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Drawing the subsurface: an integrative design approach

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Abstract

The sub-surface, with its man-made and natural components, plays an important, if not crucial, role in the urban climate and global energy transition. On the one hand, the sub-surface is associated with a variety of challenges such as subsidence, pollution, damage to infrastructure and shortages of space for new urban systems. On the other hand, the sub-surface presents opportunities in terms of solutions for flooding, reduction in heat stress, and decentralized energy systems. Therefore, it is necessary to place sub-surface issues in their appropriate perspective, to enable a more resilient design that brings together ecosystem services, climate and urban systems, and which takes full account of the dynamics of the subsoil. To achieve this, the sub-surface must be an integral part of above ground planning and design. Organization of the sub-surface needs to be reflected visually in relation to - consideration of (surface) spatial morphology. The objective of this paper is to question the role of architectural representation of the subsurface. Discussion of architectural representation should include 'design thinking'. An important element of design thinking is the concepts that are used to guide the design process. For this reason, this research tests the role of visualization in relation to a case from the Dutch context and more specifically to subsidence. The approach is built on a systematic processing of contextual information of the site under development, using the System Exploration Environment, Subsurface and results in a Technical Profile. Using input from subsurface specialists to rethink the urban landscape results in realisation of synergies between subsurface elements and the (re)design of vital urban infrastructure.

Keywords: subsurface; urban design; visualisation; knowledge brokerage.

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1. Introduction

The sub-surface, with its man-made and natural components, plays an important, if not crucial, role in the urban climate and global energy transition. The sub-surface is associated, on the one hand, with a variety of challenges such as subsidence, pollution, damage to infrastructure and shortages of space for new urban systems. On the other hand, the sub-surface presents opportunities in terms of solutions to flooding, reduction in heat stress, and therefore, it is necessary to place sub-surface issues in their appropriate perspective to enable a more resilient design that brings together ecosystem services, climate and urban systems, and which takes full account of the dynamics of the subsoil.

Soil dynamics in the western part of The Netherlands are subject to natural and human induced subsidence: the land surface moves down as the peat landscape shrinks due to pumping and to the lack of recharge of groundwater levels due to soil sealing in urbanized areas [17]. This adds to complications caused by climate change and transitional problems associated with renewable energy. Subsidence puts pressure on maintenance budgets in urban areas because sand has to be continually added to public space to keep it levelled with the entrances of homes, to stabilize the connections of sewers to dwellings and make sure there is a sufficient free-board (distance between groundwater and surface level) [22]. In addition, subsidence affects the water system: groundwater level rises relatively to the surface level and makes those buildings built on slabs (shallow foundations) suffer from wet (unhealthy) basements. On the other hand, houses that are built on wooden bearing piles are founded in deeper layers of sand - and thus do not subside - risking exposure of the piles if they emerge above the level of the groundwater. When the wood is in contact with air, it will oxidize and rot; this is a huge expense for the owners who have to undertake foundation restoration. Tackling the problem of subsidence can also be used as an opportunity to accelerate the use of innovative technologies that will be discussed in this paper. It is a matter of recognizing the subsurface as a combination of natural and man-made features and recognizing potential cascading effects between the two. Solutions beneficial to a range of problems can then be recognized. In order to achieve this, knowledge management is crucial, involving technical information in the planning and design of the city [12].

This paper argues that in knowledge management, the role of visualization of the sub-surface as a technical space, the ‘engine room of the city’, is crucial. Typically, urbanists, consider that everything beneath the surface as a little more than the back of their drawing paper: a flat and invisible part of the city. Yet, there is an element of truth in this. Since the Industrial Revolution, urban and civil engineering have developed as two independent disciplines. Civil engineers focus on the technicalities of making an urban plan possible. Urban designers respond to the socio-economic interests of stakeholders and on translating these into spatial and functional plans. The current need for renewed cooperation is threefold. Firstly, the sub-surface plays an important role in the urban climate. Larger rainstorms of short duration flood the largely covered soil in cities whilst open soil plays a major role in water storage and drainage. In addition, open soil also reduces urban heat stress and is the basis for growing green that also has the effect of heat reduction. The second pressing issue to address is the energy transition towards renewable: ATES systems and geothermal energy currently contribute 0,058% to the 5,9 % [11] of renewable sources, but have the potential to provide up to 3.4 % of the target of 20% of energy from renewable sources by 2020 [13]. Thirdly, there is a financial driver to be smarter with the subsurface because construction or adaptation of underground structures is very expensive. The subsurface is literally the unseen foundation for all visible urban interventions and influences the affordability of urban quality.

Subsidence is a problem that aggravates the effects of climate change and affects the transition to renewable energy systems. Subsidence reduces the water storage capacity in the subsoil, harms the infrastructure of energy systems and puts pressure on maintenance budgets for public space. This last issue is a key determinant for the design of public space.

The question is: In what way and to what extent does the subsurface need to be represented architecturally in order to support a new script that consciously links the surface and subsurface in urban development processes and products? The Intelligent Subsurface project [11] has led to insights in, and the establishment of methods that support, interdisciplinary design and development. It is important that the step from hard technology to the design of public spaces and larger urban structures is done consciously. To be able to do this, the Technical Profile must be developed; a visualization that connects the knowledge of the engineers and the designers.

2. Theoretical Framework

Hugh Dutton (2000) [8] has argued for an 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 sub-surface into urban planning and design, this understanding needs to be part of the design process, as well as of the governance processes, and products need to be innovative. Spatial planning of the sub-surface 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 paper is to question the role of architectural representation of the sub-surface in the application of innovative technology. A consideration of architectural representation should include 'design thinking'. Most discussions of the design thinking process, notably Change by Design (2009) by Tim Brown [5], highlight the value of visual representation. Some authors even refer to visualization tools as 'the mother of all design tools', because they are used in every stage of the design thinking process [14]. Another important part of design thinking is the concepts used to guide the design process. How is the subsurface represented in concepts such as: 'machine landscape' [15], 'field operations' [7], 'constructed ground' [18], 'mat urbanism' [1], 'drosscape' [3]. 'thick infrastructure' [20]? These concepts come from the discourse of Landscape Urbanism [23] in which landscape architecture and the landscape is taken as starting point to structure and design the functionally performance of the natural system in urban development.

Among those involved in the Landscape Urbanism discourse, Gray (2011) [9] states in relation to the concepts of 'the machine landscape mode' as defined by Mohsen Mostafavi (2003) [15] and the 'field operations mode' as set out by James Corner [7]: 'In pairing landscape with urbanism, landscape urbanism seeks to reintroduce critical connections with natural and hidden systems and proposes the use of such systems as a flexible approach to the current concerns and problems of the urban condition.' [9]. The machine landscape mode considers landscape as a cybernetic universe with its own laws [15]. The method applies dynamic systems in mapping to the study of the fluxes and processes that are inherent to the constant time-space evolution of the landscape. It comprises the gathering of information, its decoding, synthesis and systematic processing towards a design that accommodates change and indeterminacy. This approach puts this knowledge in the centre to steer infrastructure and ecological systems as guiding mechanism in urban design.

The 'Field operations mode' by James Corner is about moving away from aesthetic design towards operational logic and from aesthetic categories to strategic instrumentality, the processes. He calls for a focus on the agency of landscape (how it works and what is 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. Tran disciplinary collaboration should have a generalist approach and should start with an understanding of the natural system, before deciding on the spatial quality, technological necessities and what 'spatial technology' can solve. This should lead to a combined language, shared methods, unified concepts and integrated scales [6].

The concept of 'constructed ground' is about breaking down the oppositional system between nature and engineering. 'Constructed ground' represents a hybrid framework that crosses between architecture, landscape architecture, and urban design, to engage the complexity of contemporary urban landscape [18]. The soil is the main material for design, moulding the landscape as both a structuring element for design and as a medium for rethinking urban conditions that includes nature.

From the perspective of 'mat urbanism', [1] the bond between elements of buildings and urban environment should be designed in such a way that it can anticipate dynamics over time by many generations of users. The initial function of the building should be 'future proofed' to harness possible changes in use in the future which means that it should be adaptable by character.

In the concept of 'dross cape' [3] an urban design framework is proposed that looks at urbanized regions as the waste product of defunct economic and industrial processes. It offers new vocabulary and aesthetic to redesign and make adaptive re-use of 'waste landscapes' within urbanized regions.

'Thick Infrastructure is a design research project investigating the intervention, expansion, and re-design of public infrastructure to include elements that enhance civic and public spaces, transforming single-purpose infrastructure landscapes into multi-functional systems. The project advances the vision of infrastructure as integrated into the fabric of the city, replacing the reality of single-purpose, engineered, and disconnected infrastructural landscapes.' [20]

In the Landscape Urbanism discourse that is emanating from the United States, the natural system is put forward as leading operational logic and landscape architecture is granted the ability to make urban structures more durable and sustainable.

In this paper another interpretation of Landscape Urbanism is proposed; one that seeks (through design thinking) an integral approach between disciplines that master the natural system and those that master the technology, and deliver shared benefits at multiple scales. Thus, not only taking the operational logic of the natural system in itself as main driver, but considering the natural system together with the technological urban constructions that are already in place. Synchronisation (in time, space, technology and interests) is one of the main goals. In addition to the above concepts, this research proposes the 'technical profile' of an urban area comprising plans and section drawings on different scales, representing the natural and engineered elements in the categories of civil construction, water, energy and soil/ecology. All drawings are explained by a shared legend that enables connections and communication between the elements and the scales they perform on.

In addition to connecting the design process of the engineer with that of the urbanist, it is also important that this mode of operation can become part of spatial planning processes and documents. This means that technical information can also become part of spatial planning documents on national, provincial and municipal scales. A crucial part of these documents will again be the legend that translates technical data into information, so it can also be understood by non-engineers.

3. Results

The Intelligent Subsurface project (led by TU Delft) is building on an earlier project involving TU Delft and Deltares (2010) - *Design with the Subsurface*, in which the System Exploration Environment and Subsurface (SEES) and the Subsurface Potential Map were developed [12]. The SEES is a system overview in which the domains involved in urban development are mapped out. Each domain has its own specific specialists, concepts and language that need to be recognized if truly interdisciplinary working is to be achieved. 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 the Intelligent Subsurface project (TU Delft), 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 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) [11].

Explorative research in which the research from engineering disciplines connected to urban development (like water management, drainage, soil mechanics) are brought together in a scenario to explore possible relations. This approach is useful in a situation where there is a wicked problem [19]: a problem that is contextual and cannot be solved by applying general solutions, like a 'tame problem'. The exploration was framed by co-creation in workshops and later in a more precise elaboration of these results in the working group. The three main methods used to build the framework were: *Forecasting, backtracking and back casting* [21], Visualization by mapping and drawing sections, and Vision making to have a shared view on the future and to set out Adaptive Pathways [10] that give flexible steps to reach that future. As an outcome, by applying this framework, the direct relationship between technology in the subsurface and the design of public space and urban main structures, like road, green or water infrastructure, in urban development was made clear amongst the pool of participants in this project. In particular, focus was placed on potential future synergies, or cascading relationships, between technologies and their contribution to urban quality.

The challenge is to draw all of the different natural and engineered elements together in such a way that the relationships between them, and the surface structures, become readily apparent so that meaningful decisions can be made in relation to desired interventions and effects. Some elements also influence larger sale processes, such as water, energy and ecology, whereas others, such as cables and pipes and ecology also need to be represented on the smaller scale of a street section. The drawing of the subsurface, or the Technical Profile, has been tested on several cases of which Bloemhof-Zuid in Rotterdam is described here. For all of these cases, workshops have been organised to produce an inventory of the data and to generate a clear view on the applicability of new technologies. The first workshop per case was structured by using the SEES with the purpose of collecting relevant data and creating the Technical Profile. The second workshop per case focussed on interdisciplinary design thinking by putting forth extreme engineering scenario's and have the interdisciplinary groups critically-concretize these. First the groups perform a SWOT (strengths-weaknesses-opportunities-threats) and then connect spatial and new technical interventions to a future perspective as will be described here for Bloemhof-Zuid.

3.1. Bloemhof-Zuid Rotterdam

Bloemhof-Zuid is an urban district built in the 1930s on very wet and soft terrain with ongoing subsidence. In the middle of the district, houses are built on slabs while along the borders they are on wooden-bearing piles. This makes the management of groundwater level extremely complicated. |The owner of most of the houses on slabs, the housing corporation *Woonstad*, has placed water pumps in a number of places to prevent flooding. However, the houses are not future-proofed and the urban infrastructure does not meet modern requirements (with narrow streets, little parking space, few green spaces and play grounds).

The key challenge is how to develop the real estate in the long term, taking the subsidence into account. To this end, the municipality of Rotterdam and Woonstad have a vision in which the subsurface conditions of subsidence and water management are an important aspect. The content and role of the technical profile is developed more precisely in the process of vision making together with the technical specialists of the municipality of Rotterdam and experts of TU Delft who are involved in the research project Intelligent Subsurface.

3.2. Technical profile

The technical profile that has been created for Bloemhof-Zuid comprises the translation of all relevant technical data into a series of drawings that allow the different natural and engineered elements to be analysed simultaneously. The drawings are: a map with a longitudinal and cross section, cross-sections of street profiles, and thematic maps on a larger scale. Linking the smaller scale of the street profile to the more regional scale is important to check the impact of specific technical conditions: especially systematic elements like water and ecology have performance dependencies on the higher scale. On the largest regional scale, topics of relevance are: ecology, water, energy and infrastructure; on the smallest scale, details of the subsurface infrastructure of cables and pipelines and foundations are presented.

After drawing the technical profile on the basis of data collection and a workshop where all experts concerned present and discuss their field for the specific area a second drawing, the projection is made. This has the same types of drawings but enalbes a wide variety of solutions to be presented.

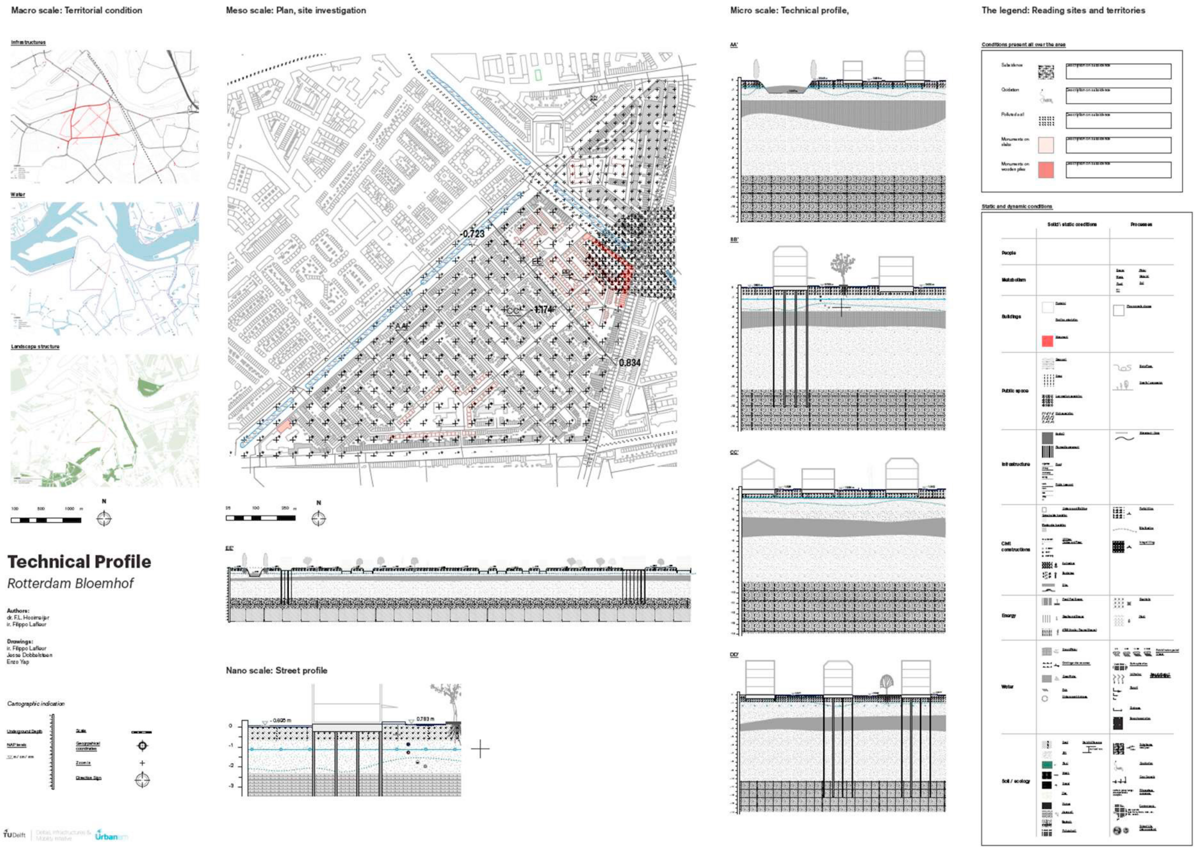

Fig. 1 Technical profile Bloemhof-Zuid

3.3. Cascading solutions

The next step after development of the technical profile is to make an inventory of new technologies relevant to the redevelopment of existing urban areas. Important to keep in mind is that these new technologies will not operate in a vacuum: they are all part of and influencing the hybrid urban system of natural and engineered elements.. The goal is to identify synergies and create positive cascading effects between these solutions. For the Bloemhof-Zuid case five solutions are considered to be applicable: Biogrout, SoSeal, partial filling, design with subsidence and new architectural typologies (see for more detailed information [11]).

Biogrout is a method of soil enhancement which can improve the carrying capacity of soil. It can be applied locally, and can create opportunities for efficient use of space. Instead of filling a whole area, it is only necessary to stabilize part of it, leaving more space for the natural system. Stabilizing a sewer with this technology can also reduce maintenance costs. It can also be used to stabilize the sewage in instable, subsiding, soft soils and thereby reduce the cost of maintenance. The application of Biogrout supports a new design approach for public spaces, whereby subsidence in parts of the space can be acceptable. For example, differences in elevation will occur due to the fact that there are some parts which subside naturally whereas others such as sidewalks and streets remain at the same elevation. The design will have to respond to the dynamics of the soil over time and provide solutions for another way of maintenance. In the case of Bloemhof-Zuid, only part of the sidewalk needs to be stabilized, and the filling of streets with sand can cease, until the houses are renewed at some stage in the future.

SoSeal is a biological way to make the soil impermeable. It can create smaller water storage units and offers opportunities for controlling mobile pollution. It enables more open soil and green infrastructure in the smaller water storage units to increase storage capacity or control the groundwater. This is especially interesting for Bloemhof-Zuid where houses on slabs and bearing piles are standing next to each other but are in need for different water management regimes. The micromanagement of groundwater supports a long-term replacement operation of the building stock. Buildings with high quality that do not need to be replaced or refurbished right away can be kept dry by applying these temporary water storage units. In this way it makes the water system on a larger scale more adaptive to local subsidence dynamics.

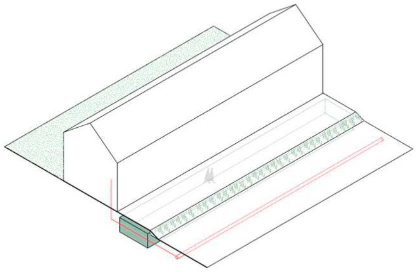

Fig. 2 By using Biogrout, the soil can be reinforced locally to stabilize the sewage and the rest of the sidewalk can be used for green infrastructure. Image: [11]

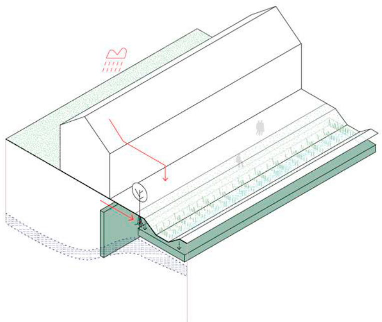

Fig. 3 With the application of SoSeal, an impermeable screen can be used to control the water system at the micro level. In conjunction with green infrastructure, a micro-water storage unit can function properly and offer adaptive capacity. Image: [11]

Partial filling with sand is a common method of building site preparation developed in the 1970's to integrate existing green structures in the new urban expansion.

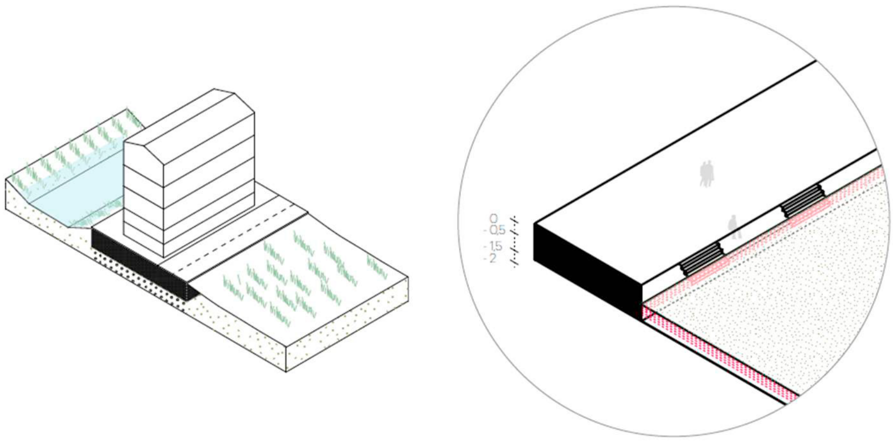

Fig. 4 When subsidence on squares is accepted and they are no longer raised with sand they will become automatically storage for surplus water in the city. Image: [11]

It is a method of designing with subsidence because it simply only raised parts of areas with sand where it is functional. This way it leaves room for the design of green infrastructure that is adaptive towards dynamics of water and soil.

Subsidence is a natural soil dynamic that transforms urban squares automatically into ‘water squares’ where surplus water can temporally be stored. Due to subsidence the city of Rotterdam has a maintenance plan in which streets and squares are raised with sand at least every 10 years to ensure stable sewerages and streets. On the left-hand side of picture 5, the streets around the square are raised, creating a water square. During heavy rainfall there is always water on the square and the slide would poetically mirror in the water. The right side of picture 5 shows that the entire square has been raised and equipped with a new public space design. The water storage capacity of the square is lost and the large trees have been replaced by young trees, as a result the spatial and natural quality is not necessarily improved.

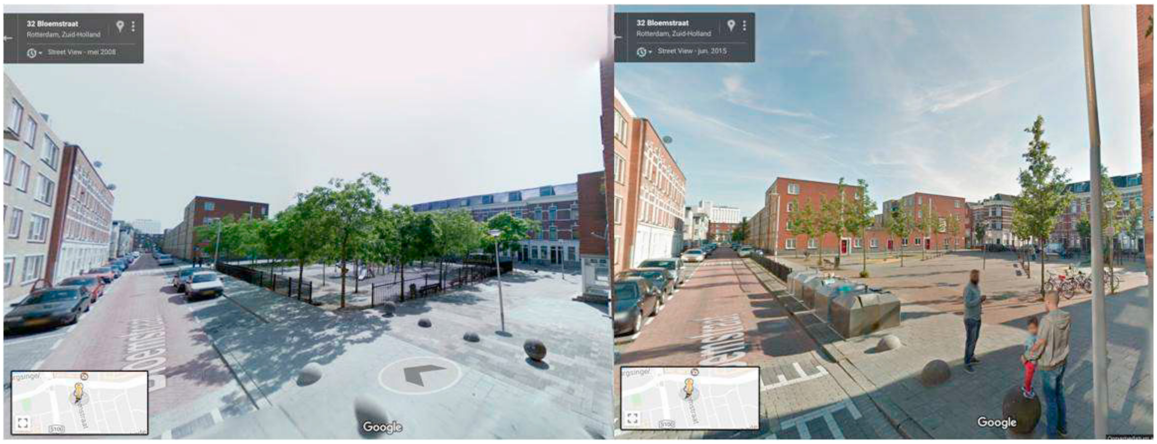

Fig. 5 This square on the Bloemstraat in Rotterdam was a water square before it was raised with sand. Unfortunately, this opportunity for water storage was eliminated when the square itself was raised (right). Image: Google Earth

In addition to the design of public space that is adaptable to subsidence also the buildings can be designed in such a way that they can respond to the dynamics of the natural system. New architectural typologies can deal with the slowly developing height difference by designing flexible access into the buildings. The fact that the building will accept the subsiding surface around does require another sewer system because they are currently designed for a stable connection. The sewer system that is called ‘sink disposal’ takes in addition to grey and black water also takes organic waste into the system and allows for flexible pipes. This system or other decentralized waste water treatment helophyte filters or constructed wetlands are not dependent on a stable relationship. This strategy can be applied in Bloemhof-Zuid it does however change largely the current way of working and thus cause a paradigm shift in the maintenance of the city.

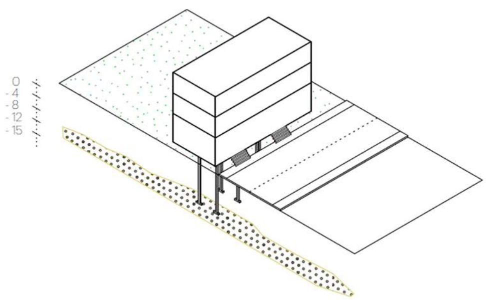

Fig. 6 Subsidence can also be adapted to by new architectural typologies that have a flexible access that anticipates to subsidence. Image: [11]

3.4. Provoking scenarios

The cascading solutions were used to design two provocative scenarios based on a extreme way of dealing with the subsidence: Polder in Polder and Extreme Engineering. The Polder in Polder scenario proposed the building of a new polder in the neighbourhood by which the water management issues could be solved. The buildings in the new polder could remain on slabs and subside together with the public space. The buildings that are outside this new polder would be built on piles and adjust to a higher ground water level (see Fig 7). The Extreme Engineering scenario replaces all buildings on slabs by new buildings on piles. These new buildings will be built on the same level as the existing buildings on piles and the subsidence of the public space will be accepted. (see Fig 8). The natural construction of soils and organic matter over time also advances the idea of low maintenance landscape and return of native vegetation. The drawing translates the idea of strategic instrumentality of the landscape over aesthetic criteria and parameters (see Fig 9).

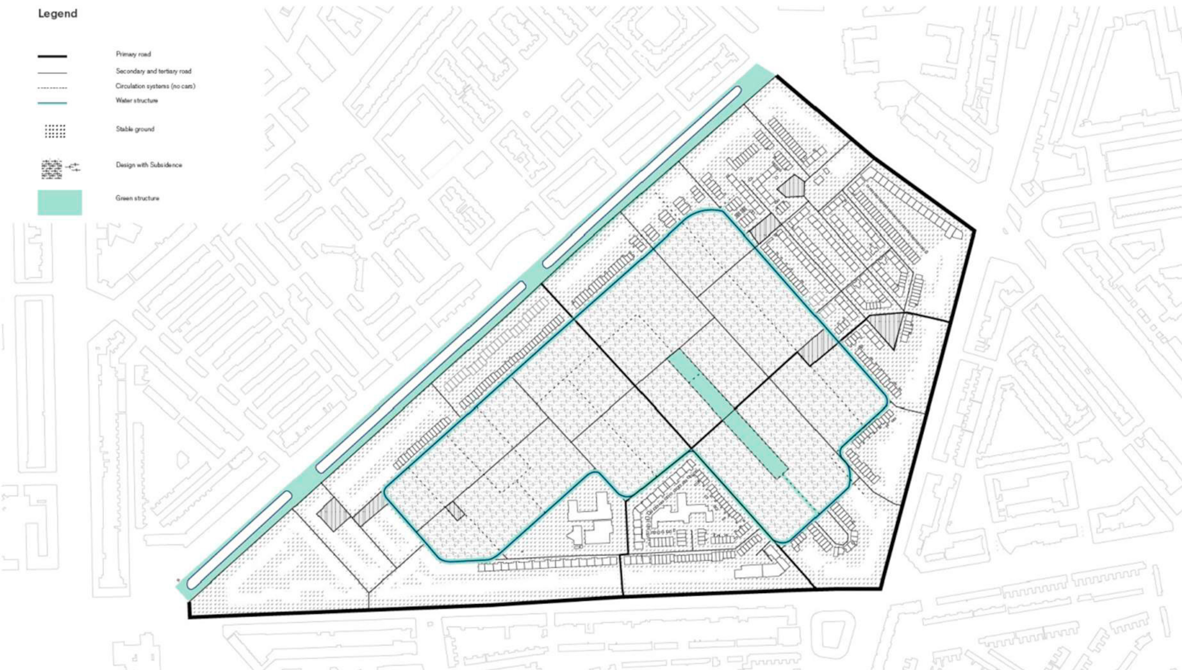

Fig. 7 Polder in Polder scenario

In the second workshop with the experts from the engineering office and urban planning department of the municipality or Rotterdam, together with experts from the housing cooperation and from the TU Delft these two scenarios were 'critically-concretized'. First in small interdisciplinary groups the two scenarios were each subjected to a SWOT analyses, considering the Strengths, Weaknesses, Opportunities and Threats. The groups thus gave more ownership to the scenario to consequently be able to make choices how to make it more concrete. The question was to make the scenarios concrete with the choices offered on cards taking into account the future dynamic in urban systems of: new mobility, water, waste and energy. The choices were on cards and consisted of the assembly of new technologies, street profiles and housing typology. The new technologies were: Smart soil improvement, Soseal, Sink disposal, Source separation, Smart piping, Infiltration crates, Helophyte filter and MUT flush fitting [11]. The choices in street profiles and housing typologies were determining the relation between green and grey space and public and private space. By making these choices the group builds on a future story line for the neighbourhood also including what this individually meant for each discipline. What do they need to do different to be able to generate a future for this area which is not continuing business as usual? How drastically urban maintenance regimes must change?

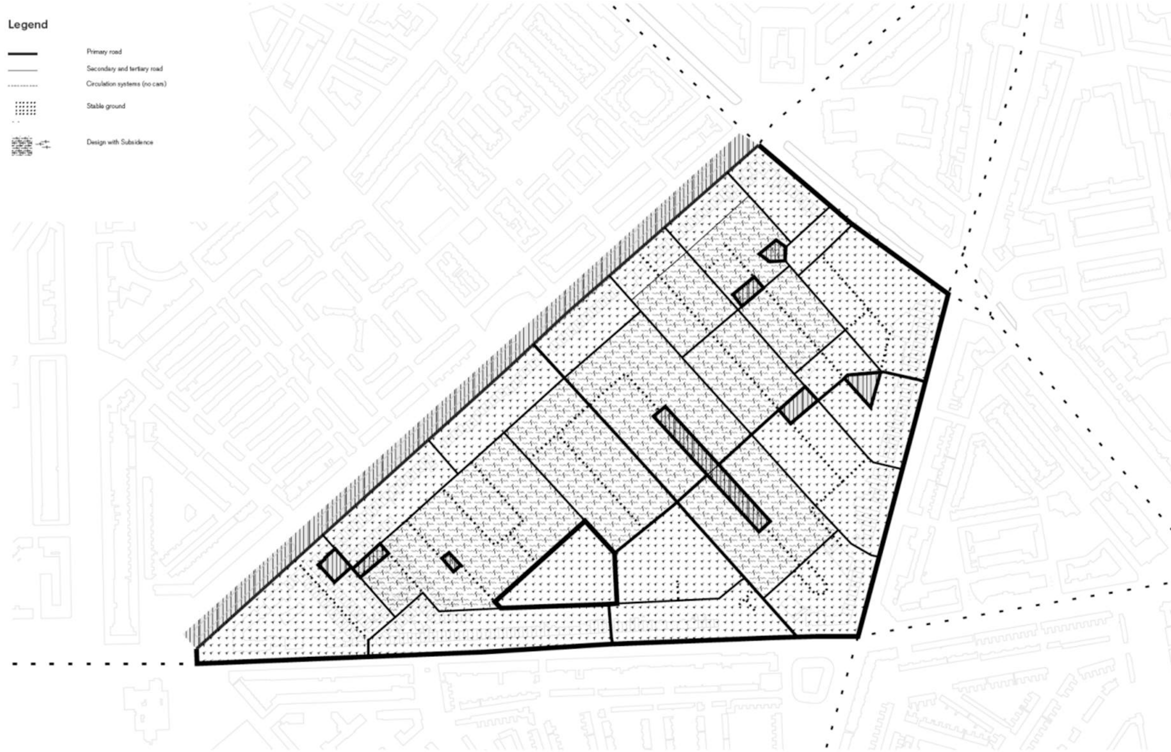

Fig. 8 Extreme engineering scenario

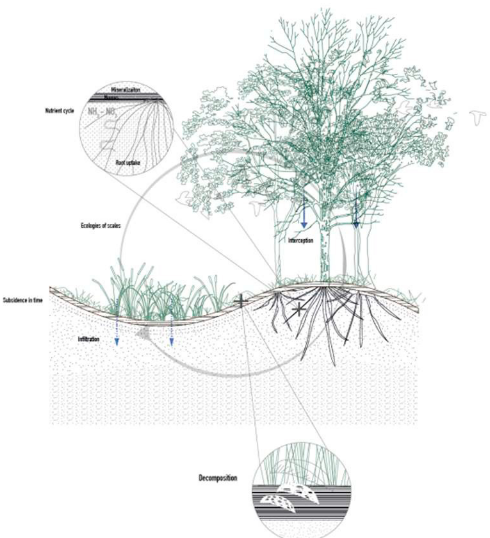

Fig. 9 The idea of low maintenance landscape and native re-vegetation

The workshop has the intention to open up idea’s towards the implementation of new approaches and technologies. The munition created is then used to make the vision for the area by the urban design office. As a part of this vision the guidelines from the technical perspective is drawn up in the ‘Projection’. This Projection map enables understanding in the cascading effects of implementation of new technologies and supports the design process further. The Projection map for Bloemhof-Zuid has to be developed.

4. Discussions: Understanding the techniques

The case of Bloemhof-Zuid is showing the approach towards developing a new concept in which the subsurface is accounting for the vision and design process. The backbone of this approach is the development of the Technical Profile first to be able to represent the technical conditions in the future with the Technical Projection map. The two maps should be considered as the 'step between analyses and design' and thus as important design thinking elements. The technical and natural elements represented in the drawings are extensive and contextual. How can these be included into concepts on urban development?

Concept comes from Latin *concipere* - *conceptum*: gathering, comprehending and understanding. In design or art it is used to connect the personal interpretation or passion as a guiding principle to the expression in art or design for a certain program. Major importance of concepts for urban development is their spatial definition and thus spatial representation. Especially because it is judged and chosen before it is built, the representation is not a luxury, but a necessity to test, communicate and sell the concept. 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 suggests 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' and 'thick infrastructure', the representation techniques are of these concepts are checked. In table 1 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.

Table 1 Representation of the subsurface elements in specific techniques used by Landscape Urbanism concepts

WHAT / HOW	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			🔴🟢🟡	🟡	🔴🔵🟣🟠🟢🟡		🔴🟢🟡	🟡		🔴🟠🟢🟡			🔴🟠🟢	🔴🟠🟢🟡				
3D PERSP			🔴🟢🟡		🔴🔵🟣🟠🟢🟡			🟡			🟠			🔴🟠🟢🟡				
3D MODEL					🔴🔵🟣🟠🟢🟡						🟡			🟢				
DIAGRAMS	🔴🟢		🔴🟢🟡	🟢🟡	🔴🔵🟣🟠🟢🟡	🔴🟢🟡	🔴🟢🟡					🔴🟠🟡	🔴🟠🟢🟡	🔴🟣🟢🟡	🟢🟡			
PHOTOGRAPHY					🔴🔵🟣🟠🟢🟡	🔴🟢🟡	🔴🟢🟡	🔴🟡		🔴🟠🟢🟡	🟣🟠🟡			🟣🟠🟢🟡				
SKETCHES				🟢	🔴🔵🟣🟠🟢🟡			🔴🟡		🔴🟠🟢🟡			🔴🟠🟢	🔴🟠🟢🟡				

- 🔴 constructed ground
- 🔵 mat urbanism
- 🟣 drosscape
- 🟠 thick infrastructure
- 🟢 field operations
- 🟡 machine landscape

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 [2]. 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 Technical Profile is a systematic representation of all the subsurface elements in plan and section. It offers the base for the projection map in which the elements in their solid or process state are re-combined, re-configured thus offering new qualities and performances. The use of 3D, diagrams and sketches is a next step to be explored to become even more integrated in design concepts.

5. Conclusions

The Bloemhof-Zuid case from the Netherlands demonstrates the effects subsidence has on the technical design and construction on building and urban scales. It could be the first comprehensive project in which the conditions of subsidence is actively taken into account and the design tries to build with it, rather than against it. This is very relevant, because there are many places suffering from the same issue. On the scale of buildings, it has major negative effects on the connection of the house to the street and to the sewer. Two alternatives are presented that break with the traditional way of maintaining public space in which sand is applied at large scale to stabilize the streets and install the desired free-board. Instead the Polder in Polder and Extreme Engineering scenarios propose drastically new technical approaches that include a new relationship between large and small-scale spatial and technical interventions over a long period of time. In both scenario's it allows the natural soil system to recover and play a role in water management, urban heat stress reduction and improving biodiversity. Offering a new way in which vital services of the ecosystem can be delivered to urban quality.

Taking a new approach to subsidence is dependent on developing integrated design projects for architecture, public space design and urban surface and subsurface infrastructure. The challenge of subsidence can be taken up together with climate change and the energy transition issues to create cascading effects with implementing new technologies in the area of sanitation and soil improvement. This does require a long-term integrated design approach that challenges us to change the urban maintenance regimes. However, in the different domains there are common work processes that are hard to change. Stopping the addition of sand to the streets and squares has as a consequence that the problem must be solved in other domains, which is not easy, but can create a design innovation. The greatest advantage of using the available technologies more efficiently is that the city's ecosystem can be restored and given much more space to facilitate the opportunity to play a role in responding to climate change and the energy transition.

Reflecting on the Landscape Urbanism concepts there is a large gain in representing 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 especially important to look at these issues in their complexity and the visualization of data into a common shared language. The technical and natural elements represented in the drawings offer a 'step between analyses and design' as important design thinking element. The approach that is taken in the Boemhof-Zuid case not only developed and improved the visualization of the Technical Profile, the provocative and speculative scenarios', the innovative technologies and the Technical Projection, but supported interdisciplinary vision making and the opening up of shared ideas not only for this specific vision but also in the daily work.

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