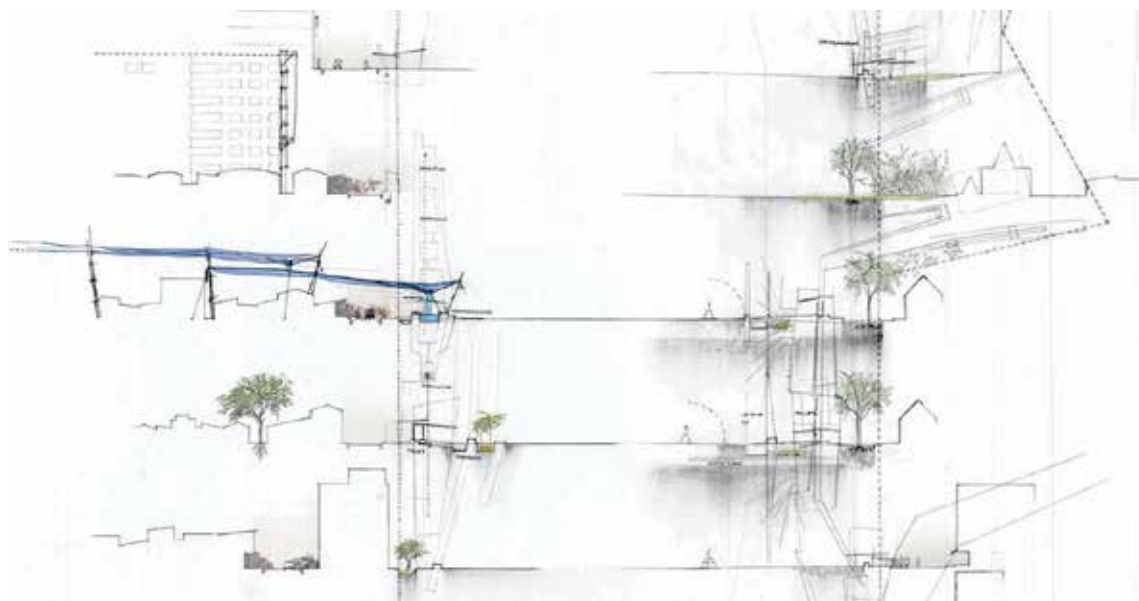


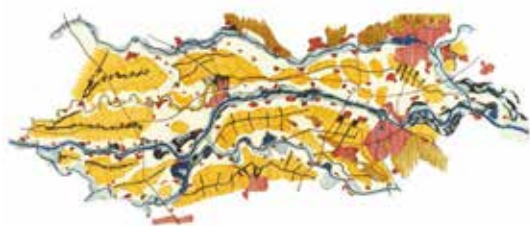
Fig 6.0. Sequential sections through maidan edges, Filter/Collector: Anchoring the Edge in Mumbai's Maidans. Nicholas Pevzner, 2009



## Framework and Content (between performance and flexibility)

The idea of 'framework' in urban-landscape development refers to the creation of infrastructure to structure and manage a landscape or a city varying from road to green structures. An early example of the framework approach can be found in the work of Dirk Sijmons in his 'casco concept' (1991). This concept is an integrated approach in which the landscape is recognized as 'framework' that is thus redesigned as fixed set of elements that can support a flexible urban and landscape development in the long term by accommodating different and emerging programs. The framework coupled with sequencing and phasing strategies becomes the guiding structural and functional factor for transformation and change. Another important contribution to further understand the idea of framework and its relation to the content comes from the work of Professor Han Meyer (TUDelft) on the south west delta in the Netherlands. In some of his work there is clear distinction between the setting and delineation of the framework, as the main spatial structure that sets the main performative scope, and the content, which is seen as a more dynamic element that can change in time according to various contingencies (Meyer, 2015).

The two scenario's designed for Rotterdam-Zuid were made to support such thinking that is connected to the agency of the section. As Franz Ziegler stated: the plan starts with the section (Hooimeijer, LaFleur, 2018). The (horizontal) plans for the scenario's showed the main spatial frameworks, while in the workshops at the municipality various options (content) for the design of these frameworks were brought up for discussion in sections. During the workshop (the options, i.e. content) were shown through sections of various sizes and topographies, entailing different operative strategies and material conditions. The interesting fact lies on the



Casco concept. From: Sijmons 1991

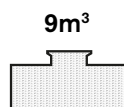
idea that once the performance, at a systematic level, is fixed through a spatial structure (framework), securing safety of water drainage and subsidence (risks), it opens up possibilities for different contents to be decided according to the composition that is preferred. This is exactly what was done in the municipality of Rotterdam, by showing a potential plan (framework) and discussing the various options for the development of the content like functions, building sizes and public space compositions.

An example of this framework or performance – content relation is shown here where the plan of the scenario (framework) is shown together with the alternatives (content) that have been pre – designed for discussion during the workshop. In the next pages the same logic is used to explain the relation between these notions during the workshop in Rotterdam.

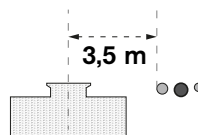


### Principles:

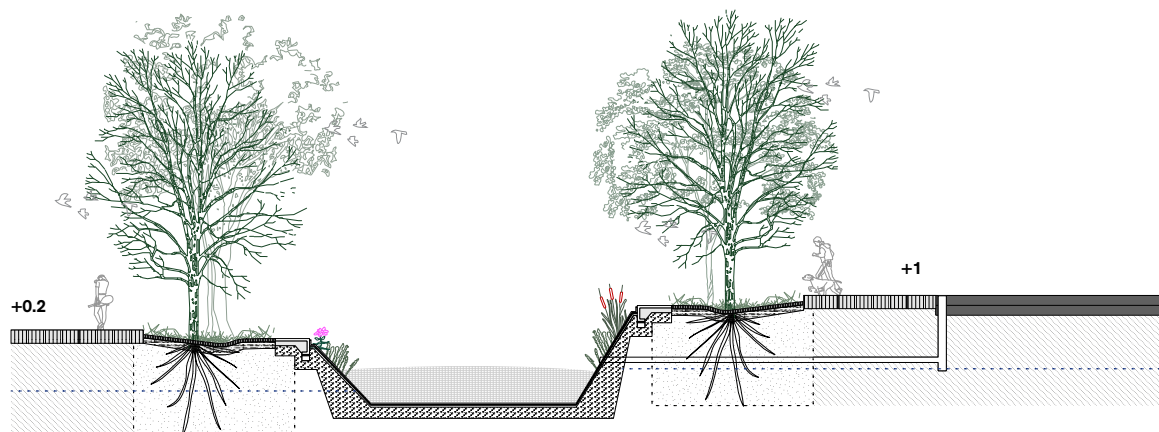
Bioengineering of Subsurface space for surface ecological performance.



Spatial planning and urban and landscape guidelines to avoid conflicts between natural and human systems.



## Polder in polder / Water loop construction detail



## Corridor construction options

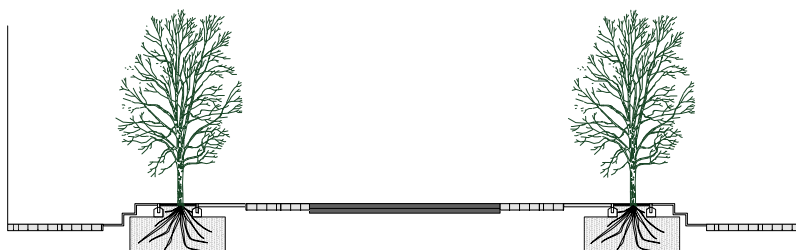
#1



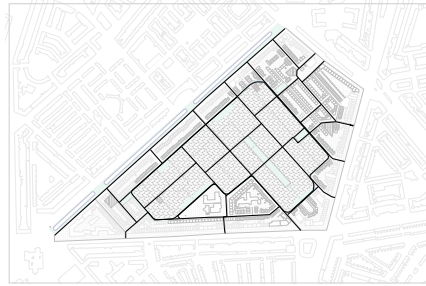
#2



#3



## Framework



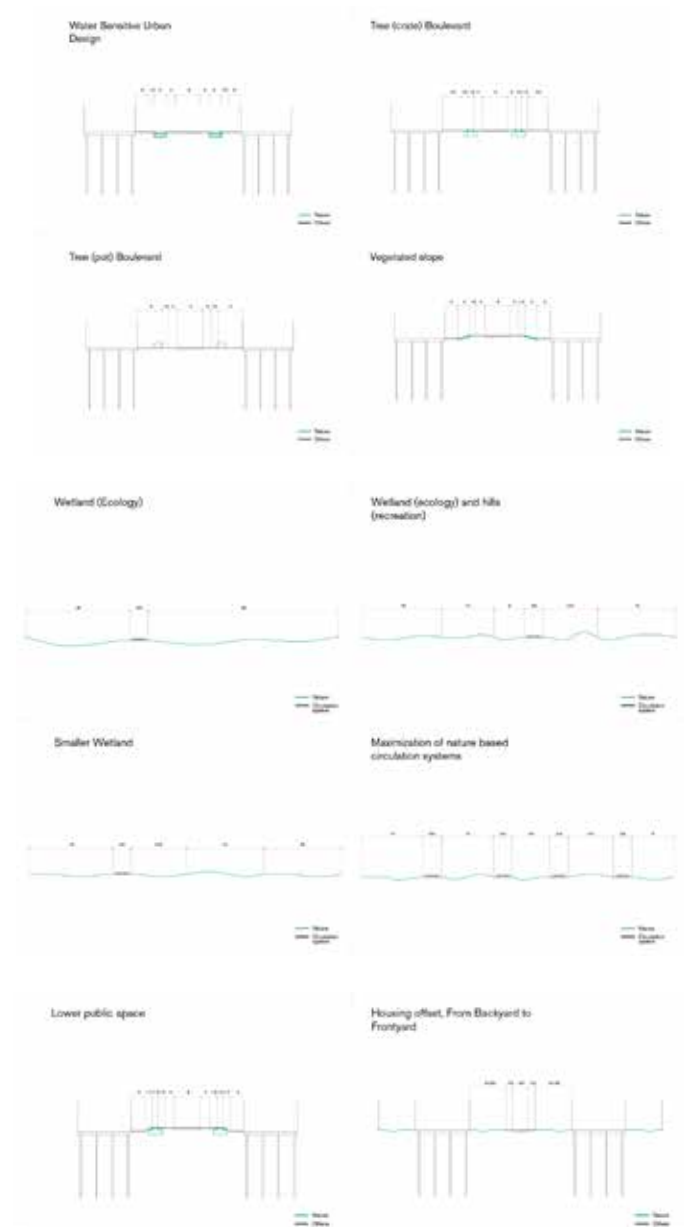
Main and secondary corridors



Ecological corridors

## Content

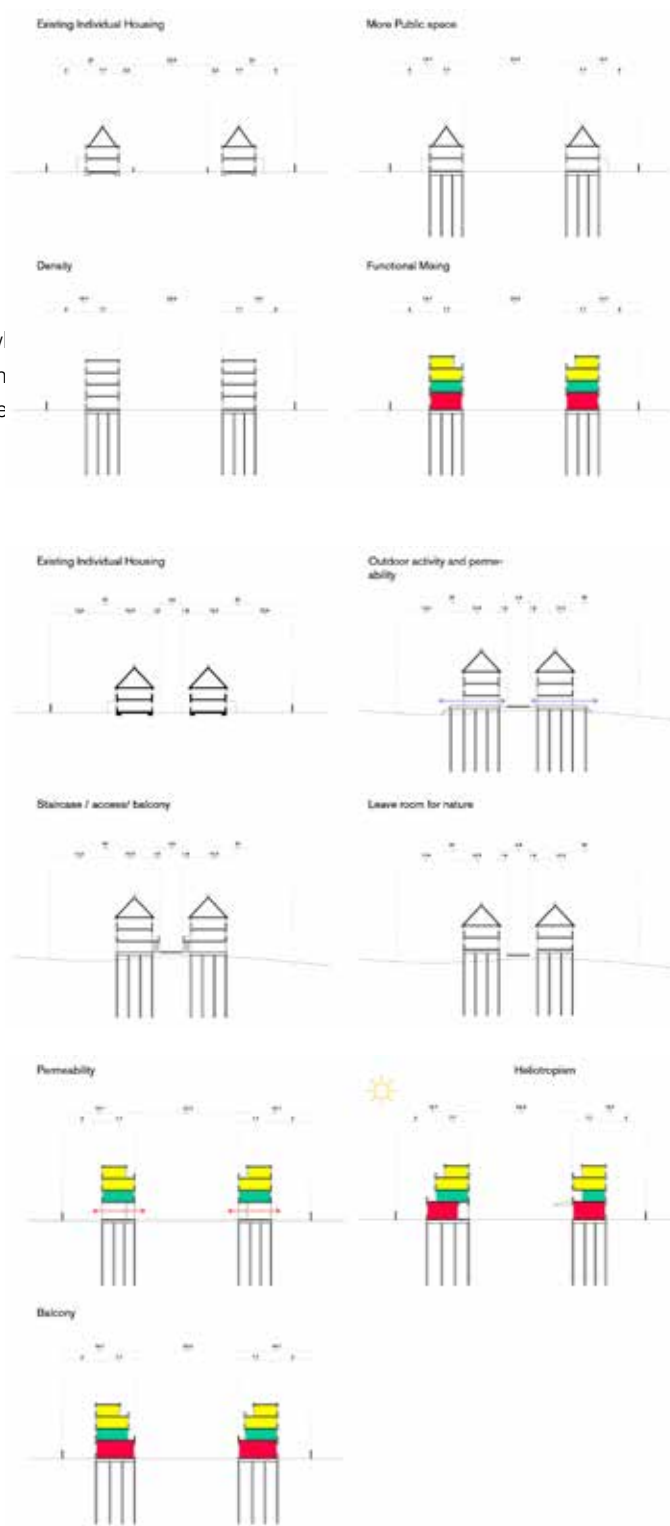
The different zones and lines of the spatial framework have been delineated, yet not designed. In order to design them, without compromising the overall strategic framework, designed options (content) were created to stimulate imagination and implications.



The application of the casco concept, specifically in design as 'process', is shown here in the variety of transformative options (content) that were presented into interdisciplinary workshops.

### Content

The content is shown under the form of a section w configurations: public, private, topographical and fun presented both for street designs, building typologie configurations.



Following this principle, which sets a clear relation between the level of detail and hierarchies in urban-landscape planning and design process, here below this series of visualization related to the master graduation project of Filippo LaFleur (TUDelft, 2016) presents the same line of reasoning. The Landscape Infrastructure Matrix at the strategic scale (framework) and the content (genealogies) are presented. Strategic design of opens spaces is designed through patches (zones) and corridors (linear elements) that define and secure the main objective at a system scale in which environmental performance is achieved through corridors defragmentation and restoration of ecological zones. The ways and degrees of change, are presented through the so –called ‘genealogies’ (figure 6.1.) that are different designed options (content) of specific typologies within the system.

These examples, and the relation between framework and content, show the role of the designer (integrated infrastructure and environment design) within the planning and design process.

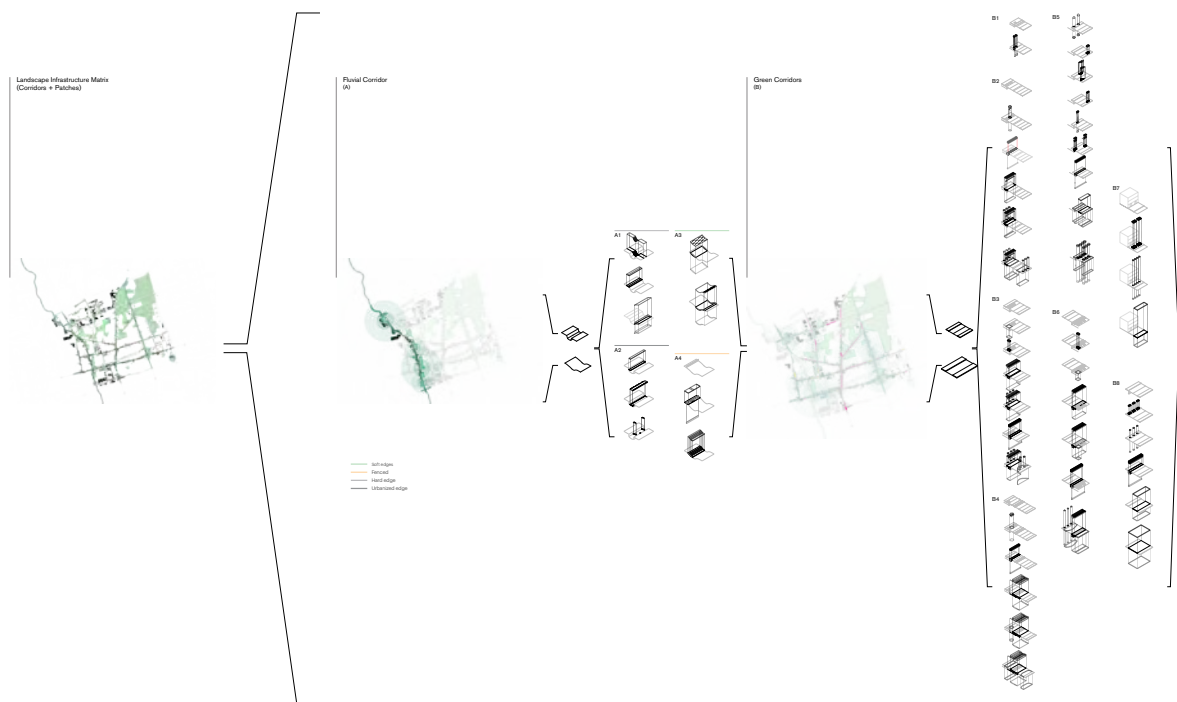


Fig 6.1. Genealogies of change, open ended design options as transformative device for ecological re-integration of urban regions.  
LaFleur, 2016

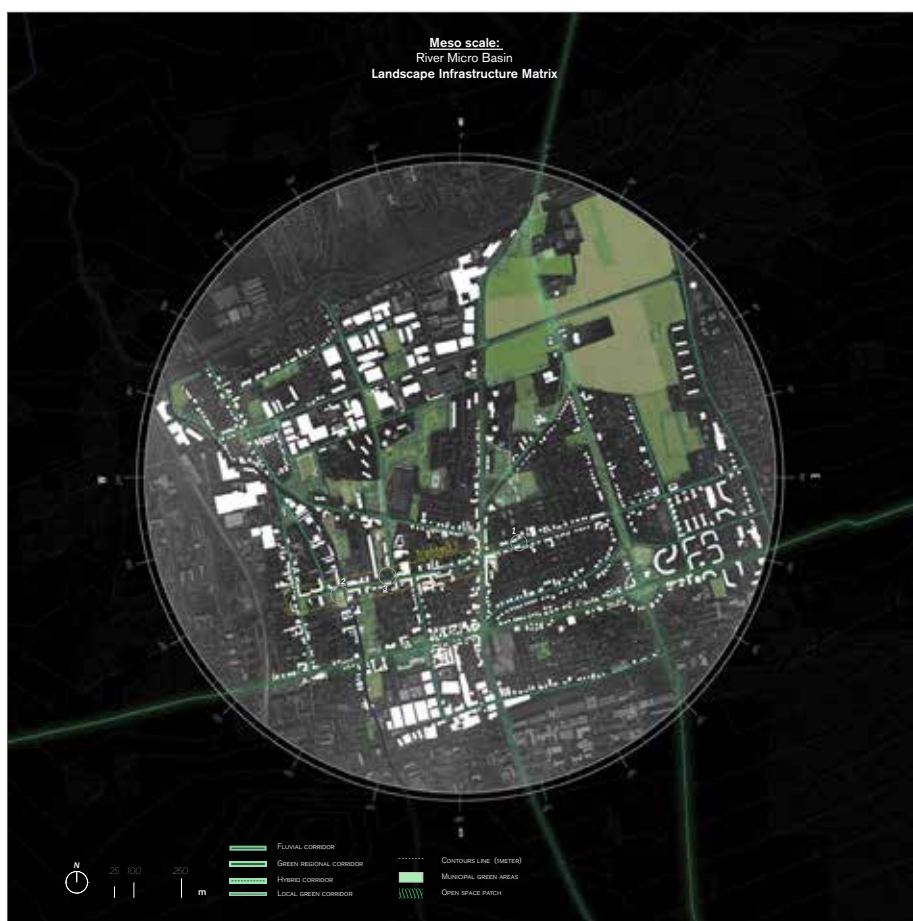
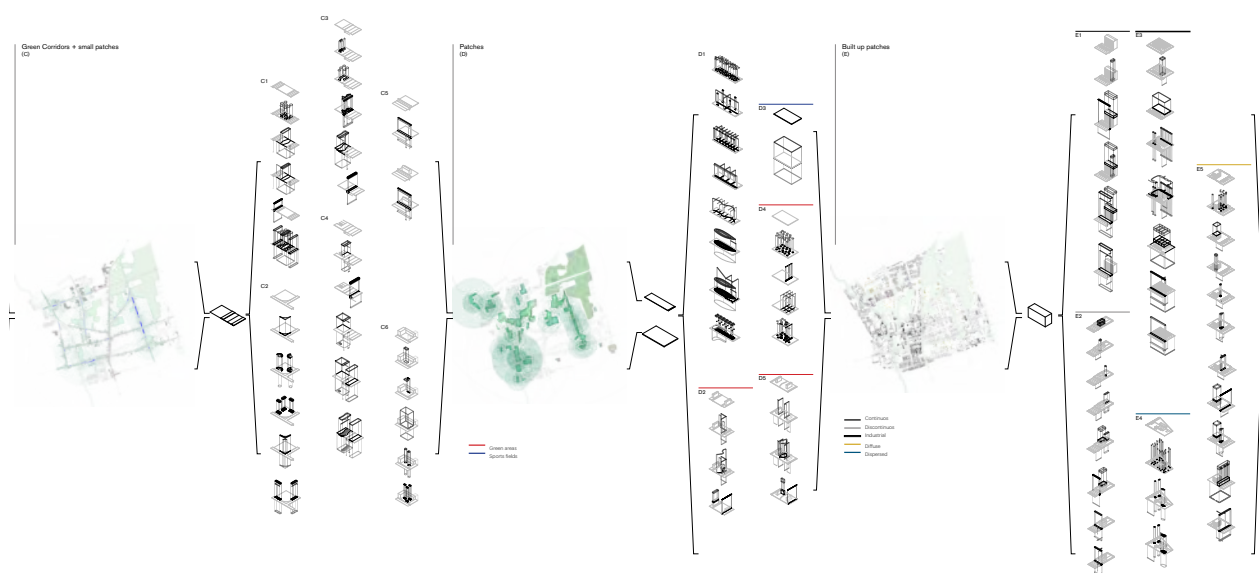


Fig 6.1. Landscape Infrastructure Matrix, corridors and patches.  
LaFleur, 2016



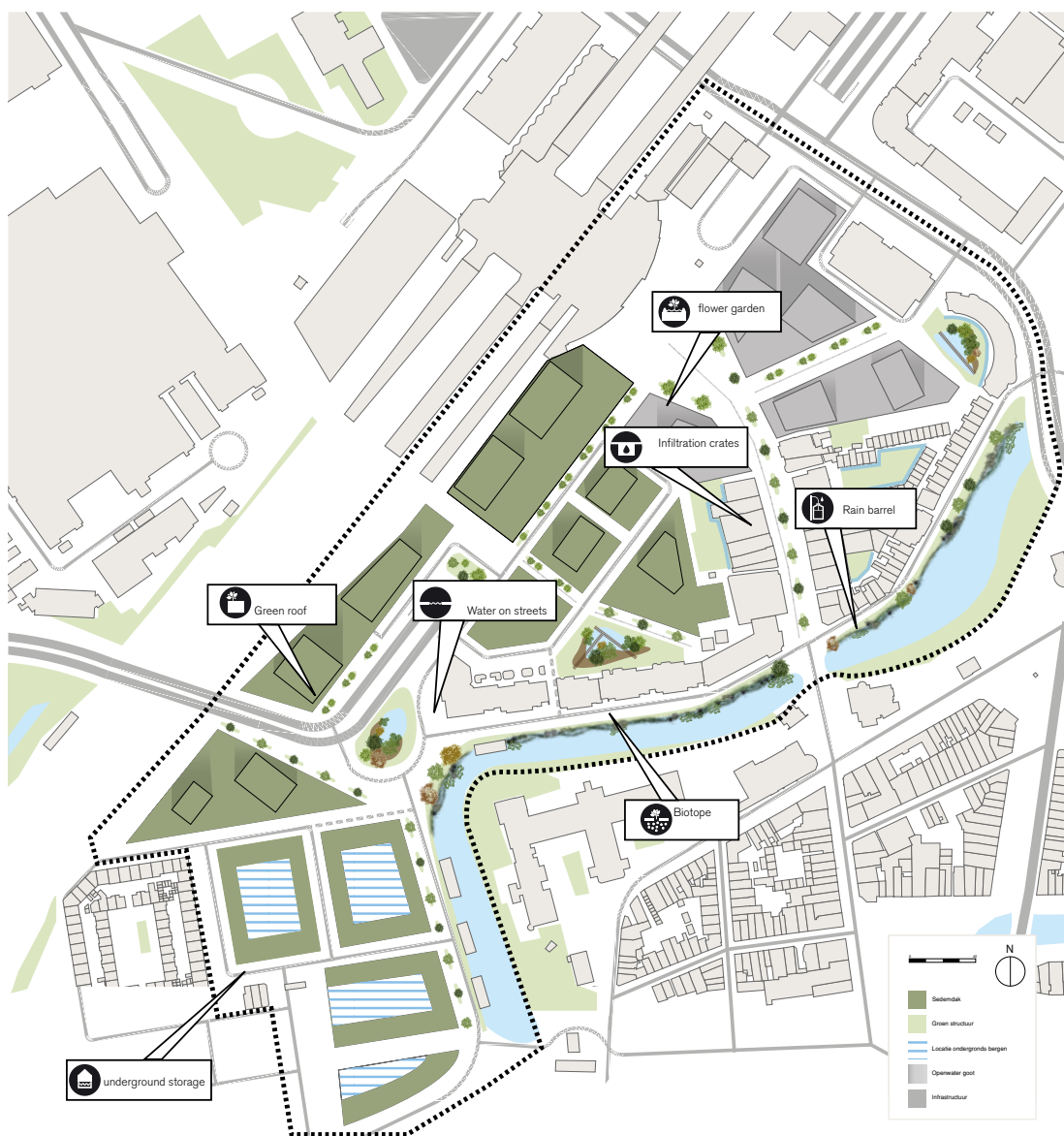


### 4.3 Use of puzzles and projection: Leiden

In the case of Leiden Station, the inventory leading to the technical profile of the area was followed up by a workshop for which a puzzle was developed. In two interdisciplinary groups the participants made choices for a specific composition of puzzle pieces that offered specific result in improving the water system, the ecological value and had certain indication of the costs. The puzzle builds on the preconditions of the water system and aimed at offering solutions that were nature based in order to unload pressure from the sewer without building a separate system. Due to the energy issue in the area, implementing an urban district heating as replacement for the natural gas, it was important to keep the subsurface as empty as possible.

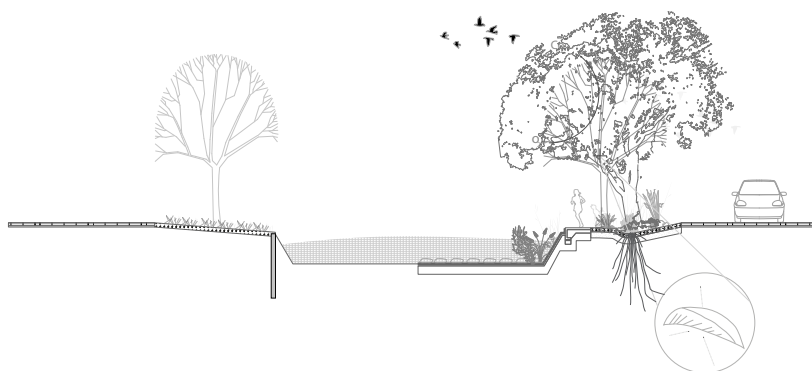
The two groups made quite different choices in how they would tackle the issues: large scale payed by the private developers or small scale in the public space payed by the municipality. The fact that there were quite different choices to accommodate better the climate issues and need for improving the ecological conditions in the area resulted in the acknowledgement by the urban development department that the climate adaptation effects should be implemented better in the current master plan and that there were easy options to improve the ecological structure in the area (Hooimeijer, LaFleur, 2018).

In order to better understand the specific relation between subsurface infrastructure and water management two experimental designs were made for a smaller part of the area, the bus station. Here the issues were either addressed with a multi utility tunnel or a vegetated strip. The main aim was to show how a potential recalibration of human and natural system could be done under an integrated infrastructure and environment (subsurface - surface) design project.



Old situation

New situation



Site plan and section showing strategic green-blue interventions and revised subsurface surface relations

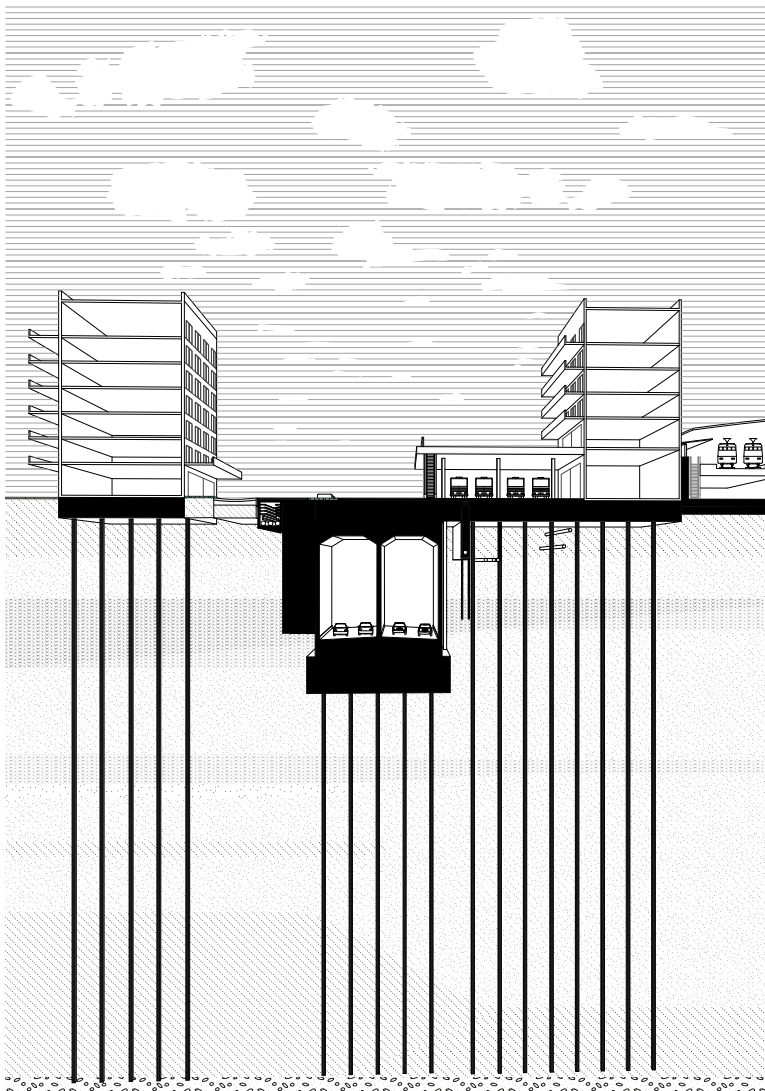
## Drawing Integrated Infrastructure and Environment

After the workshops and the interactions with the specialist at the municipality, in which the main aim was to open up potential way forwards to balance the human and natural system, the second part of the project aimed at visualizing specific possible change taking the drawing of the subsurface and the integration of infrastructure and environment as its main scope.

The image shows the representation of the subsurface and surface of station area in Leiden.

The visualization highlights the fact that half of the city is hidden in the subsurface as constructed ground with utilities that are crucial to the city. It is a hybrid mix

between what is already in place and a projection of a possible alternative for the southern entrance of the Central Station. The visualization shows the alternative option to include in the new building constructed nature on the roofs, to use a Multi Utility Tunnel to make more space for natural soil and draw the sidewalk in the buildings in an arcade to create a new equation in which the natural and human system co-exist with one another.

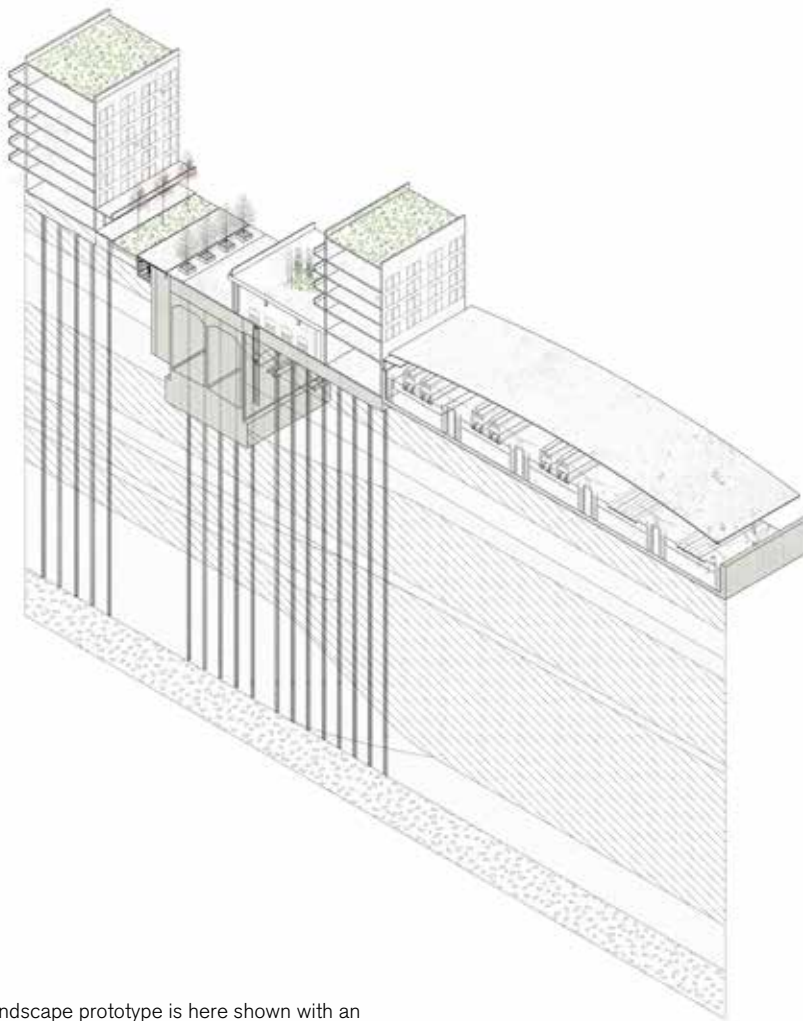


Subsurface (Geology, soil) - Surface section of a proposed recalibration of technological and ecological systems in Leiden station area

The axonometric drawing highlights the distinction between hard and stable surfaces, which permits the development of surface dynamics and the ecology that can be reclaimed in such a dense area.

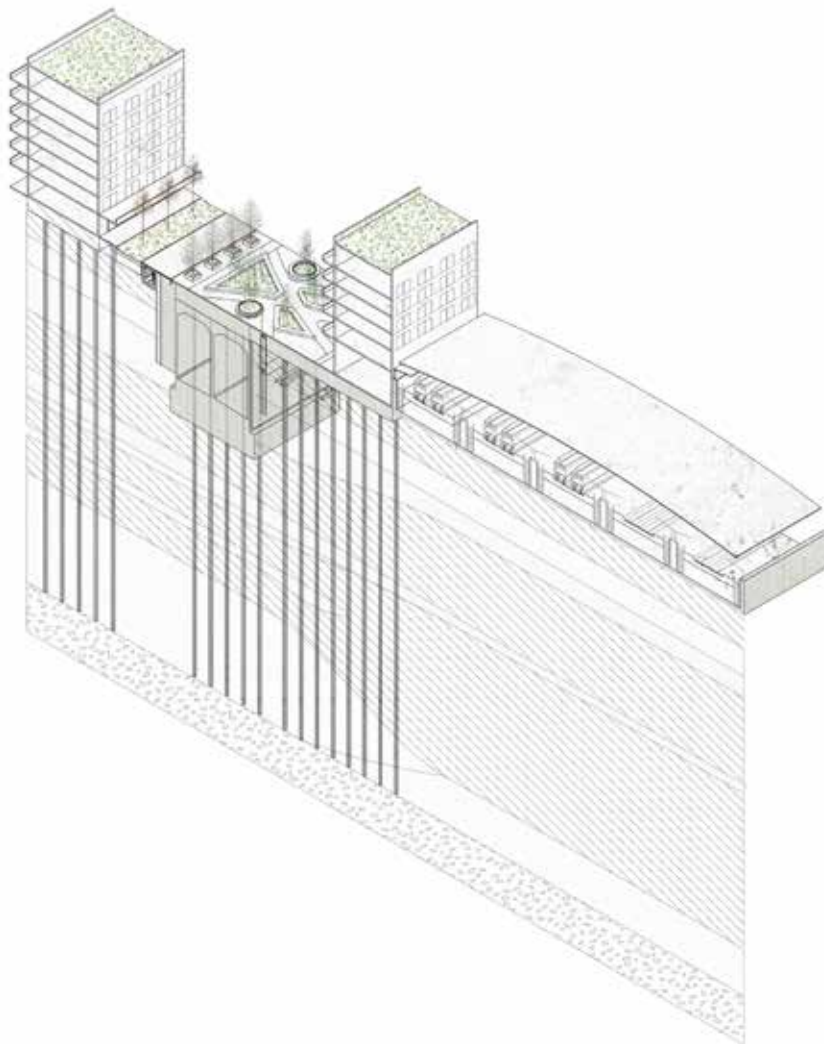
Roofs and constructed platforms can host permeable surfaces and constructed ground to grow vegetation. By offsetting the building on the left and re-uniting cables and pipes into one compact space, an open

soil strip can be projected in front of the building. The ground floor hosts an arcade or a cover in which public life and commercial function can take place, the role of the vegetated strip is to buffer this element with the road traffic and the bus station area. Even in a dense area these measures can support the reclaiming of ecosystem services and the reintroduction of spatial qualities.

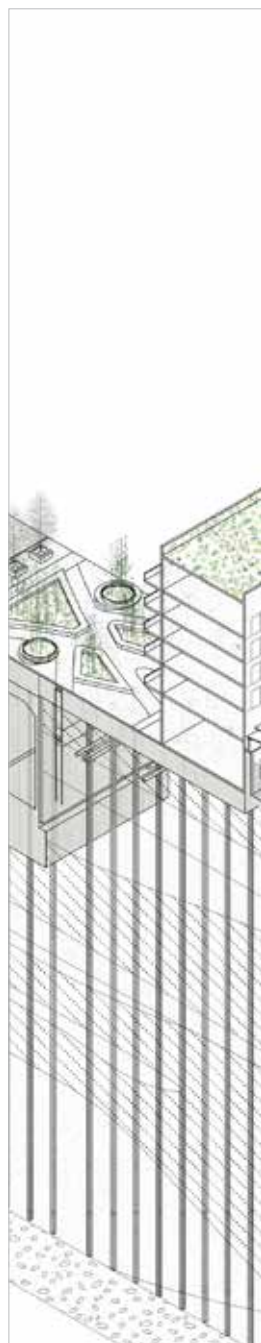
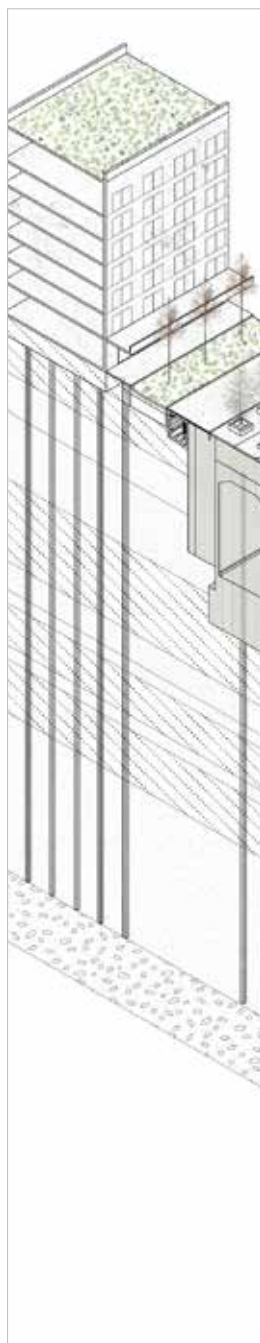


The urban landscape prototype is here shown with an integration of different domains: ecology, engineering and design

Two options were worked out for the area, the main difference is the transfer of the bus station to the other side of the railway track in one projection. In this case a public space, which carefully balances ecological zones and circulation should be designed. Anyhow even if the bus station remains in site, the drawing shows a possibility to integrate infrastructure and environment through vertical strategies of co-existence.



The urban landscape prototype is here shown with an integration of different domains: ecology, engineering and design. Specifically, the second option shows how the integration of cables and pipes in a unique space the MUT (Multi Utility Tunnel) allows for a flexible public space design where ecological re-intensification and vegetation is the main objective. On the right page the options are visualized next to each other.





## Designs

The designs speculate on a remaining or possible move of the bus station to the north side of the railway station. It provides new public space, composed of constructed nature and accessible public space that could enhance both the ecology and the public use of the area.

The area consists foremost of hard constructed ground and there is a little soft space of constructed nature and vegetation resulting into a poor quality public space with consequently problems of pluvial flooding and heat stress.

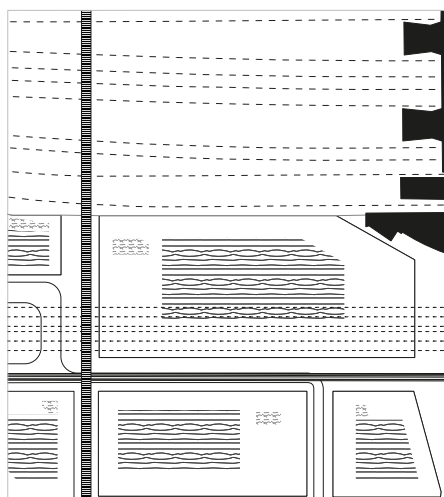
This sequence of drawing shows the possible different configurations for Leiden Station Area. Some strategies and operations remain the same for both designs, while others change according to the position and construction of the bus station.

After the spatial exploration of Stationplein by two extreme designs, the rules for buildings were visualized

in a Technical Projection. In this drawing, the amount of water that needs to be stored on the lot and the percentage of open soil were indicated for the various lots to reach an over all working water management system. This drawing indicates that the buildings occupy 50% of the area and they must realize the ratio of 35% open soil and 15% water.

No spatial choice has been made here, for example the open soil can be realized in the building, around the building or on the building. The assignment lies with the developer but can be completed in consultation with the municipality in relation to the public space. For example, by including an arcade in the building that can function as a public space will enable to realise more green space.

The following page, on the right, different sections of the ground as siteplans at different heights, aim at showing the synchronicity between artificial and natural elements. Thus, by sectioning the site at different depths, the drawings shed light on the mutual symbiosis between elements and the inseparability between the plan and the section. The visualizations reinforce and at the same time show once more the idea that for the development of integrated infrastructure and environment design the reconciliation between the horizontal and the vertical dimension is crucial.

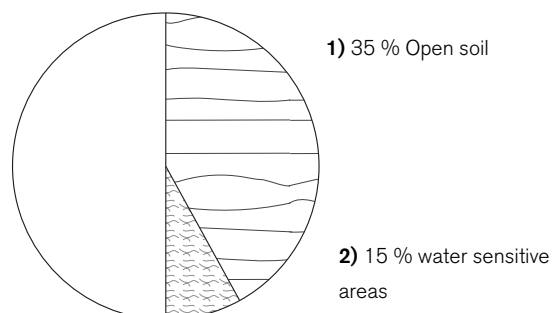


2 Metres for MUT

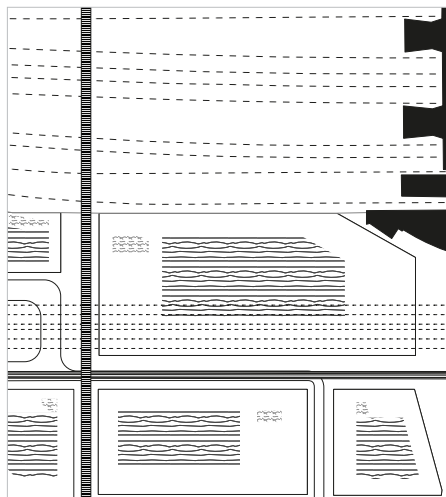
### Legend

	Open Soil
	Water sensitive areas
	Soil
	Low - middle vegetation
	Middle - high vegetation

### Allotment rules future development

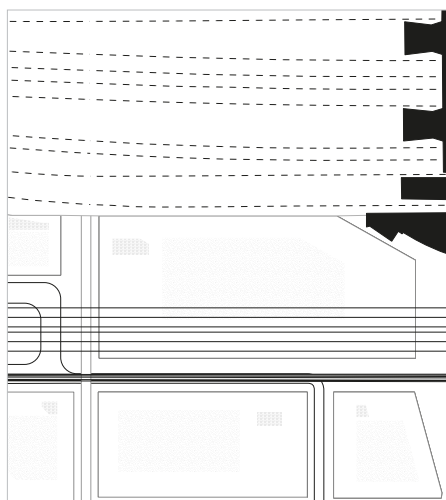


Projection of the different rules for the construction of new technological and ecological systems.



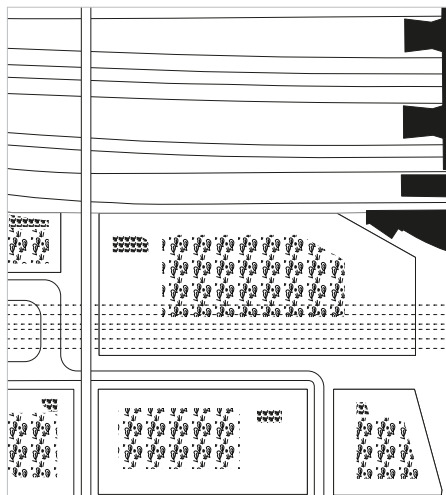
+ 0 Ground level rules for buildings

- 1) Open soil
- 2) Water retention



- 1.5 Rules for underground development

- 1) Clay
- 2) Constructed ground



+1.5 rules for buildings

- 1) Middle - high vegetation
- 2) Low-middle vegetation

#### 4.4 Use of script

As a final step in the collaboration with the municipality of Rotterdam and the housing corporation Woonstad spatial scripts were developed in order to show potential spatial configuration and prototypes following integrated infrastructure and environment design principles.

The idea of script, like in movies or plays, refers to a set of interlocking variables (in this case technologies, spatial strategies, hypothetical trends etc..) that support and generate a possible project. Moreover, this concept entails a temporal dimension of the design and the ways in which seemingly unrelated fields, layers and elements merge.

The translation of this idea to the field of architecture and spatial design has been already explored. Specifically, in the work of Bernard Tschumi, *The Manhattan Scripts* (1981) where the architect developed a sequence of scripted spaces which shows the ever-changing relation between space and event (picture). Furthermore, the script and how is it used also influenced by the concept of 'tabula scripta' by Floris Alkemade (2014) and 'Field' by James Corner (1999). Both of them are instrumental in understanding space and place as a palimpsest of endogenous and exogenous variables, in which the project is grafted. Rather than thinking of the possibility for the future of a site, the script takes into consideration the actual biotic, abiotic and cultural condition of the place with the aim to couple it with innovative forms of urban landscape development. This approach also reflects on the idea of minimum transformations (entropy) and capitalization of existing potentials (natural capital). In this way design gains almost a choreographic agency for its capacity of guiding several spatial and non-spatial elements of subtraction, permanence and addition.

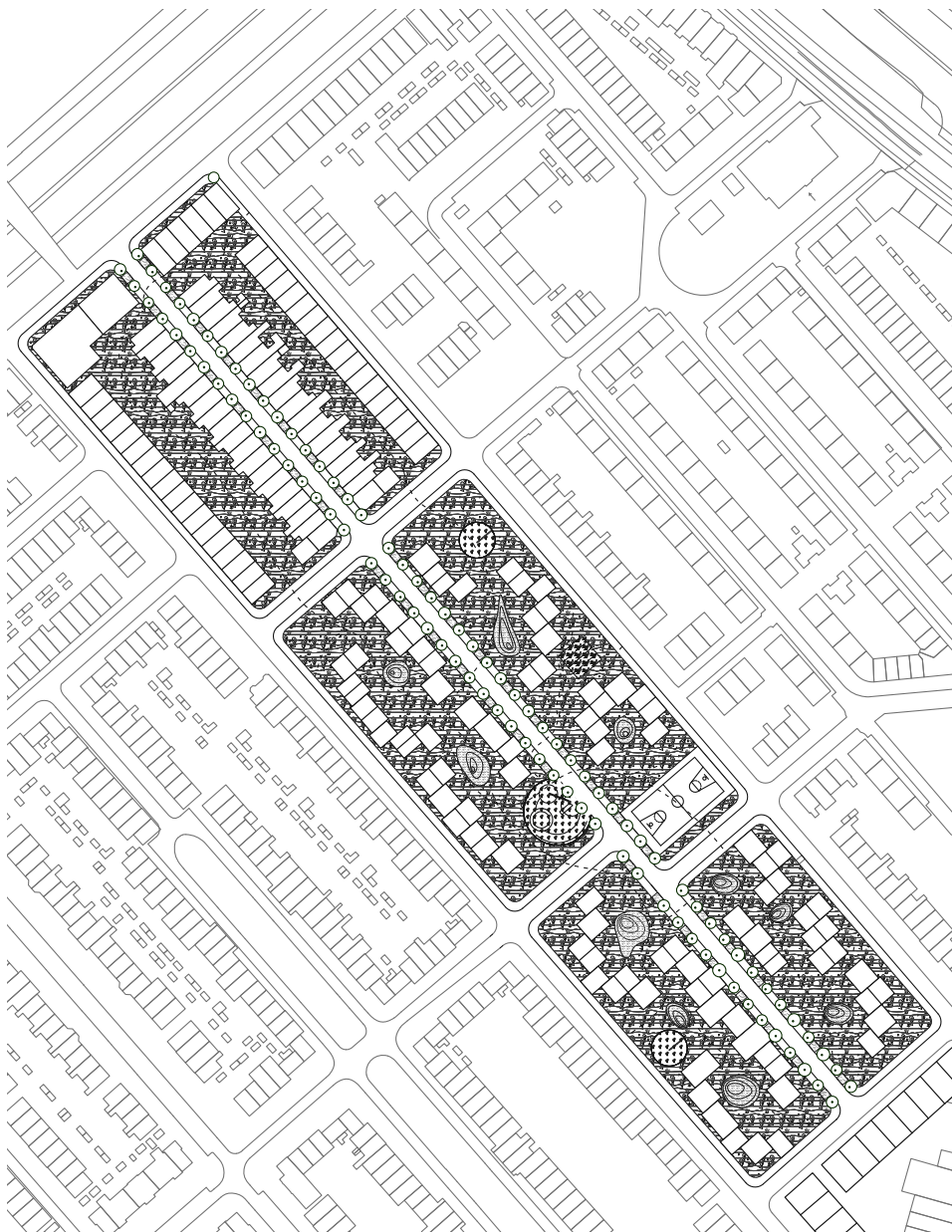
The script is delivered as a set of choices made, from a spatial, technological and legal perspective. The general set of variables for both scripts are:

- subsidence;
- raising groundwater level, wet public space;
- water nuisance in housing with slab foundations (health risks);
- renewal of subsurface infrastructure;
- connections sewer system;
- relation between the boards that are elevated on a dike and have wooden pile foundations;
- changing from natural gas for heating to other sources (electric or district heating);
- poor public space qualities;
- changing backyard space.

### Script 1: Design of the urban ecosystem aimed at co-existence

The specific set of variables

- Acceptance of subsidence by building new waterproof housing on slab foundation;
- Subsidence is managed by reduction through higher ground water tables, less maintenance on cables and pipes;
- Creation of a wet landscape that could retain and store water locally;
- Streets profiles in sphere shape to direct the water toward surrounding landscape (in the case of exceedance the runoff is redirected to the sewer system);
- All Electric energy supply;
- Organic waste is used for fertilization;
- New materials are used, both organic and inorganic;
- Collective green and gardens.



Site plan of the urban ecosystem aimed at co-existenc.

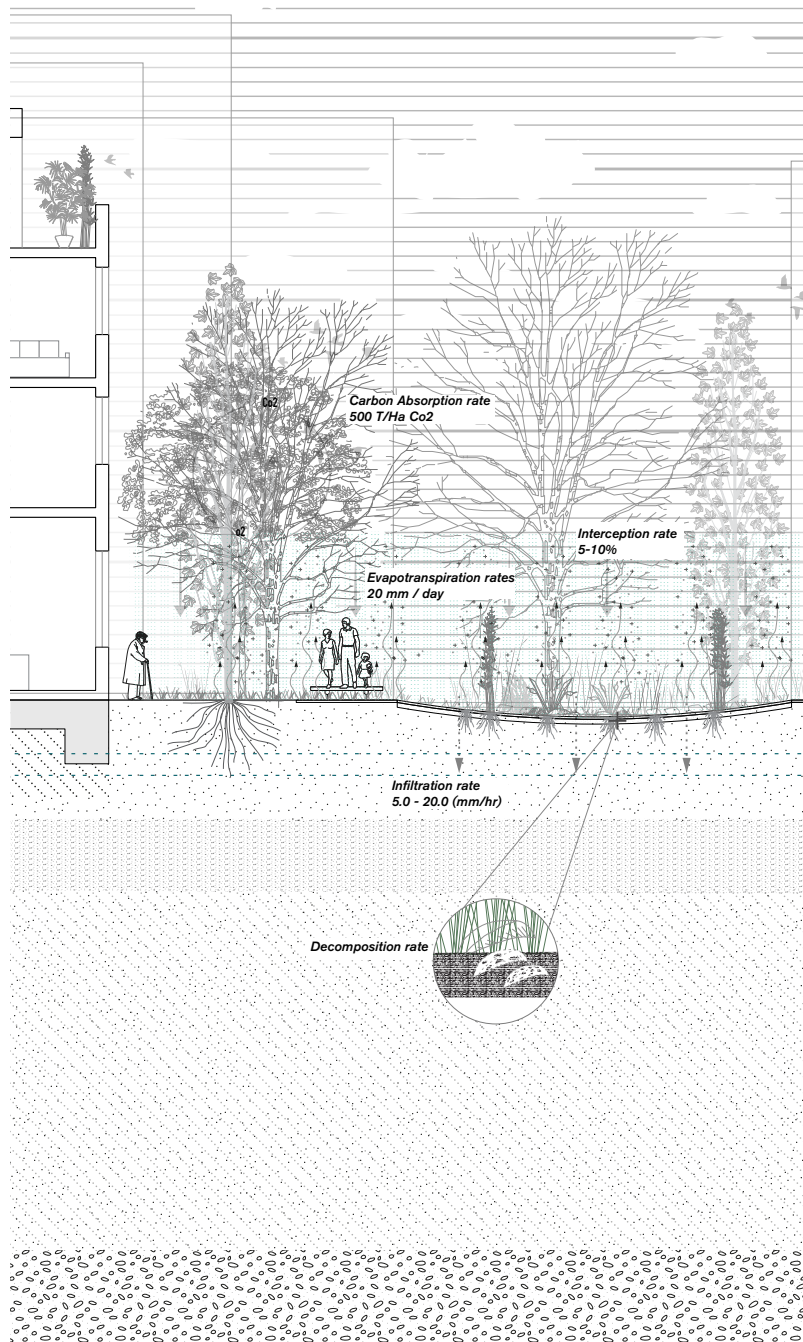
## Design Prototype of Integrated Infrastructure and Environment design.

The design of the infrastructure integrates the biotic factors (everything that lives) and the abiotic factors such as the lithosphere (soil) hydrosphere (water) and atmosphere (air). Integration is achieved by linking the cycles: the carbon cycle, the nitrogen cycle and the water cycle. The role of soil is mainly the weathering and rinsing of sediments (the deposition). The biotic factors such as plants and animals provide decomposing organic material and other by-products that is mixed in the soil with rainwater, benthos and micro-organisms.

Chemical processes nitrification and the ammonification play an important role in the new maintenance regime. Nitrification is the biological oxidation from ammonium to nitrite followed by the oxidation of this nitrite to nitrate. Nitrification is an important step in the nitrogen cycle of ecosystems, in which the dead organic material captures nitrogen that is then again available for the living plants. Ammonification is the decay process or mineralization in which ammonia is released that can be used as fertilizer but can also be nitrified again (Stefanakis et al., 2014).



Urban Landscape Prototype: by drawing subsurface-surface details, vegetation and potential 'scenes', the section shows the integration of multiple disciplinary fields into one single socio-technical-ecological space.



The section is here used to overlay intangible process related to the carbon, nitrogen and water cycle in relation to the designed prototype.



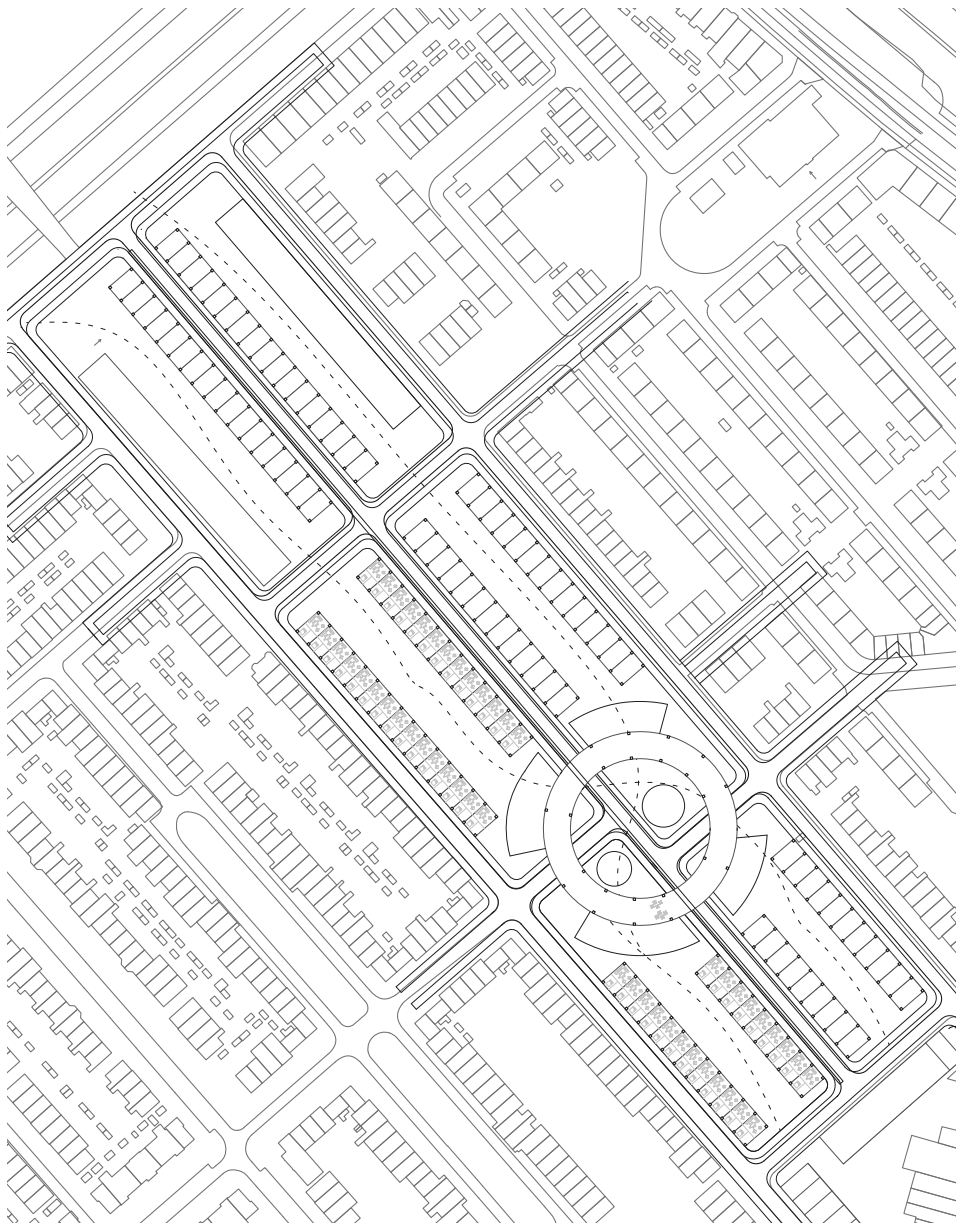
The visualization shows the new spatial qualities created by the scenario. It focuses on the transition between the private houses and the shared gardens where a new constructed nature is the main visual element.



## Script 2: Design of a dynamic urban landscape

The specific set of variables:

- Acceptance of subsidence by building new buildings on piles;
- Subsidence is managed by reduction through higher ground water tables;
- Connect underground infrastructure to building with using a MUT;
- Creation of a wet landscape that could retain and store water locally;
- Streets hollow instead of sphere for more water storage;
- All Electric energy supply;
- New materials are used, both organic and inorganic;
- Organic waste is used for fertilization;
- Semi collective green and gardens;
- Blue - green structure for water management.



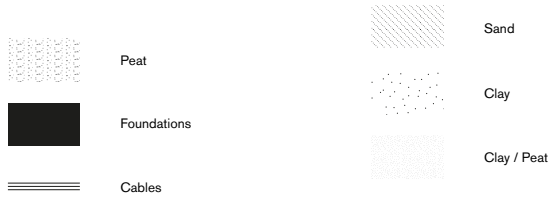
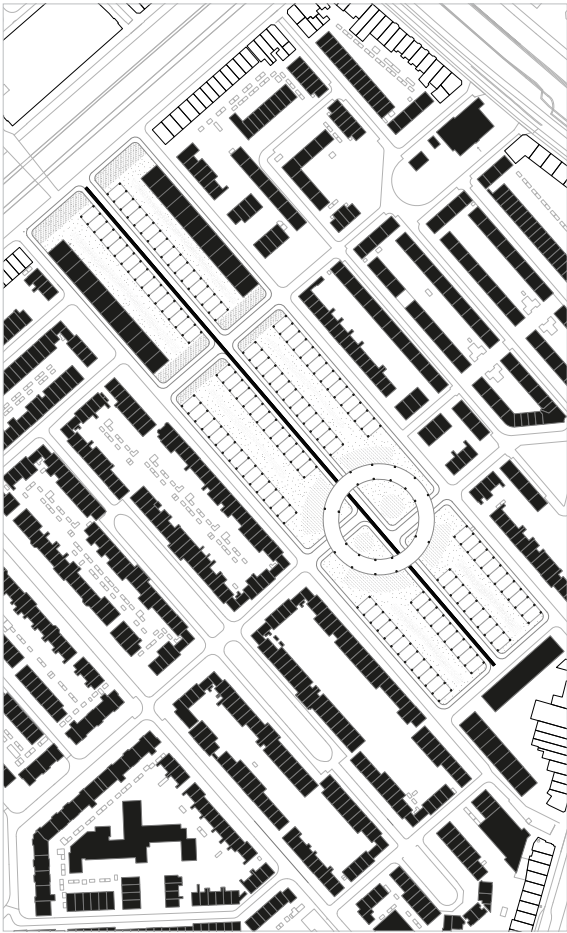
Site plan of the dynamic urban landscape

Sectioning surface and subsurface; Integrated strategies and reciprocities

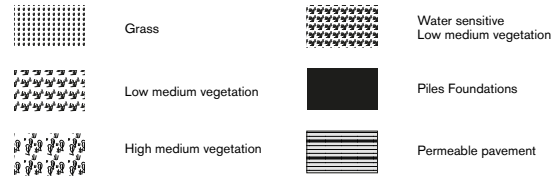
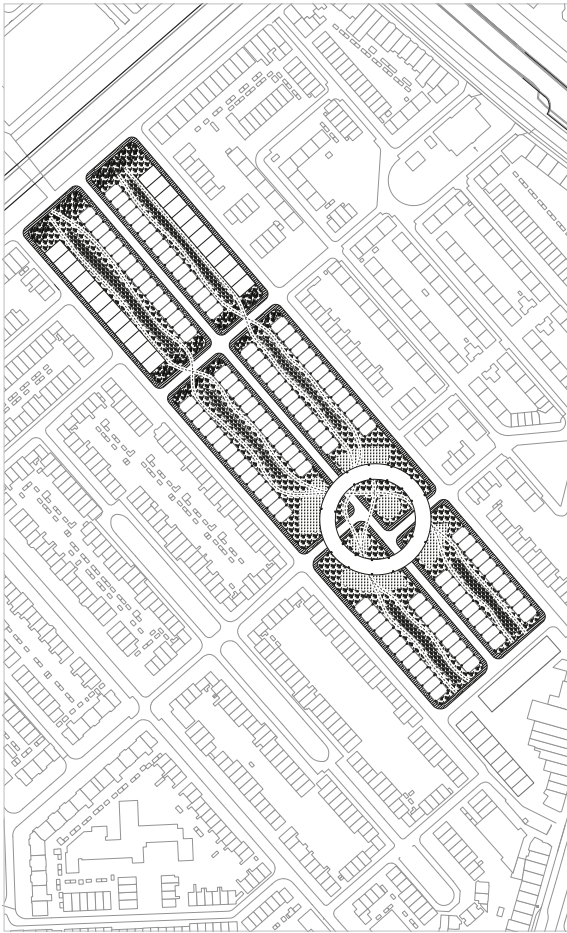
The three drawings here below explain in detail the environmental quality of the open space. Contra to the 'integral filling' or 'sand addition' paradigm, the provocative scenario foresees the implementation of deltaic soil dynamics, where organic soil, high groundwater table and the vegetation that they support, co-exist. These environmental dynamics are visualized in the section at page 92, which clearly shows the interrelations between soil, high groundwater table and the vegetation patterns. Through visualization the co-

existence can be highlighted and the idea of integrated infrastructure and environment design where air-land-water dynamics are thought as one reinforced space.

The integrated approach to the design of urban systems is characterized by synergy and co-design between the fields of civil constructions, hydrological and ecological design-engineering. This process supports the overall knowledge integration needed to generate and underpin the hybridity of the system.



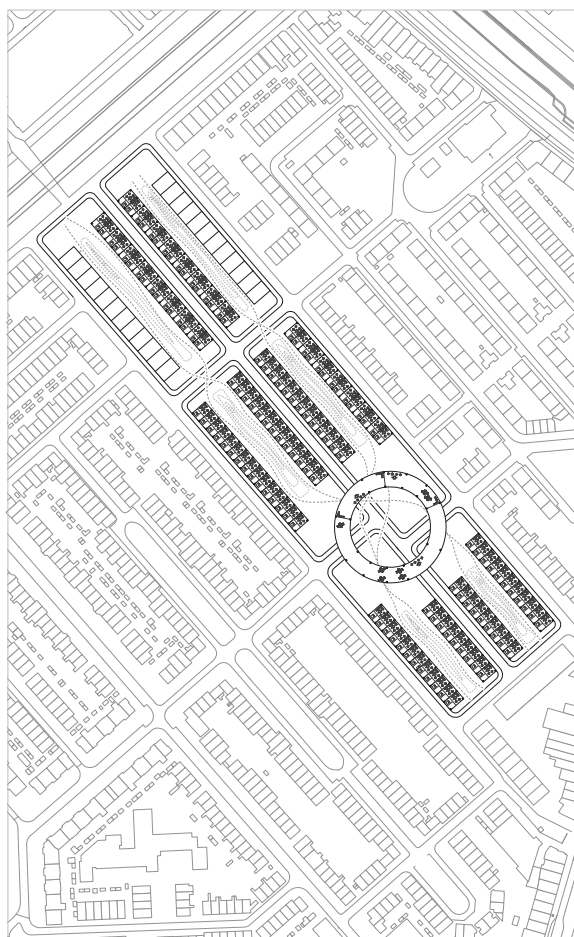
Site plan of the dynamic urban landscape, ground sectioned at - 0.5 meters



Site plan of the dynamic urban landscape, ground sectioned at + 0.2 meters

The approach is based on symbiosis, diversity and temporal design in contrast to consider the natural and artificial elements as separate and strive for total control. This new method of building site preparation does not focus on changing the natural soil structure but the return of the native indigenous ecosystems. This will create a new maintenance regime that re-introduces open soil as the storage of CO<sub>2</sub>, natural fertilization by falling leaves, accept a more moisture public space to promote bio-geo-chemical processes and reduce soil

subsidence. In fact, the organic process are offering a new engineering approach. In this sense the temporal dimension of landscape strategies becomes the main infrastructure that support 'live matter' processes as a way to deliver values in a different way (multiple benefits). When sectioning the surface and subsurface at different heights, the complexities of 'deep urbanism', are revealed in a simbiotic way. Rather than separated fields of interventions, the different domains are taken as an opportunity to reveal each others potential.



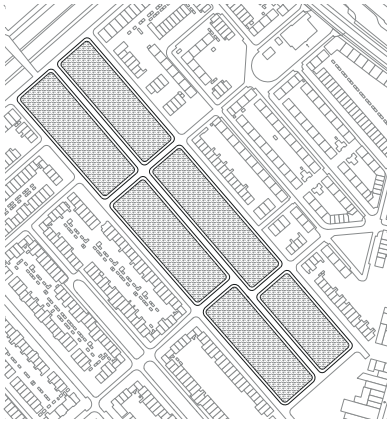
Piles Foundations

Site plan of the dynamic urban landscape, ground sectioned at + 2.5 meters



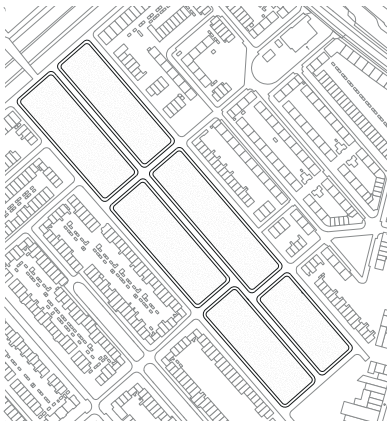
# Environmental performance

## Groundwater recharge zone

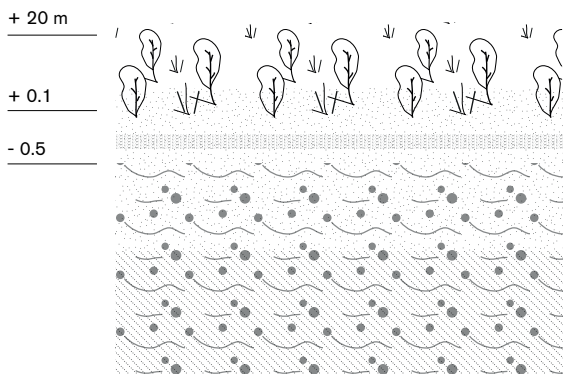


The three drawings on the left explain more in detail the environments that the plan generate. Through the section, the representation clearly shows the interrelations between groundwater, soil moisture and vegetation patterns. Eventually, it highlights and reinforces the idea of integrated infrastructure and environment design where air-land-water dynamics together with the technological apparatus are thought as one unique space.

## Soil moisture and quality



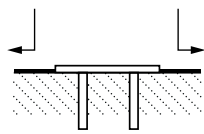
## Section



## Temporal strategies:

T1

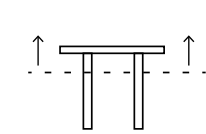
Present



- Runoff
- Imported soil

T2

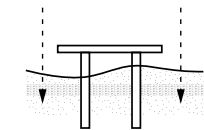
Operation



- Elevation of structure
- Replacement of soil

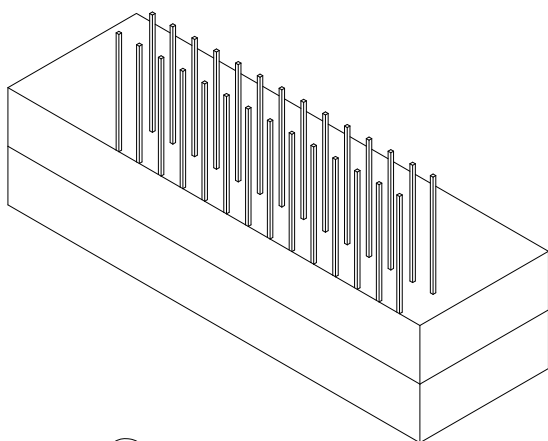
T3

New performative condition



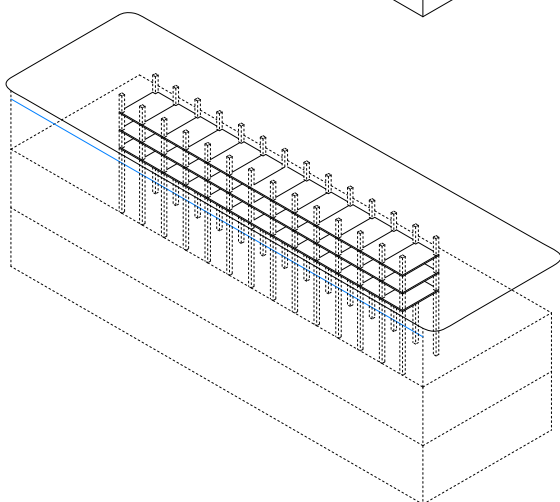
- Freeing the ground
- Soil performance

Strategies in time:

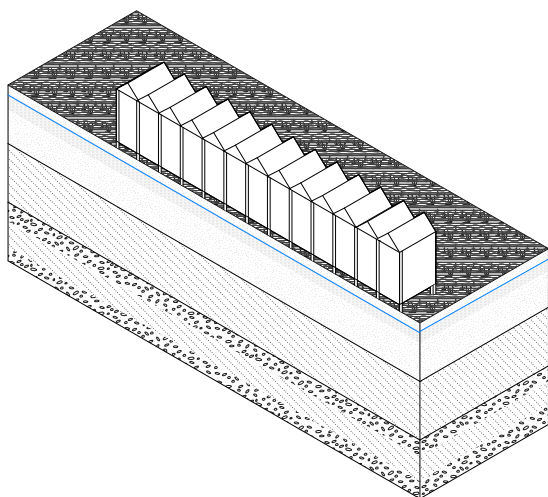


Fixed elements, low dynamics.

The urbanization of the sand layer can be seen as an occupation strategy which is somehow 'geological', a temporal and geographical strategy, thus recalling the question of time and co-existence for its scope.



Multi Storey building composition is consequently added.



Geological layers, sand, fine sand, clay and peat. Surface programming of open space (low-medium - high vegetation as low maintenance performative ground) and ground relief to free occupation for an otherwise inhospitable ground conditions.



## Design Prototype of Integrated Infrastructure and Environment design.

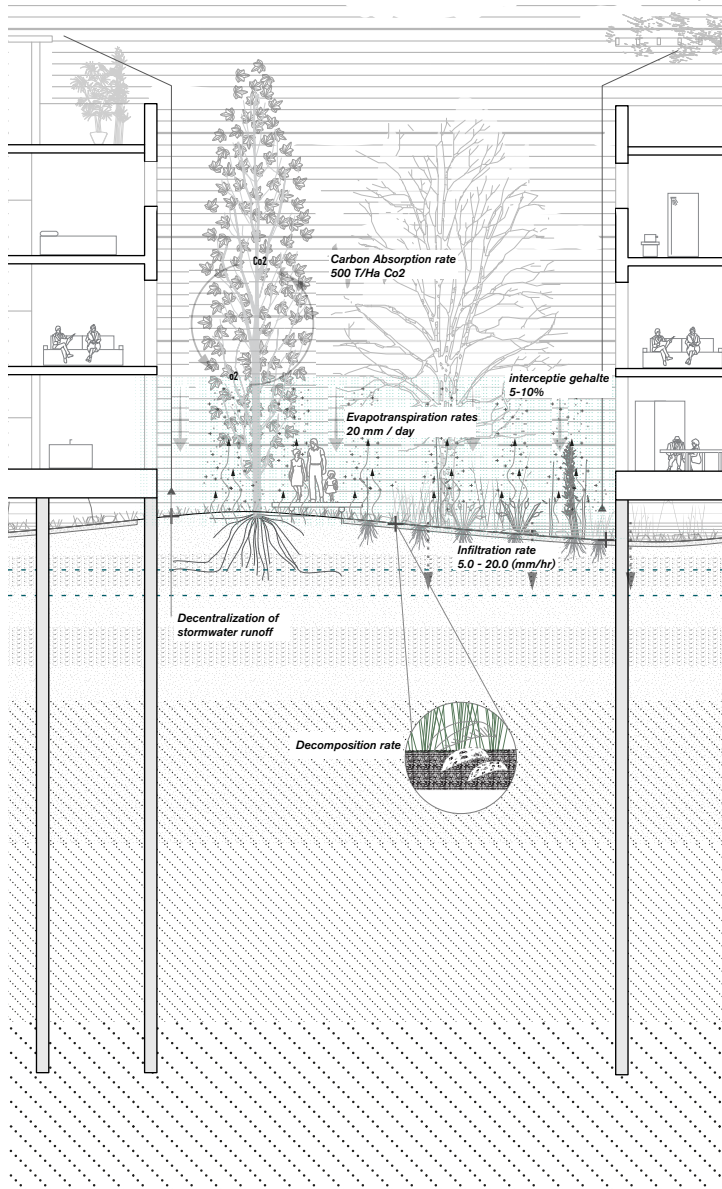
This example of integrated infrastructure design shows how geo and hydraulic engineering, urban and landscape design are blend together into a single socio-technical - ecological space. It aims at finding an equilibrium of natural and socio-technical systems in which symbiosis, diversity and contingency replace separation and control as design principles. In dealing with the new paradigm of maintenance, vegetative surface strategies are enforced to create a new regime where open soil accelerates carbon absorption and

organic matter production.

Additionally, it influences soil moisture and quality to generate a series of mechanisms in subsurface processes where exchanges and biological dynamics act as the new engineering. Water management is rethought in relation to the landscape, as a soft and on site strategy of wetness; where the interrelationships of biogeochemical cycles of 'air, land and water' interaction is reclaimed and designed.



Urban landscape prototype: By drawing subsurface-surface details, vegetation and potential 'scenes', the section shows the integration of multiple disciplinary fields into one single socio-technical-ecological space.

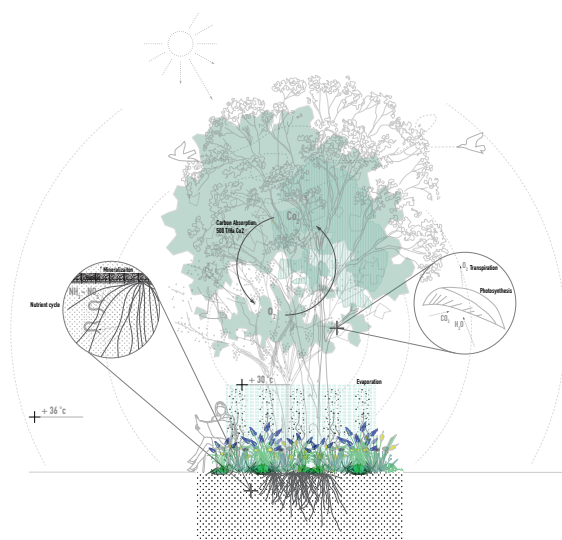


The section is here used to overlay intangible process related to the carbon, nitrogen and water cycle in relation to the designed prototype.

The visualization shows the new spatial qualities created by the scenario. It focuses on the transition of space to connect the hard and stable elements of urbanization with the soft and dynamic constructed ecology.

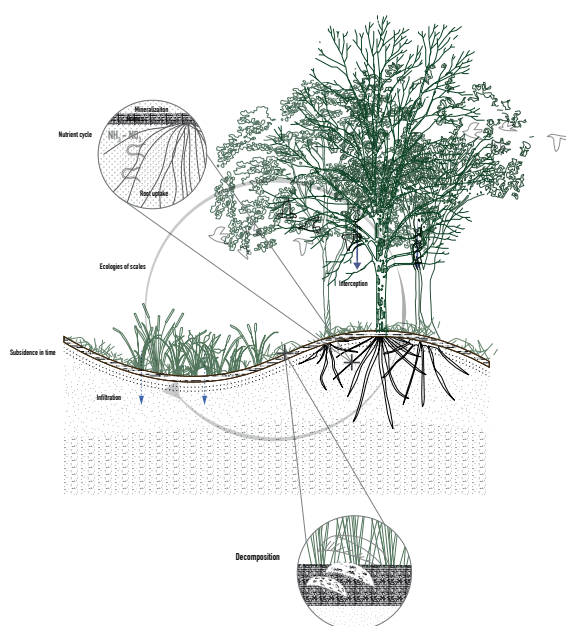


The visualization shows a set of ecosystem services and environmental processes as a result of the proposed scenarios.



The image shows synthetically and visually a set of intangible services provided by the newly constructed natural capital. Specifically, it reflects on the microclimatic benefits of such systems by projecting and speculating on possible climatic differences and biophysical temporalities, such as shade and evapotranspiration.

Drawing by Filippo Lafleur, In Re-Territorialization, A vision for Milan Urban Region, 2016



The image shows the idea of low maintenance landscapes as a strategy of time and financial management, with the consequent environmental and spatial outcomes.

Drawing by Filippo Lafleur, In Re-Territorialization, A vision for Milan Urban Region, 2016

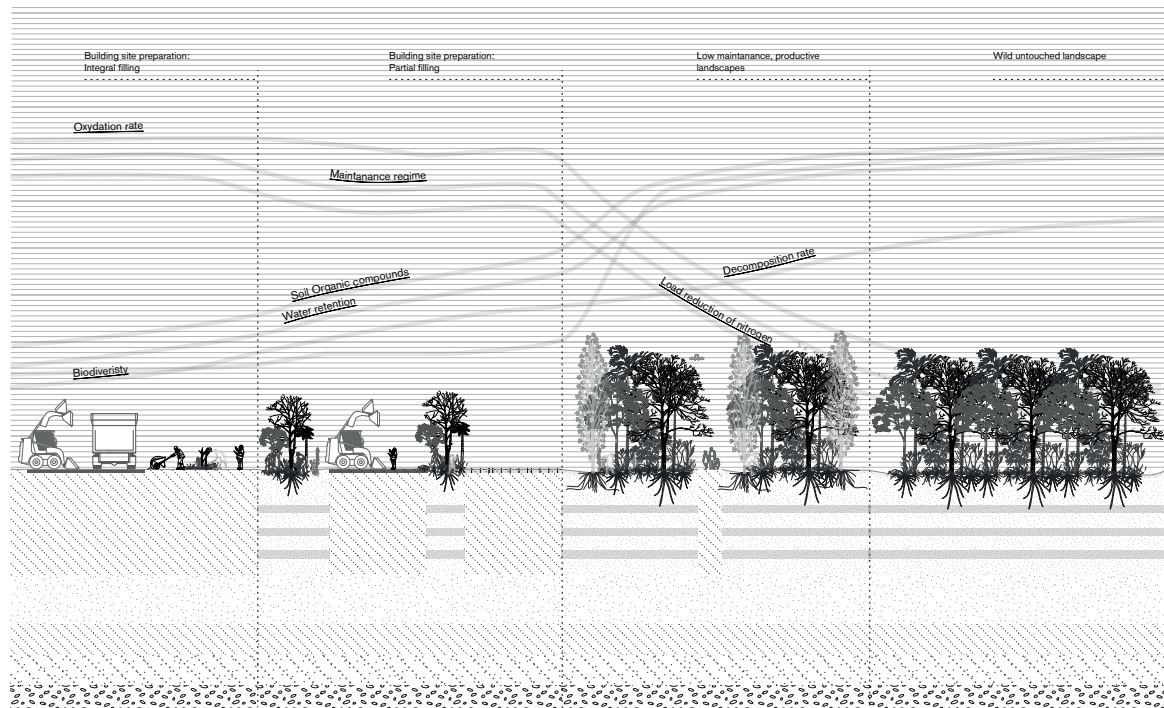
## 4.5 Gradients of maintenance

*"I am interested in landscapes as flux and change – in cycles of erosion and deposition, construction and destruction, flood and drought, habitation and migration, wetness and dryness. I am interested in landscape not as static entity that can be defined and contained, but as a shifting, living phenomenon that is both engaging and to be engaged with. Landscape in this active sense is not seen as a commodity or artifact, but as a complex, immeasurable process."*

Mathur, 2010

The gradient of maintenance is a spatial-temporal concept related to a paradigm shift in the ways maintenance is delivered. In this vision, the natural processes are used to shape the urban landscape and dictate public works regimes. In the drawing the gradient is shown as a transition between low ecologically performing practices to high performative ecologies that shapes the public space. The focus is on the third gradient (low maintenance, productive landscape) in which co-existence could be achieved. The images show the correlation between previously explored layers of building site preparation, ecological

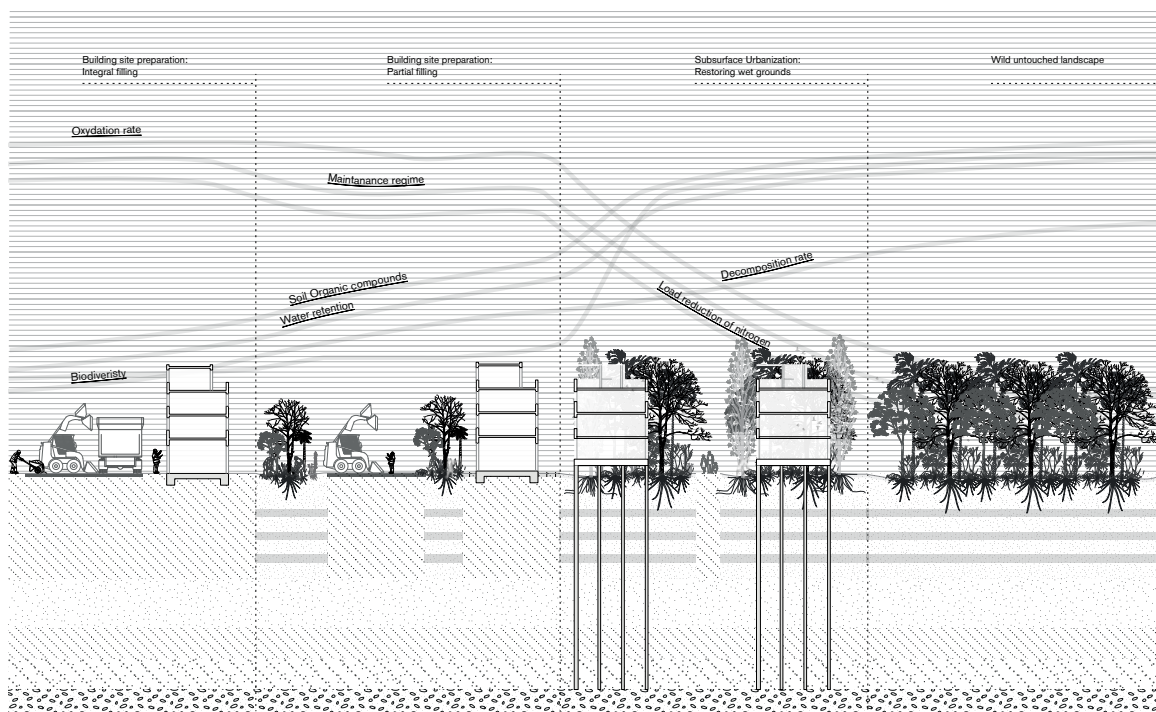
dynamics (botany and ecology), urban and landscape design, hydraulic engineering, and strategies of 'soft' or 'amphibious' urbanization that could co-exist with a new performative landscape. The question for the change in paradigm is: What are the linkages and synergies between systems of performances and maintenance regimes? Geo-engineering is here taken as the fundamental strategy to both prepare the ground but also to trigger certain types of uses and vegetative patterns.



The drawing shows the 'gradient of maintenance' in which subsurface programming is linked with surface qualities ecological performance. Can system of production co-exist with a minimal disturbance of the landscape ?

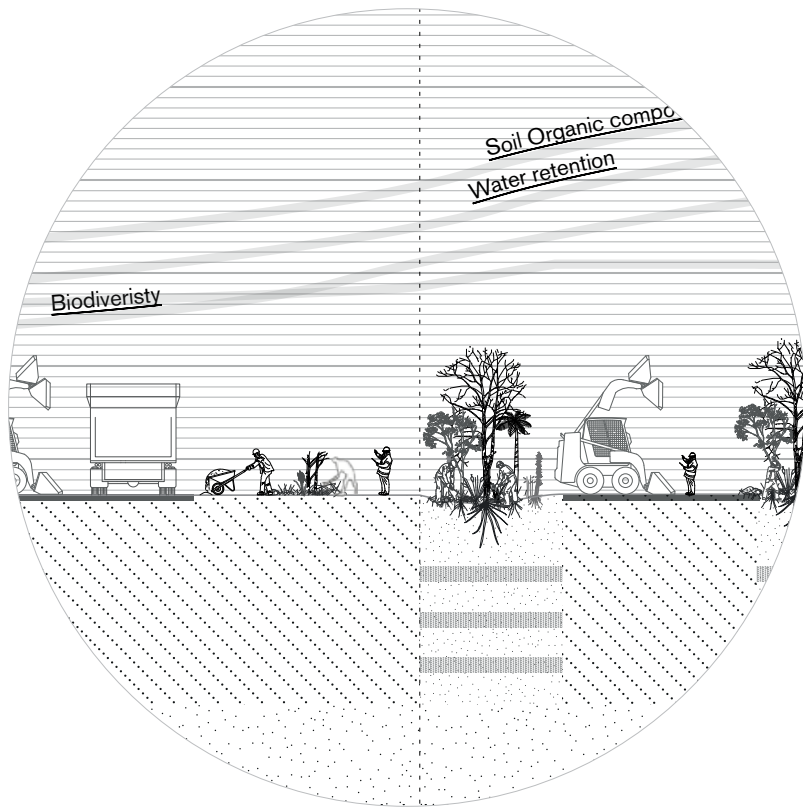
Deconstructing the mono-functional and technocratic program of current 'high entropy' maintenance regimes, in which efficiency and engineering overlooks processes of interactions, biotic and abiotic dynamics and time, could lead to the counter strategy in which the ground will be prepared for hybrid forms of co-existence of technological and natural systems. Un-designing mono-functional systems and engineering techniques require new ways of research and design in which drawing and mapping (at the intersection between space and time) plays a crucial role in explaining new practices and processes.

The drawing works with methods of superimposition and relational thinking between physical operations and environmental dynamics. The aim is to show and correlate tangible and intangible elements. As in every research by design, visualization has the primary focus of explaining new potential 'ways of doing', with the hope to change future daily practices and unfolding innovative ways in which transformation is performed.

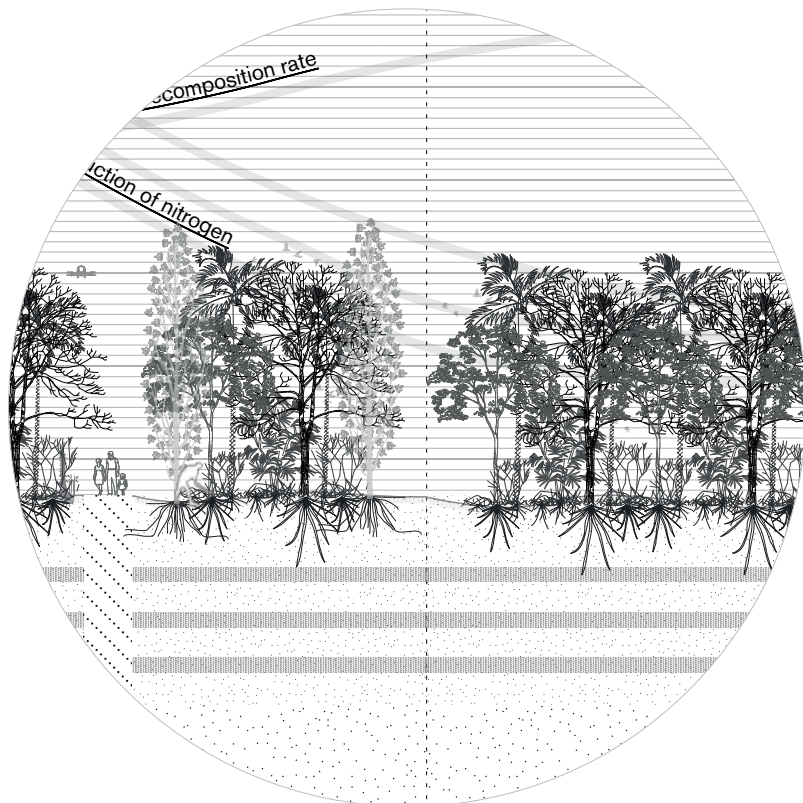


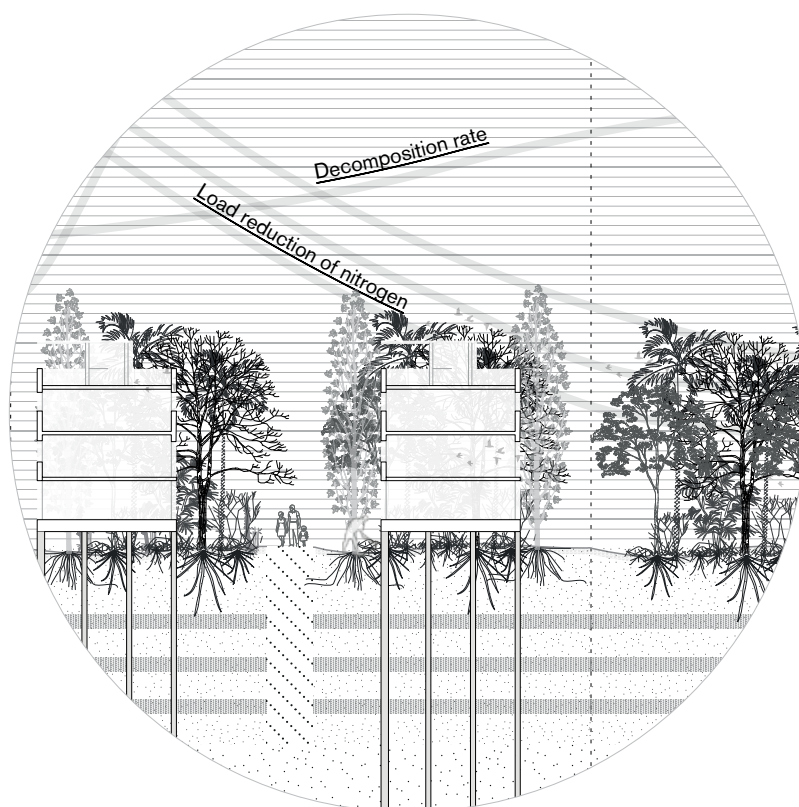
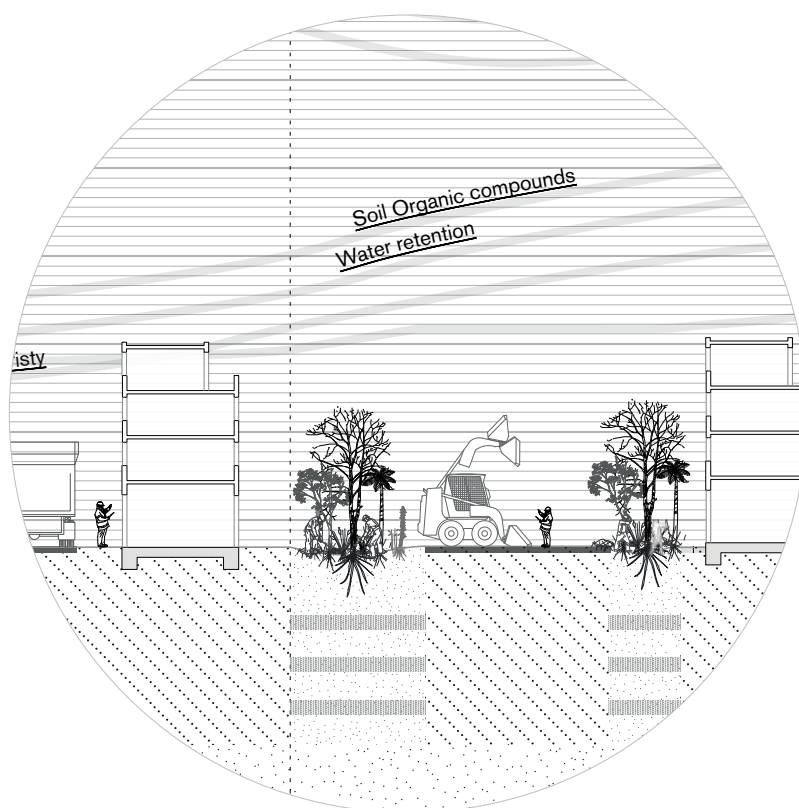
The drawing shows the 'gradient of maintenance' in which subsurface programming is linked with surface qualities, urbanization strategies and ecological performance. Can the built co-exist with a minimal disturbance of the landscape ?





The drawing shows integral filling and partial filling practices. Soil engineering, surface aesthetics, and the ecological dynamics that it underpins as well as generates. The physical, technical drawing is overlaid with key performance indicators showing a potential qualitative state of the natural system.





The drawing shows low maintenance yet potentially inhabitable landscapes. It shows the spatial synchronization and co-existence of soil engineering, surface design, and civil engineering. The physical, technical drawing is overlaid with key performance indicators showing a potential qualitative state of the natural system.

In the first phase of the project the explorative method brought forward insights and design methods for the urban renewal of (delta) metropolises where resilient, durable (subsurface) infrastructure is carefully balanced out with parameters of the natural system. The question 'how can the different technological artefacts in the subsurface be synchronized offering more space and adding to a better urban quality?' is answered by taking procedural steps from the technology (the knowledge of) to the design of public space and urban main structures. In each step the translation from the engineering language to the language of the urban designer (and vice-versa) is done producing an informative and useful overview in how to relate technological artefacts to urban quality. In order to reach interdisciplinary design, we used explorative research in creating a shared language.

Explorative research has been useful because the problem we are tackling is a wicked problem that has not been clearly defined. The exploration was framed by co-creation in workshops and later a more precise elaboration of these results in the working group. The three main methods that build the framework were:

- Forecasting, backtracking and backcasting enables all participants in a project to really understand the technological artefacts as dynamic features of the city and enable them to include them in creative thinking.
- Visualization, enables data from engineers to become information that can be included in the creative process. The visualizations offer the ability for engineers to see their technological artefacts in the complex urban context.
- Vision making, ensures that values and maximum benefits are attained to all parties from taking an integral infrastructural approach. As a planning instrument, the construction of a shared vision supports the decision making process, encouraging professionals to take up this approach. At this stage, pathways are developed towards future implementation considering cultural, institutional, financial and spatial/technological dimensions.

The second phase of the project focussed on the question: In what way needs the subsurface be architecturally represented to support a new script that consciously links the surface and subsurface in urban

development processes and products? The research was done through analyses of visualizations of the different disciplines, a literature review on the design notions stemming from Landscape Urbanism and by using the agency of visualization and drawing as a mean to provoke and instigate interdisciplinary co-creation as well as advancing the project of Integrated Infrastructure and Environment Design.

Conclusions of this phase are:

- The section makes it possible to understand the technical and natural construction as a hybrid space and is the best point of departure for the drawing of plans.
- Visualization is a communication tool that is very inward oriented towards a field, the use of form and colours are expected to be recognized by the expert in the field.
- Visualization is not only a technique to communicate but also a technique for internalization of data. The technical profile as was drawn is very much a product for the urban designer to get a proper understanding of the technology in an area, less so much an image to communicate to a wider range of people.
- Interdisciplinary research has shown that the future legacy of various disciplines is going toward the manifestation (on the surface) of previously 'hidden' technologies. Thus the relation between engineering and urban-landscape planning and design will become more reciprocal than ever. This will require new ways of working and new methods of engagements.
- The agency and potential of 'landscape' could innovate daily practice with its involvement in previously mono functional areas of expertise. Building site preparation is a clear example.
- Time as a management scale (maintenance regimes) should be incorporated in the process of planning and design to evoke new relationships and capitalize on investments.
- The re-internalization of new constructed environments (natural capital) in the domain of large and small scale infrastructural development should be further researched. In this case, Rotterdam Bloemhof-Zuid is just a first example.
- The relation between framework and content is a way in which planners and designers can engage co-creation and participatory processes without comprising the main structural performances of a given plan.
- The representation of processes at the small scale

can inform a better and more innovative ways in which change (space) is delivered and sustained through time (management scale):

- Reflecting on the urban concepts and their visualizations there is a large gain in drawing all the subsurface artefacts in their means of representation. The overview shows it is main concern with natural elements whilst these are in a new symbiotic relationship with the engineered elements on different scales.
- It is important to look at natural and technical artefacts as a hybrid system and see it in its complexity to consider representation as common shared language. The technical and natural elements visualized in the drawings offer a 'step between analyses and design' as important design thinking element.

- The provocative and speculative scenarios make it possible to include innovative technologies, support interdisciplinary vision making and the opening up of shared ideas not only for a specific vision but also for day to day practice.
- The interdisciplinary approach is a matter of forming new relation which means that it needs relation therapy.
- The subsurface is the battle ground for urban utilities and the space from which every resource come from, its design and planning should be balanced out with the ambitions for the urban development.
- The main gain for the interdisciplinary approach is that there will grow a better understanding for the urgencies coming from the different disciplinary fields.
- Nature in the city is the weakest link that should be taken into consideration first.

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