

Settling with waters. Design investigations for flood adaptation in the Sabana de Bogotá

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Abstract

The Sabana de Bogotá is facing a continuously increasing conflict between urban development and a saturated water management system. The research investigates how current contested relations between low-income housing and environmental stress can be converted into a constructive interplay. The unquestionable necessity of building new social housing can be seen as a major threat for sustainable water management but also as a unique opportunity to propose strategic spatial interventions. This paper presents the results of a doctoral thesis that investigates how can the current contested relations between water, settlement and productive landscapes become a constructive interplay? The paper is divided in two parts. The first part describes the main challenges to address these issues. The second part presents the design investigations in two case studies that cut across the Bogotá River and are undergoing development pressure. In each site the design proposes a water structure that solve qualitative and quantitative water issues while delivers a framework for new housing fabrics. The design investigations develop new low income housing morphologies, settlements with waters that are differentiated from land-based morphologies.

Keywords

Sustainable water management. Low-income housing. Bogotá. Water urbanism. Landscape urbanism.

1. Introduction. The housing problem

After 1930, un-controlled urbanization in the Sabana de Bogotá has rapidly consumed rural land and systematically encroached on water bodies, floodplains and wetlands, resulting in a fragmented ecosystem. The water system has been drastically transformed to cope with urbanization and economic growth. At the same time, demands for new housing increase daily, while the region's housing deficit re-mains unresolved.

1.1. Large-scale challenge

Bogotá's population increased ten times between 1951 and 2005. Housing stock has increased twenty-two times during the same period. This large housing production allowed decreasing the number of inhabitants per house (from 8,43 in 1951 to 3,99 in 2005) alleviating overcrowding rates. However, the housing production has been unable to cover both the qualitative and the quantitative deficit (Metrovivienda, 2011). In 2014, the total housing deficit for the Bogotá was calculated in 221,857 dwelling units (87,767 new dwellings and 134,090 dwellings that need improvement) (Secretaría del Hábitat, 2015). In the municipalities close to Bogotá (Mosquera, Funza, Chía, Cota and Soacha) the housing deficit was calculated in 52,694 dwelling units (29,782 new dwellings and 22,912 dwellings that need improvement) (Dane, 2006).

Bogotá's current population growth has reached a stabilization phase that is reflected in a yearly average of 2%. This means that each year there are 51,000 new families in Bogotá, 21,000 of which turn to the formal market to solve their housing needs. The rest depend on renting, self-construction or co-housing with a relative (Torres, 2012). This rate is supplemented by internal displacement. Between 1985 and 2008, 709,875 displaced persons arrived in Bogotá, (10% of current Bogotá population) mainly to informal origin neighborhoods in the poor peripheries (Codhes, 2008).

In Bogotá, the informal market has played a pivotal role in the provision of land for low-income housing. However, "illegal development rarely took the form of land invasions. Rather, 'pirate' developers sub-divided land at the edge of the city, sold it without planning permission and offered settlers a minimal supply of infrastructure" (Gilbert, 2009, p. 427). The low-income population built their homes through 'self-help' construction. Informal areas have been also intensely densified which decreases the quantitative deficit but hardly decreases of the qualitative deficit.

The high cost of land has both led to residential uses being continually pushed further and further out into the periphery and an impoverished quality of housing stock on the scale of urban design and architectural detailing. Large areas of self-constructed housing suffer the consequences of substandard urbanization, with a deficit of public space, social infrastructure, and low-level accessibility. Since the mid-twenty-century, the traditional agricultural lands that surrounded the city became object of speculation. Sustained population and economic growth fueled rises in urban land prices. Different legislation attempts tried to control this phenomenon of land speculation but only until the end of the 90s the Ley de Ordenamiento Territorial was implemented (Ley 388 de 1997). One of the aims was to control land prices, however, when it was implemented the prices already have significantly increased.

The large scale of the social housing issue makes for any government almost impossible to find a comprehensive solution. Public policy constrains to provide adequate housing are related with the high rate of poverty which make difficult to fulfill the conditions for access to subsidies or funding systems. The state has also a limited capacity of production even if it is through private partnerships. It also makes evident the need to develop a vision for the city and the region.

The aforementioned developments raise numerous technical questions, since a large part of the city's periphery has been built below the level of the Bogotá River. This implies that urban wastewater has to be pumped into the river. The wetlands, that once regulated the river's dynamics, have almost completely disappeared, and the effects of El Niño and La Niña will be magnified by climate change. What technical solutions would be the most appropriate to deal with these phenomena? Is it possible to restore landscape resiliency while exploiting the potential of local interventions? Can we restore the wet nature of the floodplain at Bogotá's

western urban edge? Perhaps, most importantly, where does one accommodate the persistent needs of low income housing? In short, where and how should the city grow?

1.2. A changing response

In Bogotá, the main response to housing needs and to informal growth was the creation of Metrovivienda in 1999. Originally, it operated as public land bank agency. It provides serviced land on which private builders construct legal and affordable housing to counter informality and to increase dwelling quality (Gilbert, 2009). The land bank would cut the cost of serviced land through capturing betterment and land price increases. The poor would then buy social housing from private companies using the national housing subsidies and associated credit facilities. Metrovivienda represents an exceptional case as an attempt to guarantee cheap land for low-income population. Public land banks were a widespread state response in the 1950s and 1960s. "The essential aim of a land bank is to appropriate some of the capital gain that private landowners and building developers derive from transforming rural into urban land" (Gilbert, 2009, p. 426). However, over the last fifty years, public land banks have virtually disappeared and their effectiveness has been seriously criticized, especially in developing countries (Gilbert, 2009).

In 2000, the land use plan POT defined large expansion zones for low-income housing. Metrovivienda started to acquire the land. This process was slowly implemented because some of the plots had problems regarding legal property titles. The efficacy of the procedure also depends on the number of land owners with whom Metrovivienda should negotiate the land. The selection of land location was controversial. Historically, it has been cheaper to build social housing in the peripheral lands. Soil quality and accessibility to infrastructure and services determine land prices and also explain Bogotá's patterns of growth. To effectively create a land bank Metrovivienda opted to buy large plots of land which were located in Bogotá's River floodplain. After several studies, Metrovivienda identified the areas that met the necessary conditions: cheap land prices, large plots and a small number of owners (Metrovivienda, 2012). El Recreo and El Porvenir, were selected to be developed the first large social housing projects, which comprise 12,000 and 10,500 dwellings respectively.

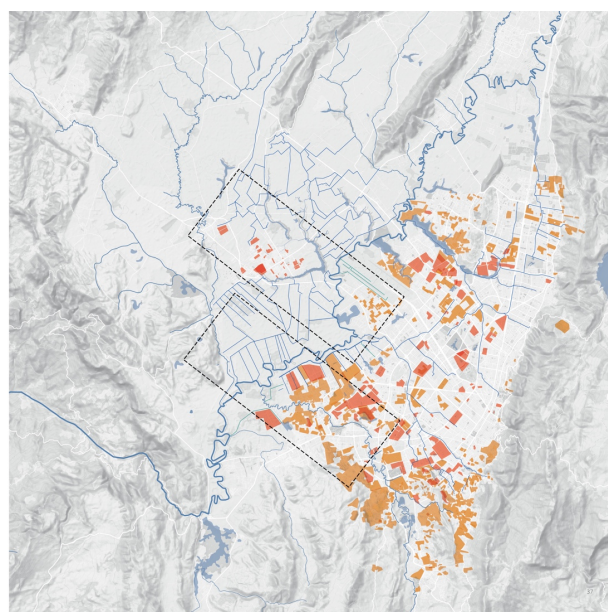


Figure 1. Low income housing in the Sabana de Bogotá and its relation to the water system 2015. Elaborated by the author.

During the administration of Gustavo Petro (2012-2016) the approach of Metrovivienda shifted towards the promotion of social housing in the "extended center", establishing projects in association with local land owners. To achieve this goal, the organization promoted the use of service land within the existing built-up area. The land and policy restrictions in Bogotá have displaced social housing production to surrounding municipalities. For instance, between 1993 and 2005 the annual growth rate of Mosquera was 8.1%, 2.92% in Funza and 1.95% in Bogotá, which is a clear indication of their speed of development. (Secretaria Distrital de Planeación, 2009).

In 2015 Peñalosa was reelected as Bogotá's major. The current approach of Metrovivienda aims to recover its original function as a land bank. The new administration argues that the projects developed during the previous administration had high costs and produced few dwelling units. The new aim of the institution is to provide

80.000 dwelling units on land left vacant by previous administration due to environmental risks (El Tiempo, 2016). The new vision of Peñalosa also includes new housing in the long term for 3 million people by 2050, for which 15,000 hectares of land will be needed. The project, that comprises different areas of Bogotá, Soacha and Mosquera, has been called "Ciudad Paz" (El Tiempo,

2016). This ambitious plan includes areas with ecological value, for instance the protected area “Reserva Thomas Van Der Hammen”, the river banks of the Bogotá River (Ciudad Rio), along of which the major proposes the construction of a concrete pier and high rise buildings, and part of the irrigation district of Mosquera. These proposals raise serious concerns as to the interplay of the projects with sensitive environments.

1.3. A regional and ecological approach to housing needs

The current approach to housing problems in Bogotá focus mainly in measurable indicators of the missing amount of dwellings in relation to the number of families (Tarchopulos, 2003). Given the scale of the housing problem there is a need for an approach that overcome the simply quantification of the problem but also that is ecologically informed, and create qualitative environments. Water is the main critical element of this approach. Regarding the relation between settlements and the Bogotá River (the main landscape of the region), at the regional scale, there are three possible scenarios for development:

- a) A radical approach: To recover the natural conditions of the river, re-naturalize the river course and reclaim the natural floodplain. This would require the resettlement of around 1 million persons that lived in flood-risk areas, which is not economically, socially of logistically feasible.
- b) A conventional technical approach: To increase the river control through conventional hard engineered practices (heighten dikes and constructing new upstream dams). However, these practices already have been proved to be inefficient to control the complexity of dynamic systems (Novotny, 2008). Furthermore, it is already recognized that control-engineering strategies need to be replaced by “more flexible, adaptive approaches to managing human activities and designing within the systems that sustain us” (Reed & Lister, 2014, p. 28). Last but not least, Bogotá has a long tradition of many, hardly or only partially realized technical water management master plans¹. In other words, implementation within the conventional technical approaches has in practice proven hardly possible and unpractical.
- c) An alternative approach: to live with water by developing new urban patterns that work with the logics of landscape, reclaiming the river floodplain whenever it is possible and protecting existing settlements. This approach that can be labelled as a landscape urbanism approach, assumes that it could be possible to embed urban patterns within the natural water system. In more general terms, landscape urbanism hypothesizes that the landscape structure has the capacity to intelligently accommodate development needs (Giro, 1999; Shannon, 2004, 2008; Shannon et al., 2008; Waldheim, 2006). Hence, in the context of the Sabana de Bogotá, this approach, understood as “working with, rather than against, the forces of nature” (De Meulder & Shannon, 2010) offers a “framework of mediation and assemblage” (Hight, 2014) which can be the basis for a hybrid approach able to negotiate the challenges of the existing conflicts between any type of development (urban, agriculture, flower production, etc.) with the (saturated) water management system.

¹ Some of these projects were the Plan Maestro de alcantarillado de Bogotá, D.E by Camp, Dresser & McKee and Compañía de Ingeniería Sanitaria — 1962), Estudios del Río Bogotá by Camp, Dresser & McKee., CEI, CIA de Estudios e Interventorías & Plan Hidro — 1973 and Adecuación hidráulica del Río Bogotá. Informe de diseño by Black & Veatch & Hidroestudios — 1985. The ongoing project “Bogotá River environmental restoration and hydraulic control”, designed in the conventional approach, is widening the river section 30 meters and will increase the treatment capacity of the El Salitre WWTP. It has a cost of 487 US million dollar, and investment that probably will not be repeated soon.

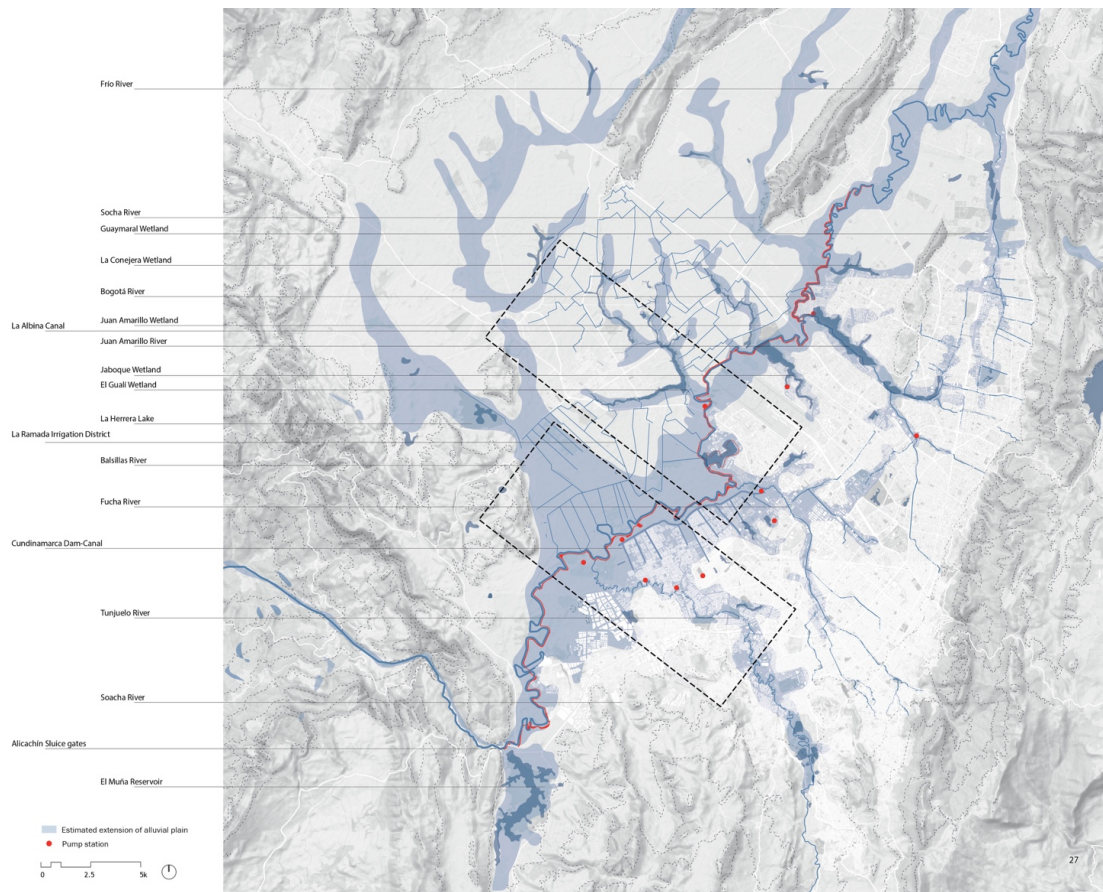


Figure 2. Water system 2015. Elaborated by the author.

2. Design Investigations in two selected sections

The landscape urbanism hypothesis requires design explorations to test its validity. Two case studies were selected, as a cross-scalar tool to read and interpret the territory and to test until what point a strategy of embedding within the landscape structure, in this case of the Bogotá Sabana dominated by the water system, is possible.

The two case studies correspond with two sections across the Bogotá River that serve to test a sufficient range of different conditions encountered within this landscape. The case 1, Funza and Mosquera is located upstream, where the floodplain is narrow and cut across the El Gualí wetland. The case 2, Bosa is located in the lower segment in the confluence of the Tunjuelo and Bogotá rivers, where the floodplain is wider and there is high flood risk². Current housing dynamics are



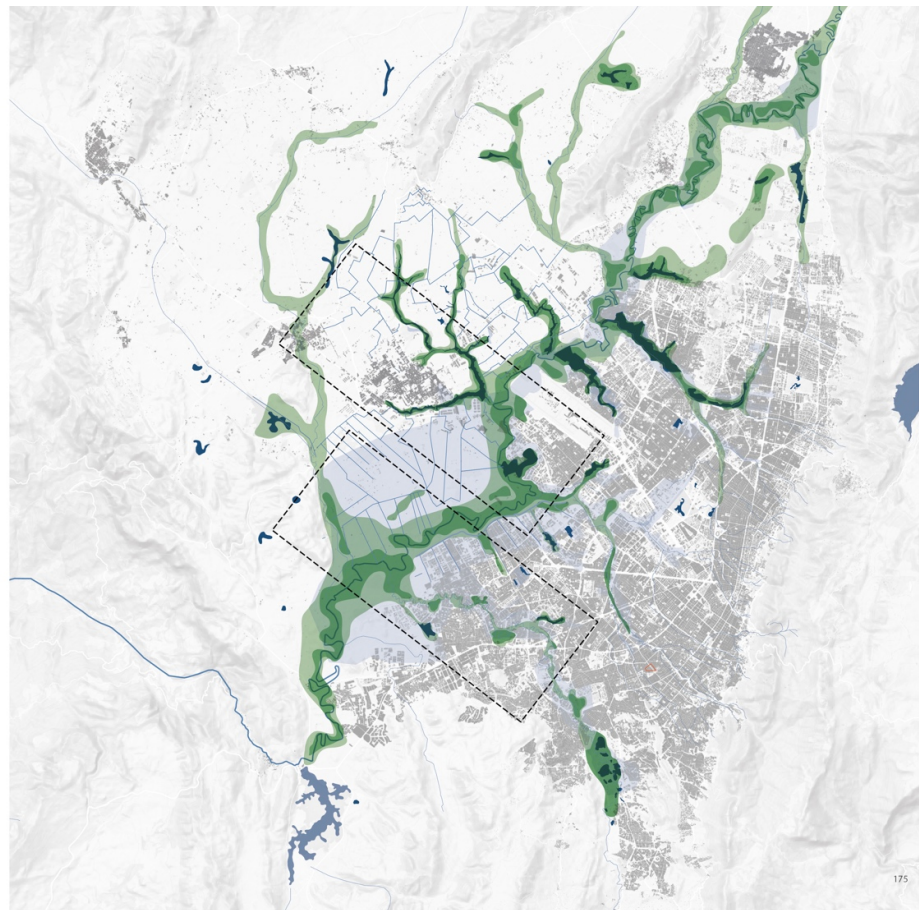
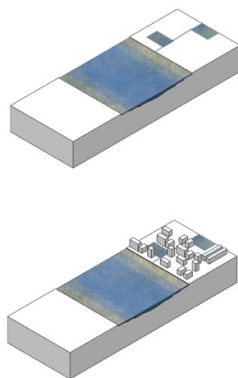
Figure 3. Landscape of the case studies. Left: Funza and Mosquera, Right: Bosa.

² These two variations in the floodplain width correspond with two segments defined by geomorphological research, the first corresponds with the area between the Frío River and the point where the El Gualí Wetland connects to the Bogotá River, the second is located between this point and the confluence with the Tunjuelo River. In the first segment, the floodplain is narrow, there are more and smaller meanders. In the second segment, the floodplain is wider, and there are fewer and larger meanders (Etayo, 2012).

also different in each case. In the first, housing projects are mostly urban fragments of medium scale that are added to the existing tissue. In the second, housing projects are large-scale projects through which large areas of land are urbanized. Three strategic sites were selected within the two cases to develop the design investigations in detail: Vereda Siete Trojes and Vereda El Hato (Funza and Mosquera), and the confluence of the Bogotá and Tunjuelo Rivers (Bosa). These sites each have the potential to create “ambiguous and rich thresholds that redefine the between urban/rural and between urban/nature” (Shannon, 2004).

The design is based on a previous descriptive analysis based on fieldwork and mapping (Rojas, 2015, 2016). Detailed information about each section was collected during three fieldwork visits, August-September 2013, April-May 2014 and July-September 2014. The last fieldwork session was developed in collaboration with students from KU Leuven and Universidad Nacional de Colombia. The fieldwork documented settlement patterns, uses and activities in selected areas through photography, sketches and interviews. It provides an overview of the urban development trends and spatial water issues. Information about urban development plans and housing projects was collected in the planning offices of Funza, Mosquera and Bogotá. The collected information was processed through an interpretative mapping exercise. Mapping is used as a preliminary stage for the development of the design and to gain a deeper understanding of a specific context³. “Interpretative mapping is a first step to transform a territory. An understanding of the context and the reading of sites — from diachronic and synchronic perspectives are necessary in order to create modifications that have logic and relate to the particularities of places and situations” (Shannon, 2008: 105). “Mapping is perhaps the most formative and creative act of any design process, first disclosing and then staging the conditions for the emergence of new realities” (Corner, 1999: 216).

Figure 4. Design investigation at the regional scale. Reconstructed wetlands and reclaimed floodplain. Elaborated by the author.



³ The results of the mapping exercise are part of an atlas of the territory that consists primarily of visual material with extended captions. The atlas presents the major challenges regarding climate change and urbanization, the historical relationship between water and settlement, the contemporary conditions of the Sabana de Bogotá and the design investigations that are part of this paper.

A first approach to the cross scalar design strategies and concepts were developed through two international design workshops⁴ and three master thesis⁵. These exercises served as a first stepping-stone, to formulate ideas and concepts about the area, to identify strategic sites of interventions and define basic concepts. These ideas were later manipulated and transformed through design to respond to the specific objectives proposed by the PhD research. The aim of the research by design is not solve problems per se, rather “questioning-reformulating problems, forming insights, staging scenarios, and spatially intervening to simultaneously accept global forces while producing local values” (Shannon, 2016, p. 87). The main objectives of the present design investigations are:

- Recover the sponge condition of the floodplain, increasing resilience and biodiversity in the ecosystem.
- Increase the protection of existing settlements and create new settlements typologies that can adapt to variable water conditions.
- Reduce the dependence and the impact on external ecosystems (water supply from páramos, depletion of aquifers, water pollution in the Bogotá River).

2.1. Design strategies

The design research strategies are not only drawn upon notions of sustainable water management, but also upon the existing logics of landscape and urbanization. These strategies condense a series of operations that lay at the intersection between redirecting natural processes and settling a terrain on which development can occur. The application of these strategies varies according to the careful reading of the potentials (landscape, economic and social) and (ecological and urban) threads of each site.

As such they are exercises in settling: organize settlements in spatial conditions highly determined by water conditions. Settling and settlement is here understood as a variation of meanings: 1. Settling as dealing with: settle the water, decide 2. Settlement as establishing place (in this case provide/establishing/making place for (mass) housing solutions) and 3. Settlement as reconciliation, as fair agreement between two opposing forces: nature and city, water and housing, 4. Settling as setting a standard, deciding a rule, the rule of water in this case.

- a) Settling waters — The different design research exercises use of topographical manipulations to create a basic “printing plate” on which to anchor future development (Nolf & De Meulder, 2013; Palmboom, 2010; Shannon, 2004; Shannon & De Meulder, 2013). The importance of topographical manipulation was already understood by the Muisca culture that inhabited the wetlands (Rojas, De Meulder & Shannon, 2015), which could be considered as archetypes of landscape urbanism (Shannon & Manawadu, 2007). The different levels, created by modifying the natural terrain, defined places to hold, circulate, clean or harvest water (all this through cut and fill operations). This reprofiling of the terrain defines a base layer that changes according to the weather conditions. In this way, the terrain works as a sponge. The variable conditions in the different levels can accommodate different programs and create habitats for endangered species. For instance, temporary flooded areas can be used for agriculture or recreation purposes and wetland ecosystems can easily flourish in permanently flooded areas. At the same time, the topographical manipulations define “safe levels” for housing and infrastructure.

⁴ The first was the intensive international workshops Water + City, with the participation of fourth-year architecture students from UNAL (Universidad Nacional de Colombia) and UNAM (National Autonomous University of Mexico) and thesis students of Master of science in Architecture from KU Leuven. The second workshop, Water + Urban borders was part of the design studio: Urban project (fourth year Architecture — UNAL), for the same students from UNAL and KU Leuven.

⁵ Three master thesis titled “Re-articulating waterscapes and urban structures in the Sabana de Bogotá” were elaborated to address the issues of water and housing by students of the Master of science in Architecture at KU Leuven (L. van Aert, B. Van Sever, C. Timmers, A. Zervas, M. Linssen and J. Van Haverbeke). The work was supervised by B. De Meulder and co-supervised by the author of this paper.

- b) Reconfiguring plots — The re-configuration of plots facilitates the implementation of the project as well as preserving landscape elements that define plot limits such as canals and trees. The design proposal is framed within this man-made nature: the grid of the plots. The grid serves as a framework but the design is not completely restricted by it. Natural processes also inform the geometry of the proposal. The selected sites have the advantage of being divided in large plots, which will reduce the negotiation process with stakeholders. A partial plan (plan parcial) is legally required in order to urbanize expansion areas. Landowners have to conclude an agreement and the public sector is involved in the definition and implementation of the master plan. Consequently, it is possible and feasible to propose new alternative approaches that can balance housing and environmental needs. Working with the grid of plots also allows development of the project in phases, according to timing in which land becomes available.
- c) Intersecting landscape and settlements — Settling waters not only attempts to cope with water issues in terms of quantity, but also to create a hydrological infrastructure that allows new interplays between housing and productive landscapes, to settle, arrange a settlement between water and housing. This hydrological infrastructure has three functions: (1) To make visible and tangible the water flows creates a general awareness about Bogotá's water crisis. Although it is difficult to resurrect the symbolic meaning of water, the magnitude of the crisis calls for establishing new socio-cultural relations with water (Shannon, 2013). A first step towards this goal is to bring backwater to the public sphere; (2) To close the water cycle by harvesting and recycling water on site; (3) To integrate biological diversity and socio-cultural uses by designing a "polytechnic" water infrastructure.

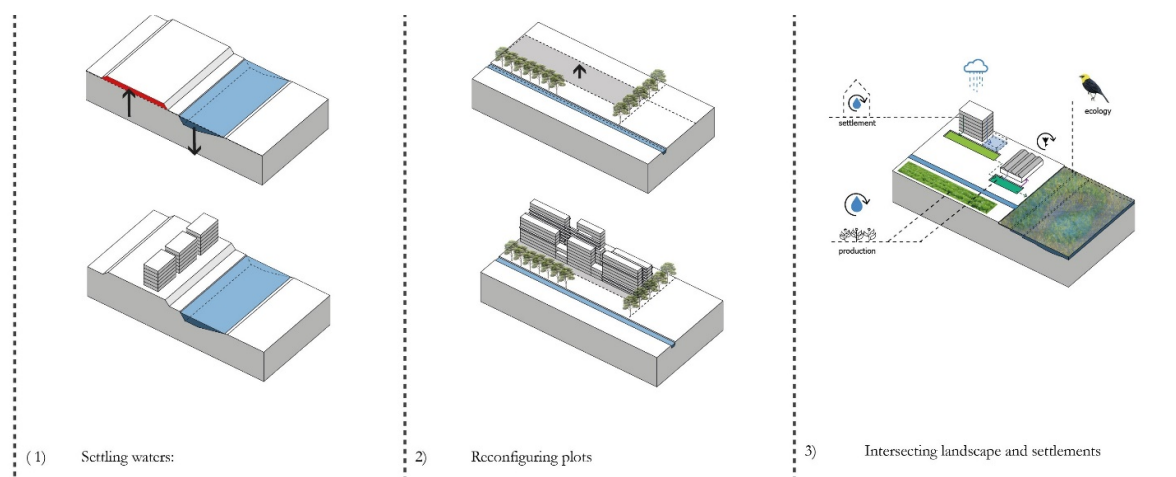


Figure 5. Design strategies. Elaborated by the author.

3. Case 1. Funza and Mosquera

The section cuts through the middle area of the Sabana de Bogotá, including the Gualí wetland and the municipalities of Funza and Mosquera. The urban growth of these municipalities exemplifies the urbanization trends in the Sabana de Bogotá. The predominantly unplanned growth is in conflict with the deep agricultural identity of the landscape, which derives from the very fertile soils and centuries of exploitation that generated an impressive accumulation of irrigation networks. During the pre-Hispanic period, land exploitation was anchored on the natural river cycles and water management was well suited to the wetlands and floodplains. One could say that agriculture inscribed itself in, 'settled' in the water system. After the seventeenth century, land was progressively reclaimed for extensive agriculture and livestock through the superimposition of a network of ditches. This network was gradually improved and later transformed in the irrigation district La Ramada that provided fresh water supply from the Bogotá River during the dry season and drainage during the rainy season (Rojas, 2015). The fast development of housing and industry after the 1990s rapidly transformed the water system. Canals have been filled and wetlands encroached, while agriculture is abandoned due to land speculation and water scarcity, the water supplied through the canals is also highly polluted.

In the municipalities of Funza and Mosquera land is cheaper and legal procedures are faster and easier for urban developers. This facilitated social housing production and resulted into the construction of 14,517 social housing units between 2002 and 2007. This growth was not foreseen in their respective urban plans. Since municipal regulations do not require the provision of social infrastructure (schools, healthcare and recreation facilities) within the housing projects, the new housing meant the rapid over-stress on the existing social infrastructure (Escallón & Quiñones, 2010).

The main landscape element in the area is the Gualí-Tres Esquinas wetland, which is one of the few environments that preserve a number of original characteristics of wetlands ecosystems in the Sabana de Bogotá. Its conservation is critical for the overall hydrological performance of the Bogotá River floodplain and for the overall environmental conservation in the region. In addition, the wetland functions as a reservoir for the La Ramada irrigation district.

3.1. Design task

Official city population projections estimate the need to construct 58,000 new housing units by 2030 (Dane, 2006). These projections ignore regional population dynamics, especially from Bogotá. The population growth will increase the pressure in the Gualí-Tres Esquinas wetland and water stress in the whole region.

In order to preserve and restore the wetland, the Corporación Autónoma Regional de Cundinamarca CAR, declared it as a protected area “Distrito Regional de Manejo Integrado” (DMI) in February 2014 (Acuerdo 001 de 2014). This legal framework is an initial step towards the ecosystem restoration, but it is restricted to the wetland and its immediate surroundings. In addition, it is unclear how this statute can be translated in spatial terms that simultaneously preserve the wetland and respond to urban dynamics.

The design research investigates the potential of a new water structure to concurrently deliver the frame in which new housing fabrics can be integrated while preserving and restoring the productive and environmental qualities of the landscape.



Figure 6. Design investigation in section 2: Funza and Mosquera. Elaborated by the author.

3.2. Sites: Vereda El Hato and Vereda Siete Trojes

Vereda El Hato is located in the eastern part of Funza. The elevation of the area ranges from 2530 to 2550 meters above sea level, descending towards the wetland. In the lowest area there is low flood risk. The vereda can be divided in two areas. An agricultural area divided in large plots of land and the urban area of Funza divided in small plots on which informal housing started to develop since 1970s. During the pre-Hispanic period, the main large Indian Muisca settlement was likely located closed to this area (Boada, 2013). After Spanish conquest, the land was used

almost exclusively for agriculture. In 2005, the first industries were constructed along the regional road US 21. New housing projects are constantly pushing the boundaries of the urban land.

The Vereda Siete Trojes is located in the north part of Funza and Mosquera. During the 1960s families dedicated to medium scale agriculture inhabited the area. Some of these medium-scale farms preserved the agricultural tradition until the end of the 1980s. Today few peasant families are still present. The disappearance of agriculture is strongly related to the transformation of the water system as a result of the development of industrial parks, flower farming and housing.

3.3. Topographical manipulations

In the vereda El Hato, the on-going housing and industrial projects are built by raising the land 1 to 1.5m. There is also a dyke of about 2m in some sections of the wetland. The proposal rationalizes these existing processes. The structure of the large plots is preserved as a major framework on which topography is manipulated to create safe areas for housing. The design attempts to create a dynamic gradient of wet and dry as interface between the wetland and the city. The new housing typologies are choreographed to dissolve within the preserved wetland.

In the vereda Siete Trojes, new platforms for housing are created taking advantage of the natural topography that is higher along the Carrera 15 (main road) and lower towards the wetlands. Cut and fill strategies define three areas and give more space to water. One along the Carrera 15 that connects with the colonial centre. Here the typologies create a civic axis with commercial activities, social facilities and a series of open/public spaces. An intermediate zone that combines high density housing with agriculture. And a lower area for the extension and preservation of the wetland in which flower is combined with ponds for rainwater collection.

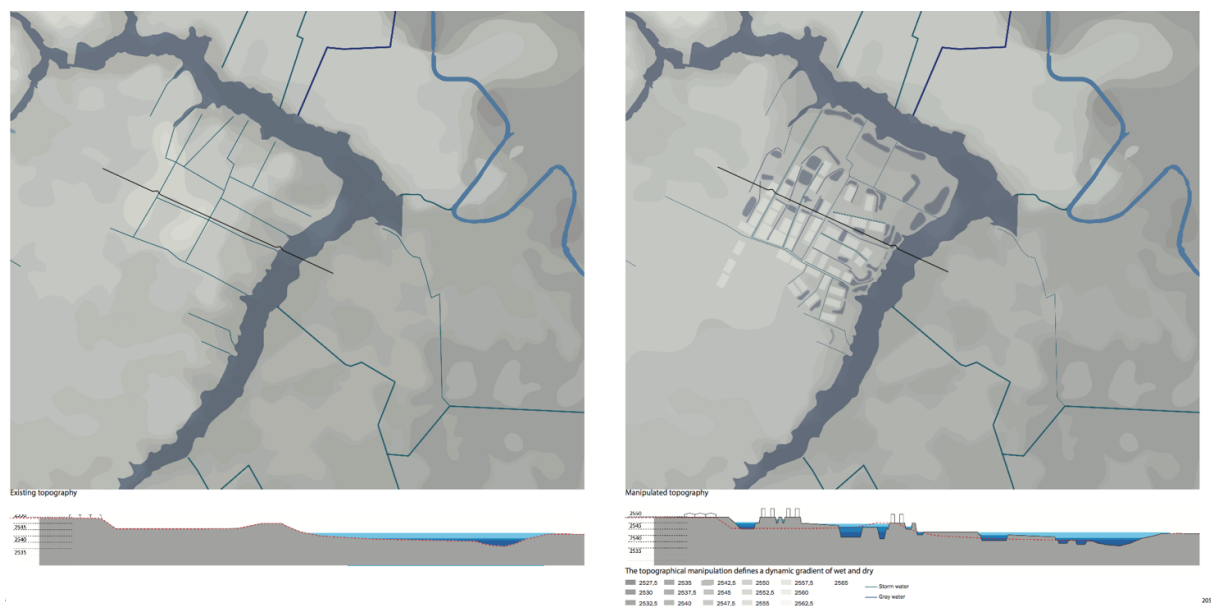


Figure 7. Topographical manipulation in the Vereda El Hato. Existing (left) Proposed (right). Elaborated by the author.

3.4. Reconfiguring the water cycle and recovering productivity

Every year Funza receives an average rainfall of 600mm. Since the soils here are mostly impermeable most of this rainfall is lost in the drainage pipes. At the same time, the aquifers are being pumped out and the water table is descending quickly. The growing demands for fresh water, the effects of climate in the reduction of the paramos ecosystem and the changes in rainfall patterns, worsened by “el niño” effect, make necessary to introduce a system of storm water collection and gray water recycle and re-use.

The families that still preserve the agriculture traditions plant small orchards in their plots on which they grow tree tomato, vegetables, herbs, potatoes and corn. However, these activities are not their main economic resource. Family members work in the industrial sector, in the flower

farming industry or in tertiary activities. Due to water shortage, they are facing more problems to preserve the rural life style as well as pressure from development to sell their plots.

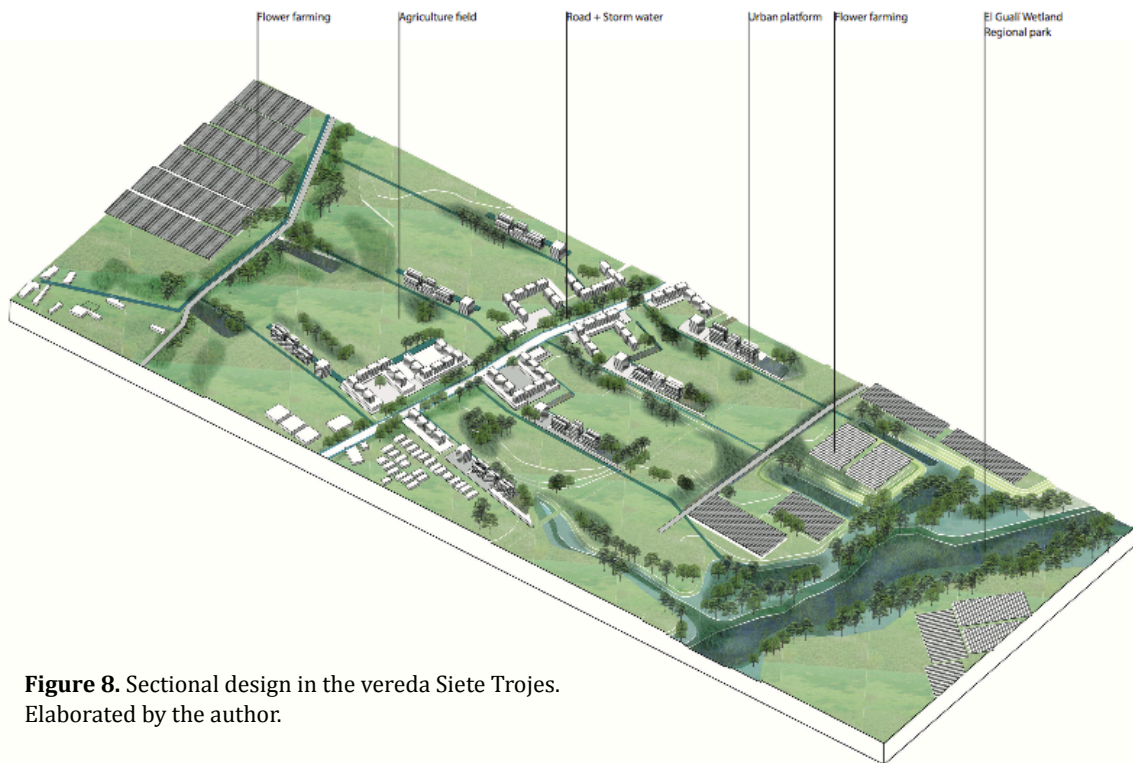
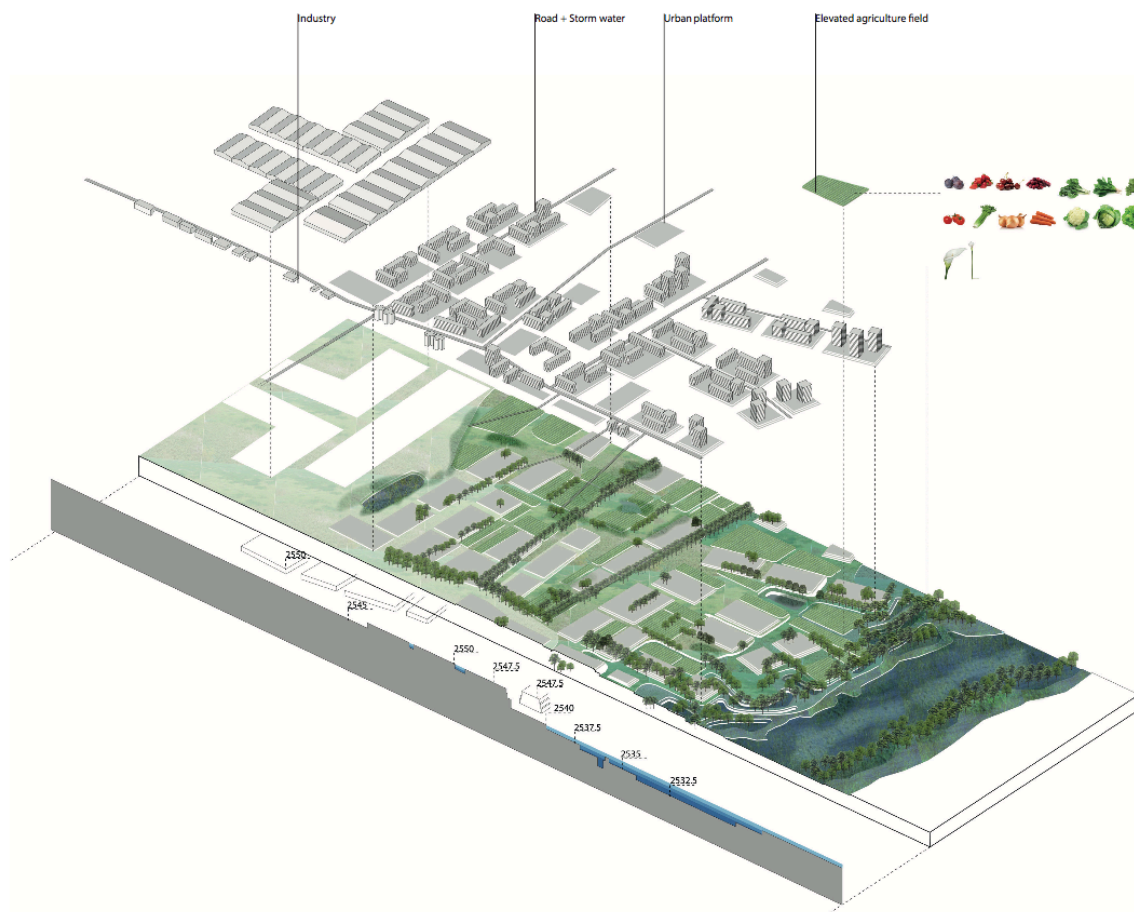


Figure 8. Sectional design in the vereda Siete Trojes.
Elaborated by the author.

Figure 9. Sectional design in the veered El Hato.
Elaborated by the author.



The preservation of the agriculture identity has a potential role in “determining the economic, ecological and spatial order of the city” (Waldheim, 2010). The irrigation system, built after 1920, is critical to guarantee food security for the region. The design manipulates this layer, integrating a new agricultural order that simultaneously functions as a structural framework for housing. The proposed grey-water system is organized as an independent series of decentralized units. In each of them grey water from the housing blocks is cleaned through a sequence of wetlands. Agricultural plots are arranged to benefit from the treated grey water, preserving the existing land subdivision. Storm water run-off is integrated in the street profiles, cleaned through linear swales and directed also to the agricultural plots or wetlands. Recently, flower farming industry started to collect the storm water in order to obtain international certification in sustainable practices. Integrated systems of harvesting rainwater can also be incorporated to the design of the social housing blocks.

3.5. Polytechnic water infrastructure

Modern water management prioritize a “monotechnic” technology for the sake of technology progressively eliminating biological diversity and socio-cultural uses. This approach was question under the paradigm shift of sustainable water management that advocates for the return of a “polytechnic” approach that provides a complex framework to solve human and environmental needs (Rojas, 2016). The proposal provides a framework for the urban blocks that is defined by topography and water flows. The sectional design combines the re-engineered of the water system with landscape programs. Street profiles are designed as boulevards and integrate storm water management. Water treatment ponds can be used as ecological devices and recreational activities. Agricultural areas could be temporarily flooded in order to cope with major extreme events.

3.6. Open housing tissue and urban armatures

Elevated plots are distributed according to the existing topography and the water flows. The plots cluster along the main infrastructural lines given continuity to the urban tissue and creating a civic axis that contains commercial functions and services. The occupation of the land decreases towards the wetland while density increases taking advantage of the view over the natural surroundings.

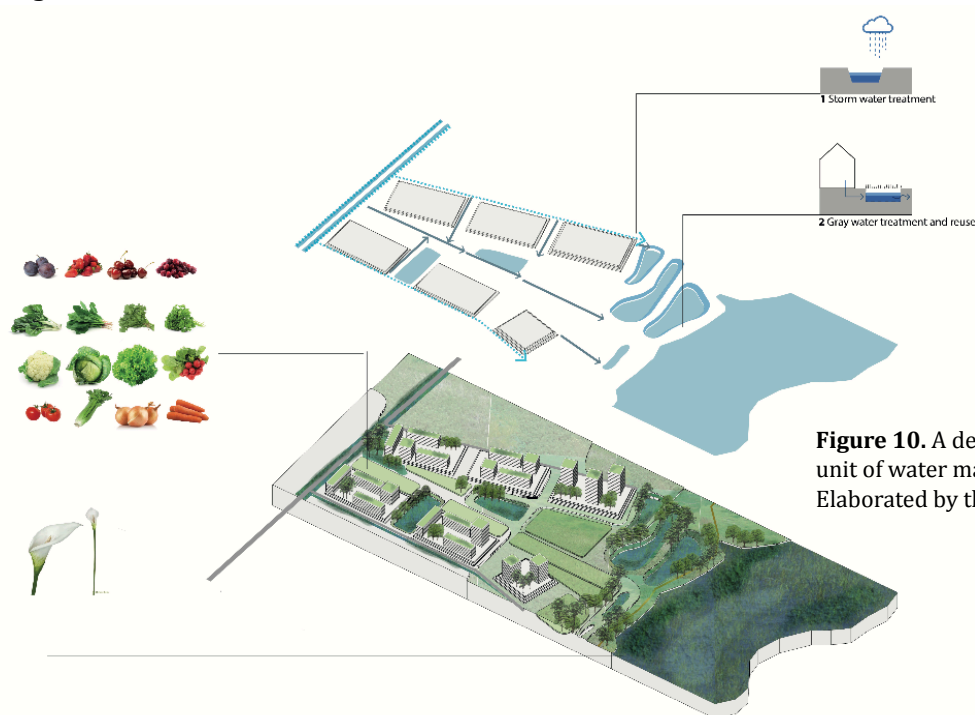


Figure 10. A decentralized unit of water management. Elaborated by the author.

4. Case 1. Bosa

The confluence of the Bogotá and Tunjuelo Rivers is one of the few areas with vacant land within the administrative boundary of Bogotá. It is part of the southwestern area of the Bogotá River floodplain, which was gradually reclaimed for housing. The interest to formally develop the area

for housing dates back to 1953, when the municipality of Bosa was annexed to Bogotá. The first informal neighbourhoods appeared as a result of the subdivision of agricultural estates, draining the land with rudimentary canals and building on low quality fill from waste construction material. Such strategies did not provide protection against frequent floods. Several studies for the Bogotá River flood control and environmental recovery developed between 1963 and 1988 studied drainage alternatives for these low lands. Not much from these plans was implemented, except emergency works between 1979 and 1981 that responded to the severe flood of 1979 (Rojas, De Meulder & Shannon, 2015).

By 1991, EAAB formulated the project Santafe I. The project had two main objectives. One was to reduce flooding. The other was the construction of sewer networks in the periphery to enable the construction of large social housing projects (Hidroestudios, 1999). The water infrastructure works began in 2000, guided by a water management plan for the El Tintal watershed. Works included the construction of the Canal Cundinamarca, a long canal parallel to the Bogotá River that collects rainwater from perpendicular canals and wastewater from new sewerage interceptors. The same year, the area was officially included in the Bogotá's POT (land use plan). After the construction of the Canal Cundimarca, the area became the largest container of social housing projects, among them the El Recreo and El Porvenir.

4.1. Design task

At the moment, the most southern area, which is still undeveloped, it is not covered by water infrastructure. The area is undergoing huge pressure due to proximity of legalized neighbourhoods and areas of emerging subdivisions. There are two partial plans (urban development plans) proposed in the area: Campo Verde and El Eden. The implementation of both face difficulties: Campo Verde mainly due to flood risks and El Eden because the Indian community of the "Cabildo Musica de Bosa", that owns part of the land, was not included during the planning process (Caballero & Amaya, 2014). In addition, part of the land was declared as ecological structure in the Bogotá's land use plan: POT of 2000 (Plan de Ordenamiento territorial).

As well, the confluence of the Bogotá and Tunjuelo Rivers suffers from seasonal river overflows and water pooling due to the low level of the land. New studies to update the flood prone areas will be developed when the construction of the project "Bogotá River environmental restoration and hydraulic control" is finished (POT, 2013). There are three options for the area: (a) to keep the land agricultural. However, the agricultural activities have decreased and informal settlements are emerging; (b) to develop the land following the existing master plans. The plans were designed dependent on traditional hard engineered solutions for water management and left little room for climate change adaptation; and (c) to develop the area providing space for water, protecting exiting settlements and integrating environmental protection areas. The design research investigation aims to develop the last option.



Figure 11. Design investigation in section 1: Bosa. Elaborated by the author.

3.2. Topographical manipulations

The new topography creates three distinctive landscapes: (1) a new multifunctional dyke that serves as a threshold between the existing and the new tissue; (2) elevated urban islands that create safe levels for housing and infrastructure; and (3) a floodable research park by transforming the under-used agricultural areas into water detention ponds.

A new paradigm of water management appeals for a “soft engineering” approach that manipulates the existing layer of water infrastructure according to natural processes and urban dynamics as well new ways to anchor development to this hybrid infrastructural system (De Meulder & Shannon, 2010). The continuous heightening and strengthening of the dykes created a physical barrier that disrupts spatial continuity and reduces the rivers and their ecologies to a narrow strip (Prominski, 2012).

Instead of being a continuous line, the proposed dike is designed as a green infrastructure that bifurcates and interweaves with the urban fabric the road infrastructure. The dike is coupled with other programs by varying its width. Part of the dike is transformed in the proposed highway Avenida Longitudinal de Occidente A.L.O, while other parts serve as a platform for social housing or social infrastructure. The geometry of the new dyke follows the main lines of existing plots. It protects existing settlement from floods and, at the same time, is a landscape of integration that gives space for the confluence. The dike serves a platform and provides visual and physical connectivity toward the new water landscapes.

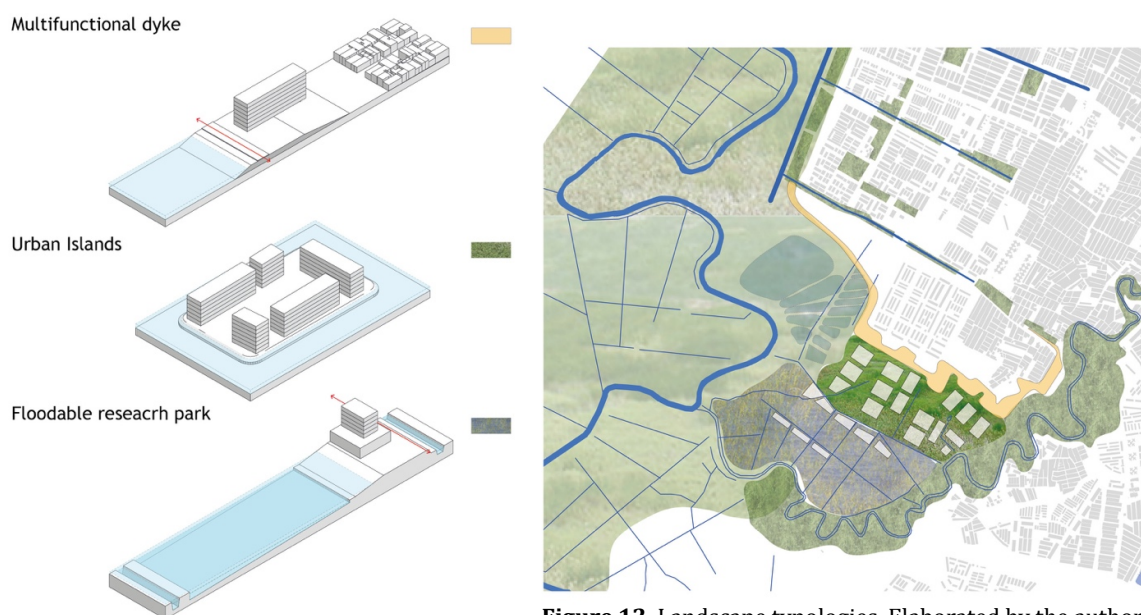


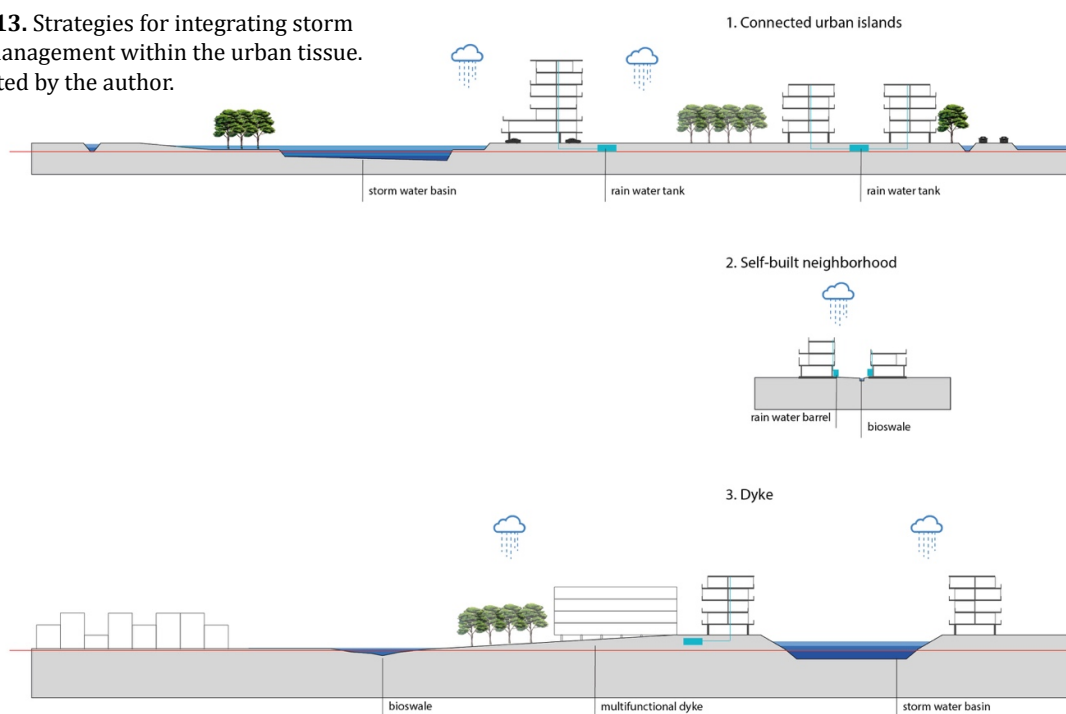
Figure 12. Landscape typologies. Elaborated by the author.

3.3. From water lines to water fields

One of the most effective strategies to increase resilience is to provide space for water (Prominski, 2012; Shannon & De Meulder, 2013). The possible strategies to provide space for water retention include: (a) to recover the floodplain the associated ecologies at the river edge; (b) to expand the water retention capacity of existing water elements. For instance, transform the section of existing irrigation canals or change under-used agricultural areas into wetlands; (c) to integrate spaces for storm water collection within the new and the existing urban tissue.

Creating space for water not only reduces dependence on traditional engineered systems, but also improves ecological performance as water flows nourish a range of plant and animal species. It also creates a tangible link between people and climate change. “Water is political, not only in moments of scarcity, but also in moments of abundance” (Picon, 2015: 37). By making visible the relation with water, design can make visible its value as environmental and civic common space (Orf, 2016).

Figure 13. Strategies for integrating storm water management within the urban tissue. Elaborated by the author.



3.4. Floodplain re-programming

Originally the confluence was a marshland. Currently, there are agricultural activities but it is defined by the land use plan as part of Bogotá's ecological structure. The area is at the edge between urban and rural landscapes, will have good connectivity once the project for the ALO (Avenida Longitudinal de Occidente) is constructed and the proposed manipulation of the topography will create new areas where water levels fluctuate. This could be an opportunity to create a new type of productive and research park for Bogotá, on which different uses for the ponds and wetlands can be explored. Research activities could include, water treatment technologies, fish farming, hydroponics and solar energy. Research can also include the recuperation of the indigenous ridged fields. Traces of some of them are still visible in the proximity to the Bogotá River and can provide an opportunity to respond to the demands from the Indian community and at the same being an important archaeological landmark along the river course.

Investment in agricultural research is one of the key components of the recently signed agreement between the government and FARC. Investment in the implementation of this agreement can be canalized towards realization of the research park. More importantly the outcomes of the research can be replicated on other areas of the Sabana.

Finally, these activities can be combined with recreational uses, such as camping or fish farming. This research park would be articulated with existing public armatures, such as the extended Alameda El Porvenir, a boulevard of 18km that forms a civic axis and structuring element of the neighbourhoods east of the Bogotá River. Traditionally, non-formal activities, like farming and animal husbandry have been excluded from the formal city. This park could provide an opportunity for alternative programs for rural immigrants and internal displaced people; it could become a landscape of integration between the city and the Sabana, between the rural immigrants and their new environment.

5. Conclusion

The design investigations elaborated in this paper are an attempt to rethink Settling with Waters, to move beyond the contradiction between the city and the "natural" Sabana, to restructure settlement and productive landscapes in relation to water systems and to rethink the structure of water systems themselves. The research proposes a landscape urbanism approach to deal with the contradiction between environmental protection in the Sabana de Bogotá, the provision of social housing and new economies. This has been done by projecting new settlements, public

space and production morphologies that are inscribed within the landscapes, in relation to topography and hydrology.

The research attempts to contribute to the debate of how the city should grow by developing hybrid strategies that work with the forces of nature. Water and soil are the main natural resources in the Sabana. It is already clear that the main issues regarding the future sustainability of the region are the supply of potable water and social housing. Productive and economic activities need to be reconsidered and the agricultural identity need to be preserved. This is especially clear when we consider that expanding world population is leading to a food crisis and local food production as an important factor for ecological sustainability, biodiversity and environmental health. In addition, there is a need for an overall strategy social housing provision that considers the particular conditions of the territory.

The ecological crisis in the Bogotá Region requires a deep understanding of its water system in relation the development pressures, particularly low income housing and economies that continue to inhabit the territory in contradiction to its inherent logics. To return the watershed to its “natural” state is a naïve objective. Urbanism has a crucial role in developing hybrid assemblages that respond to the contradictory challenges embedded in the landscape of the Sabana and the river’s watershed. “Settling with Waters” has tested the possibility of alternatives to contemporary water management, productive landscapes and housing paradigms through two case studies.

These design investigations allow identifying three key elements that can be the base for developing a constructive interplay between water and settlement in Bogotá and also elucidate the application of landscape urbanism principles in contexts of rapid development:

Site Specificity: Design investigations started by understanding the natural and socio-economic conditions of the site. In order to increase landscape resilience in the Sabana de Bogotá urban tissues should recreate the original field condition as a “sponge”. The landscape typologies developed in this paper illustrate how this condition can be restored in different sites by creating an open tissue that is intertwined with the hydrological infrastructure and productive landscapes.

In the first case, that of Funza and Mosquera, it was crucial to preserve the fertile soils for agriculture and to protect the El Gualí wetlands. The preservation of the wetlands can be supported by its function as reservoir of the La Ramada irrigation district. “Settling with Waters” in this case relied on a careful reading of the fine-grain irrigation network and how it could become the land division system for both innovative agricultural (and aqua-cultural) economies and housing typologies that worked with the ebbs and flows of the rivers water levels. Settling is taken as to settle, to inhabit and live on and from the Waters.

In the second case, that of Bosa, it was critical to address the problem of flooding, to protect existing settlements and preserve natural ecosystems (the remaining wetlands that are not protected by law). “Settling with Waters” in this case, enough room had to be created for the extreme changes that are associated with the river’s dynamics (which will be exacerbated by climate change), while at the same time creating housing and public amenities that work with the dynamics. Settling is taken as to come to agreement with, to settle a claim between things, with the Waters.

Double coding: Design strategies were defined to address multiple issues simultaneously. In the case of the Sabana de Bogotá de hydrological infrastructure creates a framework to solve housing needs while improving the environmental conditions. The design started by de-constructing the complex water system. The water network is a support for the spatial structure, but it is partly hidden. However, when it is visible it creates conflicts with the public sphere due to pollution. The potential to transform this water network can be explored by understanding its physical relation with the built environment as well as the way in which water is metabolized by the city. The new relations between water and settlement proposed by the design are based on the specific characteristics of the water network and the different layers that composed it. The traces of indigenous field, the irrigation and storm water canals, the wetlands, and the defensive elements like dykes. Each of these layers has their own logic and there potential depend on the relation with

the topography and with the water cycle. Once the water network is transformed into a visible structuring element it allows to make evident process and cycles creating awareness in the population. The interrelations constructed along the new water system also hold the potential of supporting new economies that are closely tied to existing activities and landscape logics.

Sectional representation:

Design research investigations are always at the intersection between the reading of the site and its logics and the potential to intervene and transform existing structures. During the development of the design investigations sectional design played a crucial role. As an interpretative tool, sections enable the integration of different types of knowledge and the highlighting of the interconnect-edness between different systems, which enabled a deeper understanding of the site. As a projec-tive tool, sections settle a terrain in which development can occur and also organize new relations between different uses and programs that close the water cycle.

The design investigations elaborated new alternatives regarding the urban conditions of the hous-ing production, in order to preserve fragile ecologies, create qualitative public infrastructure, guaranty a more sustainable use of water and create new relations with existing economies. More research has to be done regarding the quality of the dwelling units and the funding schemes for housing production.

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