Innovative Solutions for the Delta

Innovative ideas for deltas cities to respond to climate change challenges in the complex urban environment

ROTTERDAM.CLIMATE.INITIATIVE
Climate Proof

Deltas in Times of Climate Change
Rotterdam 2010
Connecting world science and deltas

DeltAlliance

ROYAL HASKONING
thinking in all dimensions

DeltaCompetition 2010

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Foreword

DeltaCompetition 2010: Innovative ideas for deltas cities to respond to climate change challenges in the complex urban environment

Dear reader,

Half of the world's population lives in densely populated city regions in delta areas. These delta cities are among the most dynamic areas in the world. But delta cities are also highly vulnerable to the impacts of climate change. Rising sea levels, increased river discharge, extreme weather conditions, salination of groundwater and subsidence constitute significant and increasing threats to the delta cities and the people living in them.

The increased pressure on delta cities has led policy makers and experts to rethink their development strategies. Countries all over the world are looking into ways to adapt to climate change. All over the world, people are trying to find practical, innovative, sustainable solutions to adapt to the impacts of climate change and facilitate sustainable development of delta cities.

Since 2006, the DeltaCompetition has sought new, creative and innovative solutions to these challenges and received many original, feasible and scientifically sound ideas for pioneering projects. In 2010 we have involved new partners who share our vision in this regard. They are Delta Alliance, an emerging worldwide network devoted to the problems of deltas, and the Municipality of Rotterdam, a delta city that has already made significant steps towards a sustainable, climate proof development.

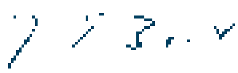
This year there were more entries than ever. In total no fewer than 24 teams from all over the world sent in their ideas. We were pleasantly surprised by their high quality. The broad scope of the proposals was also remarkable. In addition to 'classic' engineering solutions, this year we received many entries with a landscape or managerial slant.

Take the entry by a team from America's Harvard University. Their project explored the disadvantages of climate change in the Netherlands and sought to turn them around. The result was a far-reaching, long-term vision with ecology as the keynote, which could not fail to stimulate and challenge.

An entry by Novi Rahmawati, of Indonesia's Gadjah Mada University, examined the consequences of urban land subsidence, probably the greatest challenge in that region. Based on a thorough model-based study, she presented a readily applicable solution.

Virginia University's David Wooden also contributed plans to cope with the consequences of subsidence. However, his entry offers a different innovative solution, tailored to the local situation in New Orleans. A feature of his entry is its integral design.

The ten best papers of the 2010 DeltaCompetition have been incorporated in this book. We hope they will inspire you, like Royal Haskoning, the Delta Alliance and the City of Rotterdam, to respond creatively and sustainably to the challenges facing the world's delta regions.



Jan Bout,
Chairman of the Board of Management
Royal Haskoning

Report of the Panel of Judges

The judges of the 2010 DeltaCompetition received and reviewed a total of 24 papers submitted by students from all over the world with great pleasure and interest. As set out in the DeltaCompetition rules, entries were appraised by the judges with particular attention to:

- relevance to a problem that delta cities face with climate change;
- scientific fact and reasoning;
- innovative elements and ideas; and
- presentation of concepts and ideas.

In general, the judges were impressed with the range of subjects and the innovativeness of the papers. The high quality of submissions made the selection of winning papers a difficult task, but the judges finally reached a verdict with three winning papers and seven runners-up. The ten chosen papers are presented in this volume, together with comments from the judges on the three winning papers.

The following papers have been selected as the three winners:

Ecology as industry

Haein Lee, Gyoung Tak Park, and Soomin Shin, Harvard University, Landscape Architecture

This vision for de-engineering water management in The Netherlands presents a regional plan for capitalizing upon the local ecology while addressing increasing flood hazards and land subsidence. Four transformations for the Dutch delta are outlined: coastal, infrastructure, estuarine and urban. These transformations include multi-use de-poldered areas, constructing barrier islands, relocating port activity, new industries of aquaculture and alternative energy production and an expansive recreational landscape. Through thickening flood-defence and allowing sedimentation and peat growth to match rising sea levels, the transformations promise to improve safety while simultaneously restoring diverse habitats.

This increasingly popular concept of harnessing natural processes in designing flood defence is elegantly presented in this paper. Specific measures are incorporated into a strong overall vision, which is supported with substantial background on the Rhine-Meuse delta and striking images. It powerfully illustrates that the issues facing delta cities require regional approaches that view the delta as a landscape system.

Groundwater zoning as spatial planning in Semarang

Novi Rahmawati, Gadjah Mada University, Water Resource Management

The Semarang delta, like many of the world's deltas, is encountering increasing flooding problems due to land subsidence. In parts of the delta land subsidence due to groundwater exploitation and construction loads exceeds 16 cm per year. Intensive groundwater abstraction in the coastal areas of Semarang is addressed in this paper through the idea of groundwater zoning – spatial planning based on identifying the areas most degraded and at risk of degradation through groundwater abstraction. Novi Rahmawati modeled the groundwater flow in North and East Semarang sub watersheds to delineate appropriate zones for groundwater recharge and discharge.

The paper shows clear insight into the local situation by addressing the greatest threat of Semarang. The judges consider the proposed solution a practical proposal for confronting subsidence, which is also highly relevant for many deltas around the world. Jurors also noted that the modeling of the groundwater flow was well supported with detailed data

The Big Leak: Adaptive responses to New Orleans' land subsidence crisis

David Wooden, Virginia University, Landscape Architecture

The land subsidence crisis of New Orleans is tackled with the proposal of an adaptable stormwater conveyance system that intentionally "leaks" to maintain water tables in the city. Low water tables speed up the process of subsidence, and water that would otherwise be replenishing the water table is currently being diverted by the stormwater system. Replacement of this system with parametrically derived surface canals would act as an ex-filtrating infrastructure for strategically recharging the water table, stopping or reducing the rate of land subsidence.

An intelligently crafted concept for combating subsidence, this paper beautifully presents an integrated and very applicable solution for a sinking city. Judges were impressed by the innovative idea and excellent presentation of this paper.

PANEL OF JUDGES CVS

Prof. Dr. Sybe Schaap (Chair)

Professor Waterpolicy and governance at Delft University of Technology
VU University of Amsterdam, Lecturer in Philosophy
Former Chairman of the Union of Water Boards of the Netherlands

Sybe Schaap has an agricultural background and an education in economics, social sciences and philosophy. Dr. Schaap wrote several publications on philosophical, organizational and agricultural topics. He is involved as a Lecturer in Philosophy at the VU University of Amsterdam and the Charles University in Prague.

Sybe Schaap is actively involved in water management issues in the Netherlands. During his six years as Chairman of the Union of Water Boards, Sybe Schaap modernized the board's financial structure. As Chairman of the Water Boards, he focused on the importance of safe dikes and the impact on society. He also expressed this importance in an international context and put this on the international water agenda. He gave several presentations on international missions and was a presenter at the last World Water Forum. Sybe Schaap was an advocate of the second Delta Committee of the Netherlands, long before it was established.

Alongside his involvement in the Dutch and international water world, Sybe Schaap is actively involved in politics. He is also a member of the Dutch Senate and was awarded the royal title 'Officer of the Order of Oranje-Nassau' for his work in 2009.

Prof. Dr. Hans Opschoor

VU University of Amsterdam, Professor in Environmental Economics
Institute of Social Studies, Professor of Sustainable Development Economics

Hans Opschoor is Professor of Sustainable Development Economics at the Institute of Social Studies and Professor in Environmental Economics at the Free University of Amsterdam. Hans Opschoor has worked in the field of environmental and ecological economics since 1971. Since 1978, he has specialized in international aspects of these fields, especially north-south ones. He has worked and lived in Southern Africa (Botswana) and been involved in projects in India and China. Recently, Hans Opschoor has focused on the economics of climate change as well as environment and poverty. In addition to that, he has a strong interest in scientific/academic co-operation in research and capacity development in the North-South nexus. Hans Opschoor has published 13 edited volumes and monographs and more than 170 articles, mostly on environment and development, environmental economics, environmental policy, and environmental policy instruments.

Prof. Dr. Pier Vellinga

Wageningen University, Director of the Knowledge for Climate Program in the Netherlands

Pier Vellinga is Professor in Environmental Sciences and Climate Change at Wageningen University Research and Vrije Universiteit Amsterdam. Originally he specialized in coastal engineering contributing to the Delta plan of the Netherlands and currently Pier Vellinga is one of the Netherlands' experts on the impacts of climate change. In addition to being Chairman of the Knowledge for Climate Research Program, Dr. Vellinga is Vice Chairman of the Climate Changes Spatial Planning Program. In 2009, he initiated the international Delta Alliance, a collaboration among low lying coastal areas in the world vulnerable to climate change. Pier Vellinga is a Board Member of several research institutes and environmental organizations in the Netherlands and abroad.

Mr. Tom Smit, LLM, MSc

Director of Royal Haskoning's Spatial Development Division
Organization of the Delta Competition in 2006 and 2008

Tom Smit is a Senior Management Consultant with law degrees from Leiden and Harvard Universities and has extensive experience in the public and private sector. He has advised numerous governments in the Netherlands and abroad on transport, infrastructure, utilities, water, environmental and spatial planning legislation and administration.

During his career at the Ministry of Spatial Planning and the Environment, Tom Smit was responsible for the drafting and implementation of the Dutch Environment Law. In his capacity as Director of the Union of Water Boards, after serving as Director of the Limburg Water Board, he was involved in the drafting and implementation of the Law on the Water Boards. After that, he joined Twynstra Gudde management consultants, ultimately serving as Managing Partner at this firm. In 1998, he joined Royal Haskoning, first as Director of the Environment and Water Divisions, and currently managing the Spatial Development Division.

At Royal Haskoning, Tom Smit has been involved in the regional consultation process leading towards the formulation of the new National Water Plan and an international comparative analysis of (integrated) water legislation. Alongside various evaluation studies and consulting assignments in the Netherlands, in recent years he has also provided advice on the water and environmental management capacity of governments in countries such as Romania, Bosnia-Herzegovina and Greece and was involved in various Environmental Impact Assessment projects, such as the extension of the Maasvlakte in the Rotterdam Harbor.

ECOLOGY AS INDUSTRY

WINNER

Haein Lee

Gyoung Tak Park

Soomin Shin

Harvard University, USA

Project Statement

With climate change and changes in energy structure, the Netherlands is witnessing major challenges with its lowlands and rising water level. Through de-engineering the Dutch water management, this project explores the effect on the urban landscape from the reuse of sediment for soil economies, diversification of energy resources and the potential for reducing energy-intensive pumping systems that dangerously contribute to land subsidence and increased flood hazards. The ecology of estuaries becomes an industry that builds land, informs new urban typology and generates energy.

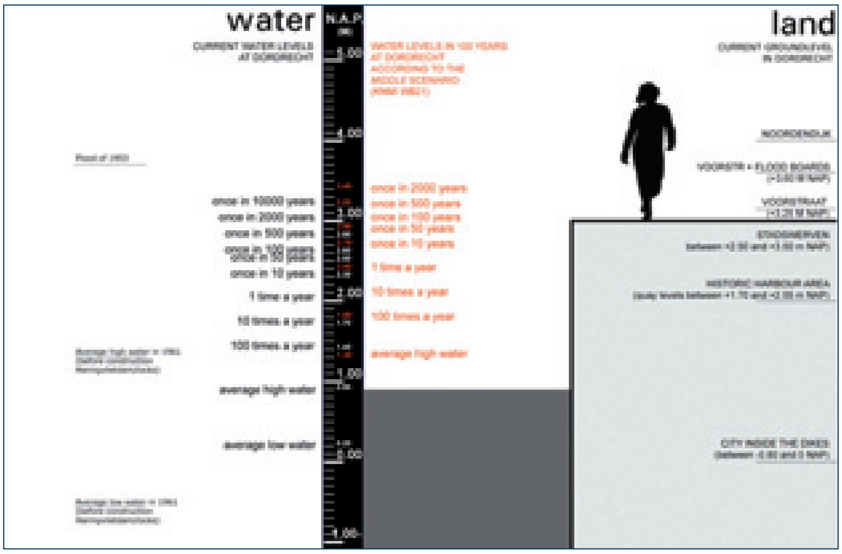


Figure 1 Rising water level in SW delta of the Netherlands

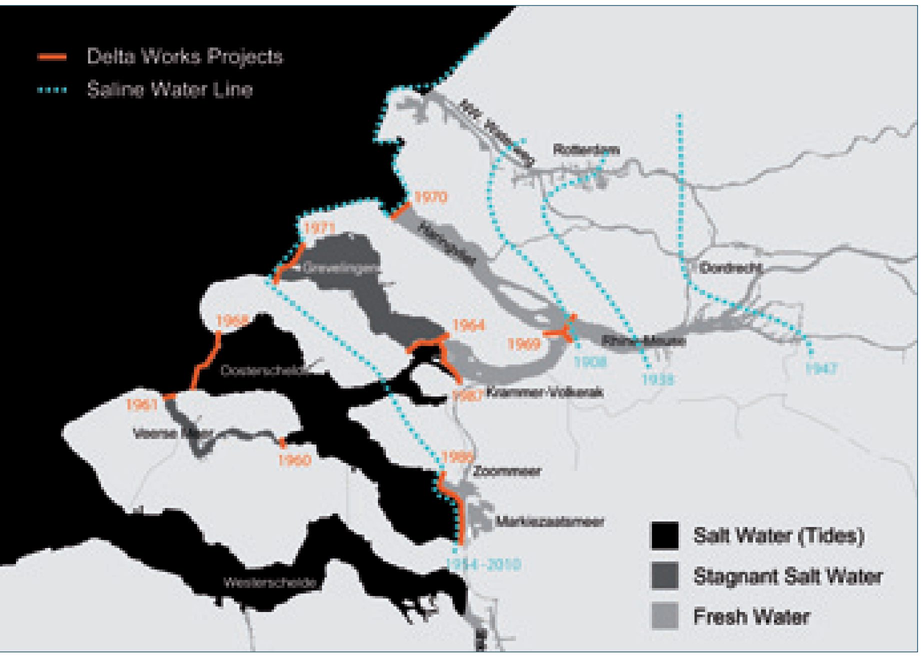


Figure 2 Change in saline gradient due to the Delta Works projects[2]

1. Man-made Lowlands (context)

The Netherlands is a low-lying country with a quarter of its land below sea level. Without tremendous investments for flood defense systems, these lowlands that produce about 70% of the national GDP are prone to flood hazards. The south-west delta of the Netherlands, the delta of the Rhine-Meuse river near Rotterdam, is experiencing double potential flooding due to the rising sea level and increased extreme climatic conditions that cause river floods.

2. Landscape of Delta History (historical analysis)

A research on the history of Dutch water management of over a thousand years reveals a repetitive pattern of responses in which they magnified and intensified the mechanical and engineering measures of flood defense and dehydration. Ironically however, the evolution and advances of such engineering solutions expedited the subsidence of land that, in turn, increased the impact of flood hazards and required an even higher level of infrastructural works. (figure 2)

Energy is also an inseparable issue. The construction and maintenance of such civil-engineering measures have heavily relied on the import of fossil fuels, which is alarming as the depletion of non-renewable energy resources is impending. (See Appendix A.)

3. De-engineering (strategy)

The project Ecology as Industry is about de- engineering the Dutch water management, in order to decrease the gap between increasing flood hazard and land subsidence from both directions. (See figure 4).

Instead of raising dikes higher that only provides a myopic and false sense of safety, utilizing natural processes of ecological systems will build land through

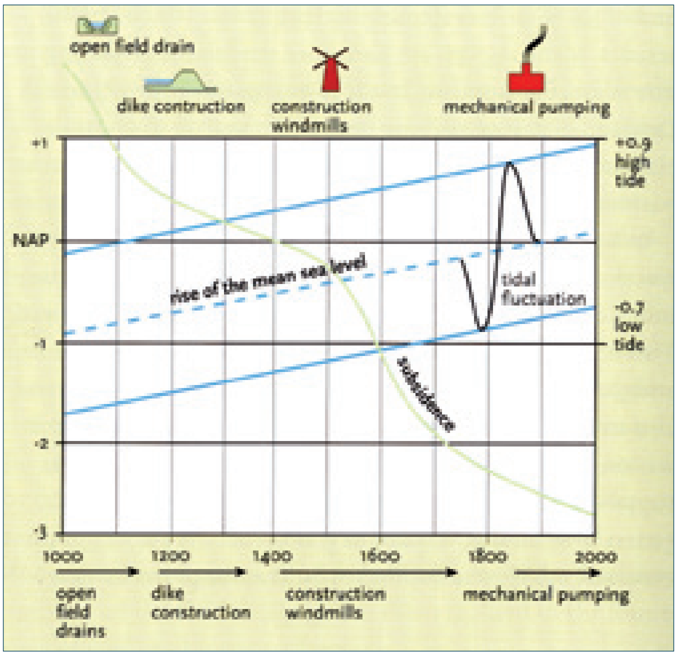


Figure 3 *Rising sea level and land subsidence graph from 'Man-made Lowlands: history of water management and land reclamation in the Netherlands'*

sedimentation and decrease flooding potential by providing more room for the river.

4. Processes — Four Transformations (interventions)

The project involves four areas of transformation that summarize the processes and interventions required with the subsequent changes as explained in this chapter.

While these transformations are categorized based on the different aspects of changes, it does not necessarily represent phases of the proposed interventions. The sequence of the processes and interventions are illustrated in more detail in Appendix B)

4-1. Coastal Transformation

The first step is to de-polder near the Nieuwe Merwede to allow the deposition of sediments through inundation of the river. Harvested sediment and excavated soil from this floodplain will become the source of material for constructing barrier islands outside the Haringvliet in the North Sea.

As shown in figure 6, the Nieuwe Merwede and the eastern end of the Holland-Diep receive sandy sediment that is currently being dredged regularly for a shipping channel. Based on this finding and also on the re-assessment of the energy-intensive practice of agriculture in the Netherlands, it is proposed that the polders near the Nieuwe Merwede in the city of Dordrecht be de-polderized for soil industries.

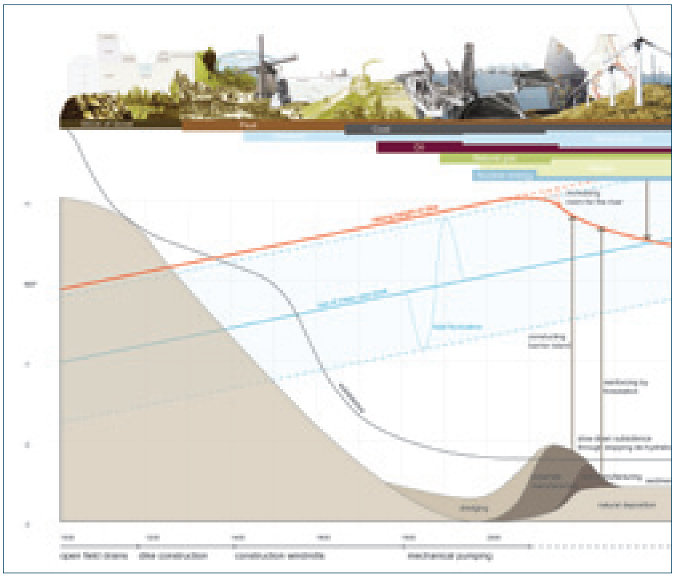


Figure 4 *Revised graph adapted from figure 3 showing the concept of De-Engineering in relation to the energy timeline of the Dutch water management*

Outside the Haringvliet in the North Sea, the construction of the barrier island is proposed within the bathymetric line of 10 meters as shown in figure 5. The North Sea's coastal process of sand replenishment also builds up the islands to grow as shown in figure 7.

4-2. Infrastructure Transformation

The infrastructures that have impeded the ecological process of land formation — the Port and the Dam - are deconstructed.

Port: Due to depletion of oil and with the diversification of energy sources to renewable ones, most of the port of

Figure 5 Coastal transformation

Rotterdam that is currently occupied by petrochemical industries will retrocede. (See figures 8 and 9.)

Concurrently, due to containerization of the port, ongoing deepening of ship draft and increasing pressure for urbanization of adjacent former industrial land, the remaining function of the containerized port will be relocated to the coast, liberating the delta from channelization and dredging to allow fluvial sedimentation. (See figure 10.)

Dam: With protection from storm surge provided by the barrier islands, the Haringvliet Dam will be opened to restore the intertidal zone in the Haringvliet and the Holland-Diep as shown in figure 11.

4-3. Estuarine Transformation

Tidal fluctuation and saline gradient create a productive estuary with sand dunes and mud flats built through sedimentation both from the sea and the river. De-poldering for fish farms and mud flats is to cultivate such estuarine landscape altering the existing infrastructure of dikes and polders. Replacing the energy-intensive practice of agriculture, aquaculture becomes a land use that yields higher productivity with less required resources needed for maintenance. (See figure 12.)

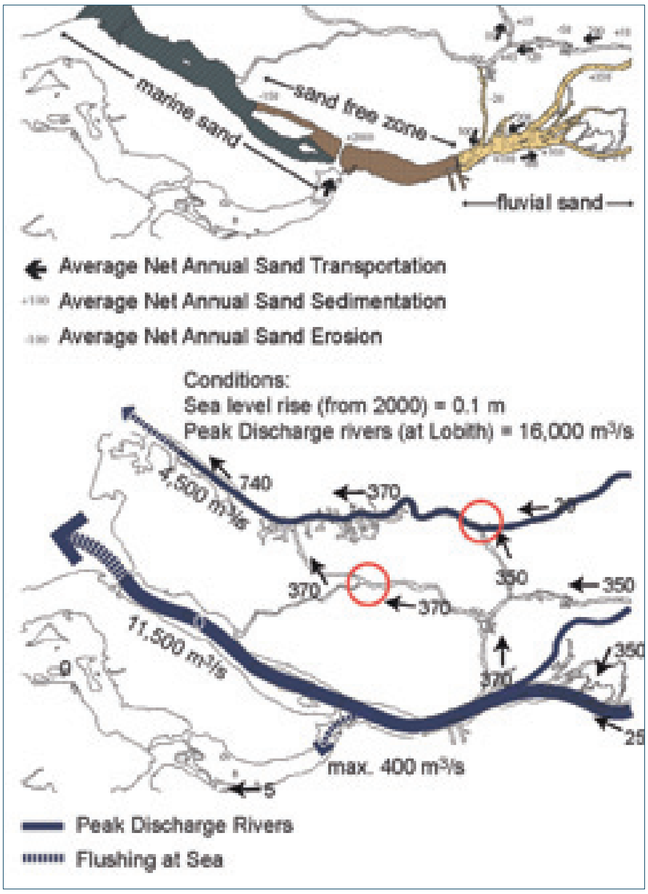


Figure 6 Fluvial sediment (above) and discharge (below) through the Haringvliet in the SW delta of the Netherlands[4]

As shown in figure 14, de-poldering the outmost polders establishes the estuarine ecosystem with much richer flows and exchange of nutrients and energy. The relationship between land and water after the proposed intervention will be discussed in more detail in chapter 5.

Additionally, partially opened polders with controllable sluices provide "room for the river" that increases the holding capacity of the river discharge in case of floods. This explains the top portion of the revised subsidence graph (figure 4).

4-4. Urban Transformation

Coastal, infrastructural and estuarine transformation together impact the urban landscape and economy of the SW deltaic region. (See figure 13) The new vertical and horizontal configuration of water and land along the estuary transforms the pattern of urbanization with introduction of terps (high mounds), fresh waterways and forestation. Figure 18 shows the abstracted relationship among these urban elements near fish farms.

As the primary dike against the river moves inward to the existing second tier of dikes, residential uses will be introduced on terps behind the second dikes. The landscape connection for recreational uses and the mixed-use development (fishery-related industries, commercial uses, etc.) will infiltrate perpendicularly to the mud flat and fish farm area. The fresh waterway in between urban uses and fish farm functions as salinity control and as a new landscape feature.

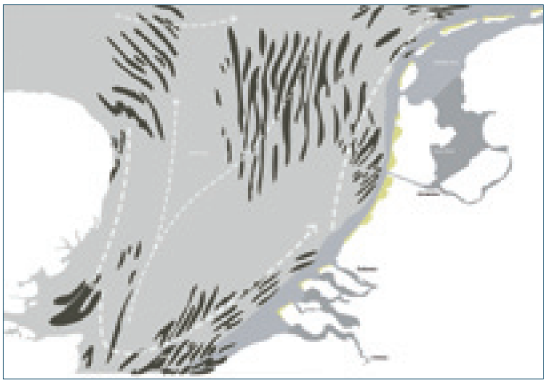


Figure 7 Coastal process in the North Sea showing marine sand banks and the dominant sea currents[5]

Changes in the vertical relationship among these elements are illustrated in figure 16. When the Haringvliet Dam is opened, the flood defense system is thickened from a dike to a depoldered area between two dikes. The effect is to have more frequent flooding events with a lower social and economic impact. It allows the sedimentation process and peat growth to match the rising sea level from the opposite direction to the precious Dutch water management. In this estuarine landscape, terp (high mound) provides secondary protection for urban programs that emerge around this depoldered aquacultural area[9].

On the other hand, Lake Oostvoorne becomes a new estuary of the Oude Maas, as the port of Rotterdam is freed up from petrochemical industries, as discussed in Chapter 4-2. The shift in the primary operation of the river goes away from the repetitive pattern of an engineering solution in which the constant dredging has prevented the sediment from natural land formation. The shortened Nieuwe Waterweg (the canal connecting Rotterdam to the North Sea) in the north and the restored Oostvoorne estuary in the south creates an riverine archipelago that is built and grows through siltation. The remaining canal structure will accommodate urban transportation and recreational uses of the waterway with much less force of engineering maintenance. (See figure 17.)

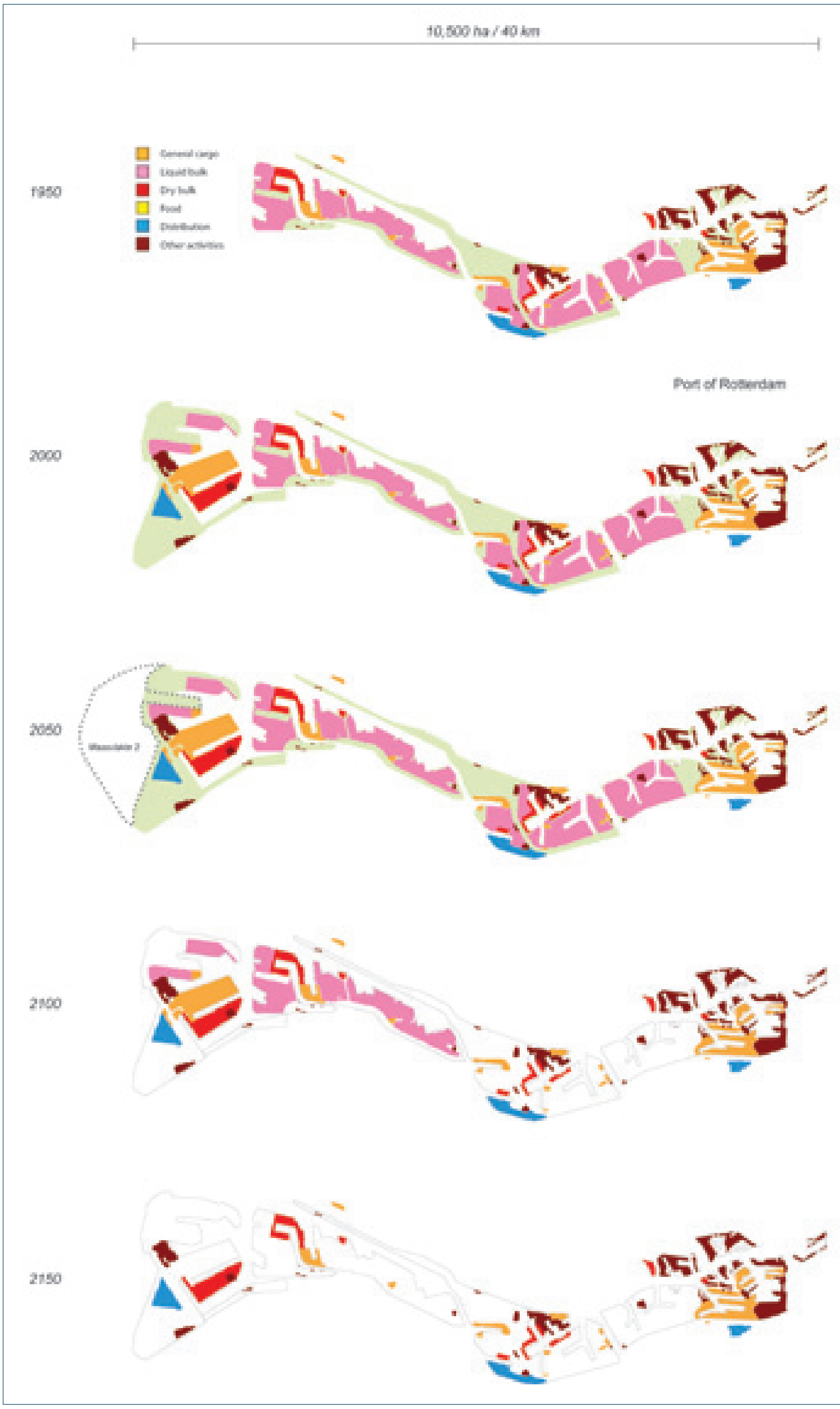


Figure 8 Footprint of petrochemical industries in the Port of Rotterdam' (above)

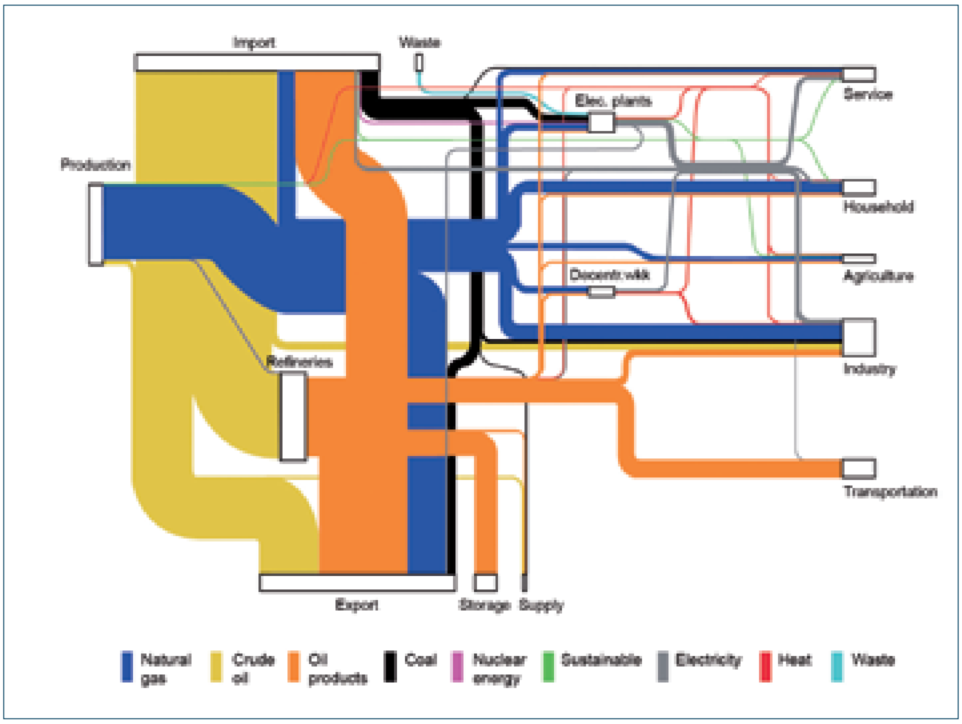


Figure 9. Existing Energy Structure of the Netherlands'

Figure 10 Port locations in the North Sea (solid dots: relatively new ports on the shore. Hollow dots: old ports in the estuaries)

Figure 11 Infrastructure transformation

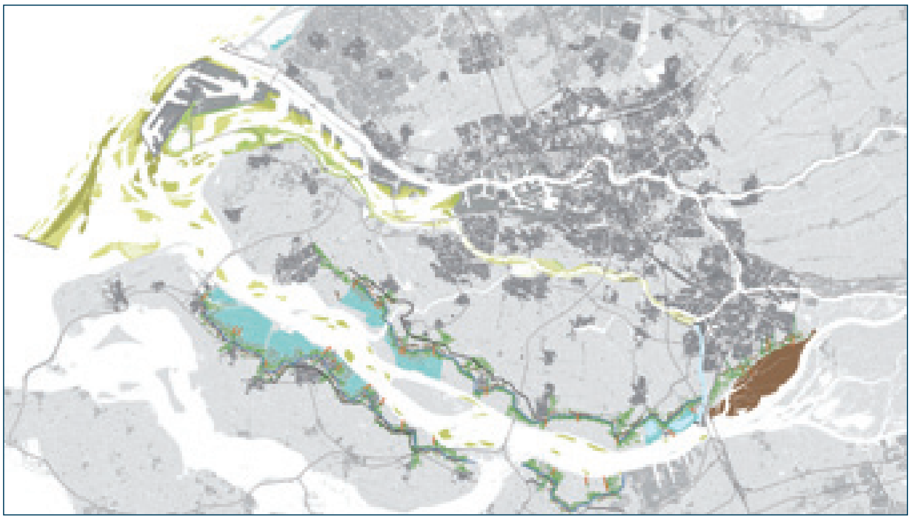


Figure 12 Estuarine transformation

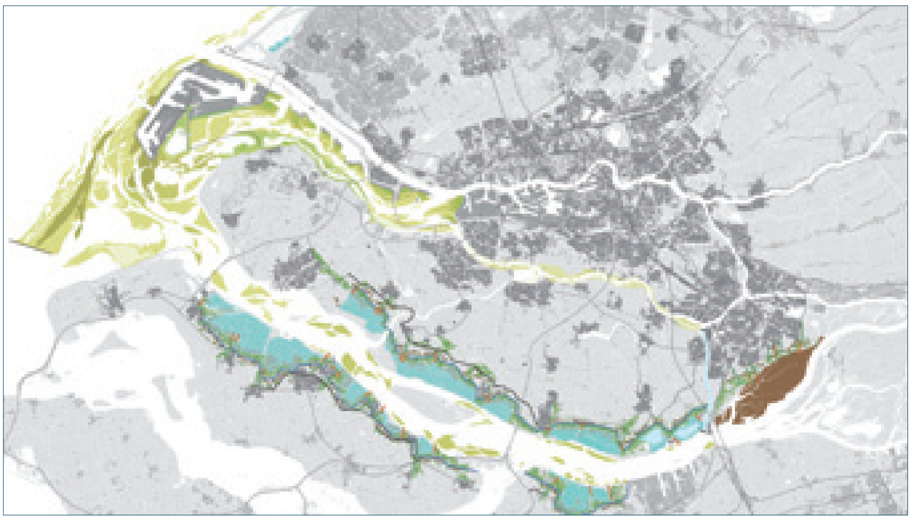


Figure 13 Urban transformation

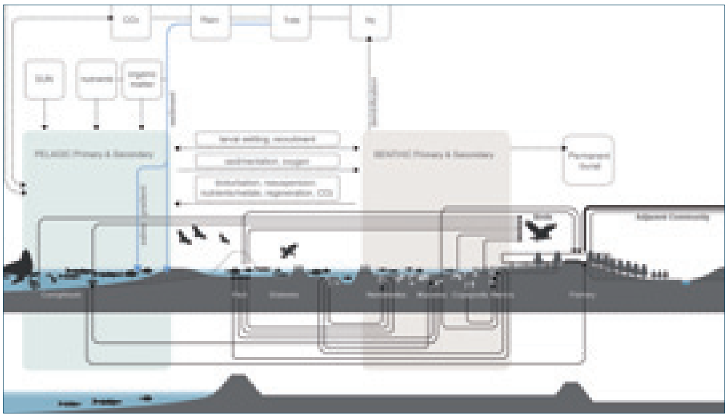


Figure 14 *Conceptual diagram showing the nutrients and energy flow in the de-poldered aqua-cultural area in relation to land, sea and atmosphere*

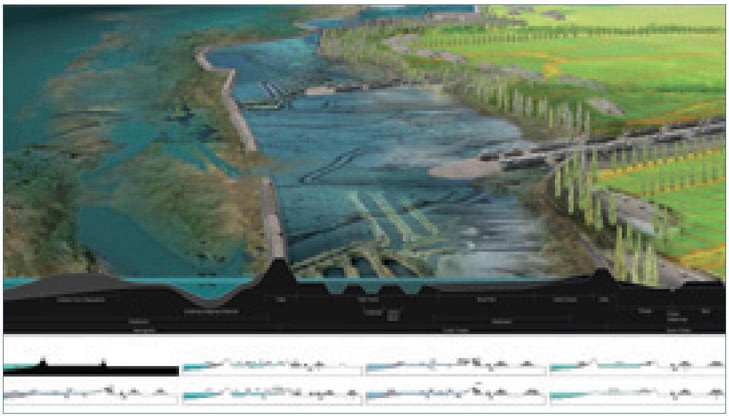


Figure 15 *Thickening of estuarine edge: sectional studies and perspective view*

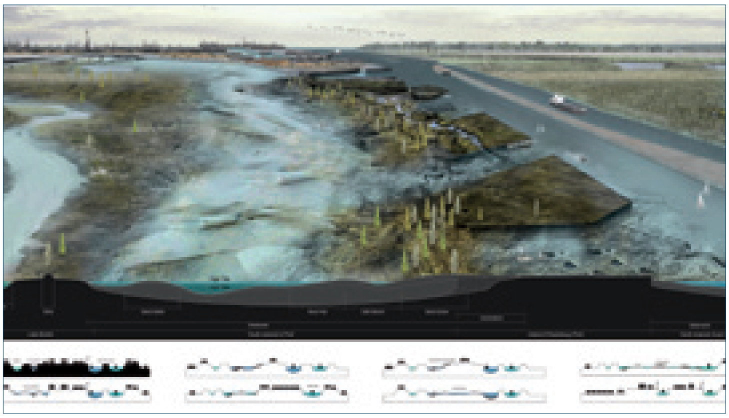


Figure 16 *Creating estuarine archipelago: sectional studies and perspective view*

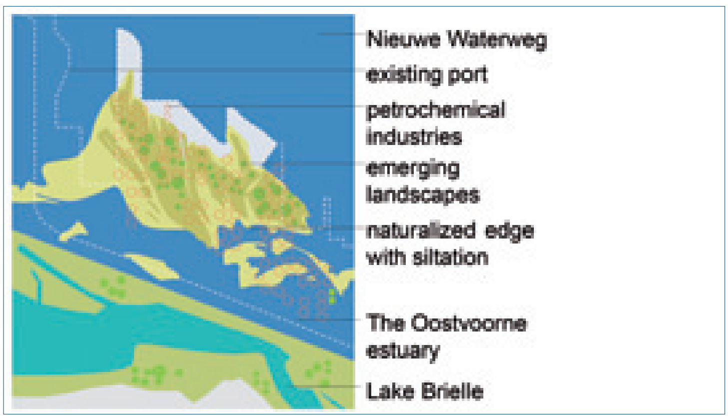


Figure 17 *Conceptual diagram of estuarine archipelago consisting de-constructed ports*

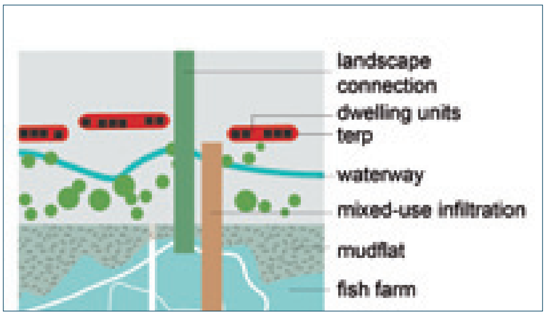


Figure 18 *Conceptual diagram of urban elements and new configuration near fish farms*

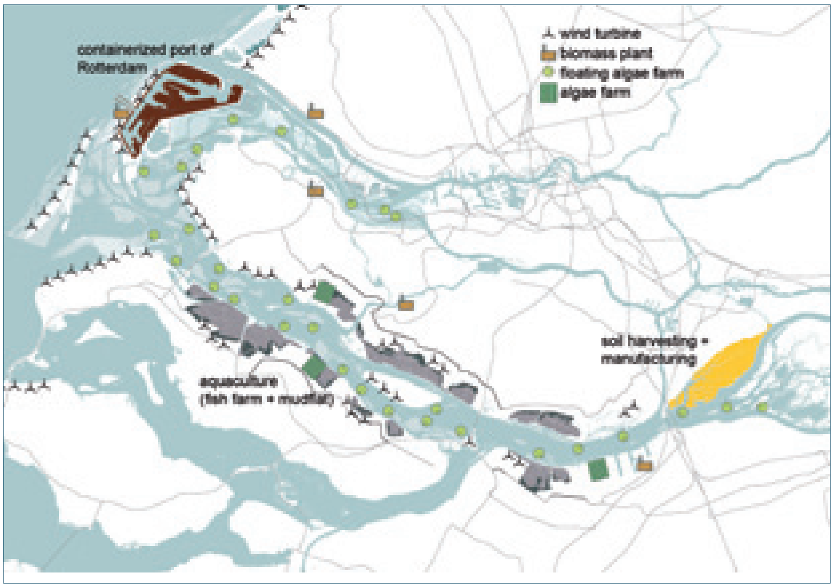


Figure 19 *New industries*

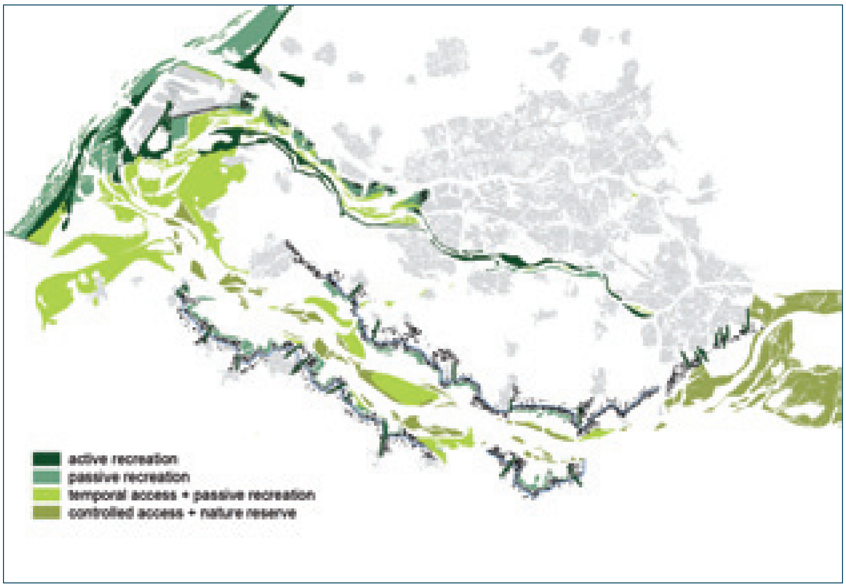


Figure 20 *Recreational Landscape*

5. Delta as Estuary, Beyond "Room for the River" (effects)

As a result of these interventions, the two estuaries in the Oostvoorne and the Haringvliet form a new coastline through the sedimentation process. With diversified saline gradient, such sediments restore diverse habitat including vegetate coastal plains, mud flats, salt marshes, brackish marshes and fresh water tidal marshes. Dredging and damming will no longer be necessary for deep ship draft for the inland port. The island of Rozenburg will be deconstructed into a series of smaller islands that make up the estuarine archipelago that grows with the siltation process.

To counterbalance the opening of the Haringvliet Dam, the room for the river is significantly increased through various de-poldering strategies including the Nieuwe Merwede's soil harvesting site, fish farms along the Haringvliet, and the deconstructed port of Rotterdam. (See figure 21.)

Moreover, this project goes beyond increasing room for the river, in that the de-poldering sites are designed toward cultivating the new landscapes, through new industries, aquaculture and alternative energy production (wind turbines along the coastline, biomass plants on the barrier islands, algae farms in the estuaries), which consequently produces changes in the urbanization of the deltaic area. (See figure 19.)

Finally, an expansive network of recreational landscapes emerges, which can be categorized into four as shown in figure 20. The barrier islands, the beaches around the new port of Rotterdam and the Lake Brielle provide the most active recreational opportunities. Mud flats along the Haringvliet and the estuarine archipelago connect the urban centers and the active recreational area by allowing passive recreation. In addition, temporal landscape such as sand dunes and a nature reserve area such as Biesbosch complement the network of landscapes.

6. Ecology as Industry (conclusion)

The issues facing the cities in the delta do not lie within their city boundaries but call for a regional approach that views the deltaic area as a landscape system. Capitalizing on the ecological potential of the estuary, the economic reuse of sediment for land creation and the imminent economic shift in energy production, Ecology as Industry is the future of the cities in the Southwest Delta of the Netherlands as much more than just a city; it is an urban prototype for climate change in the 21st century that introduces a sustainable and adaptable way of rehabilitating nature and exploiting the specific characteristics of the estuary, while transforming the urban landscape and economy.

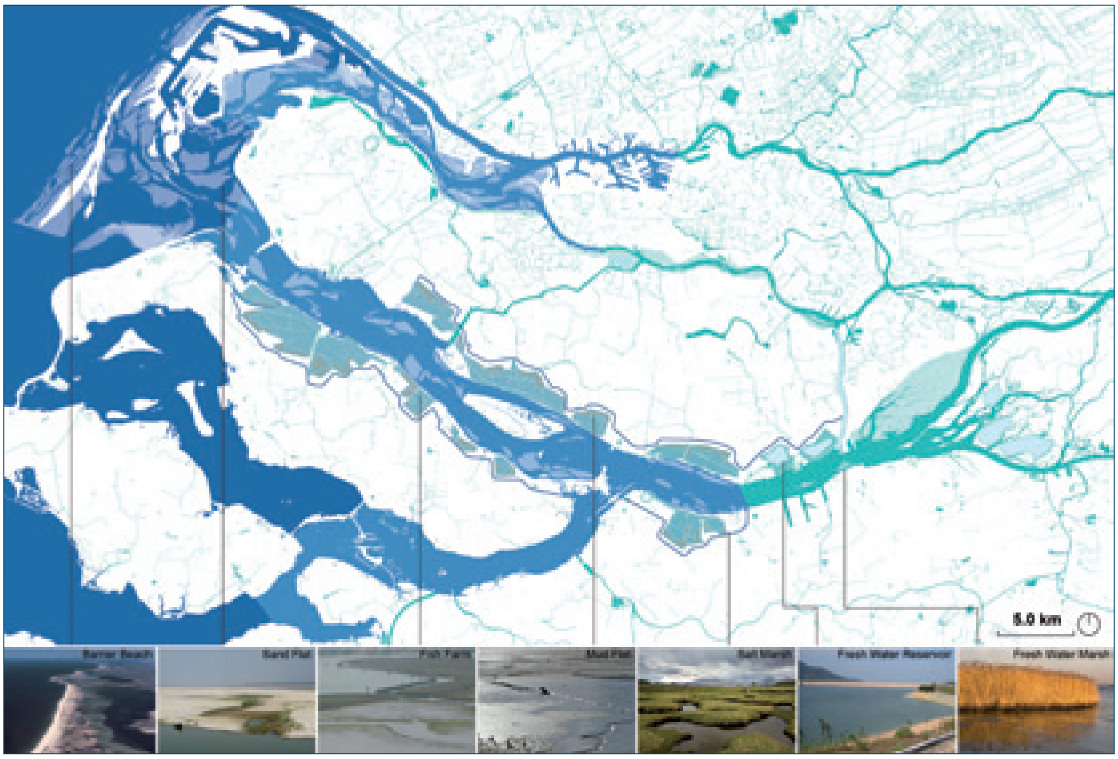
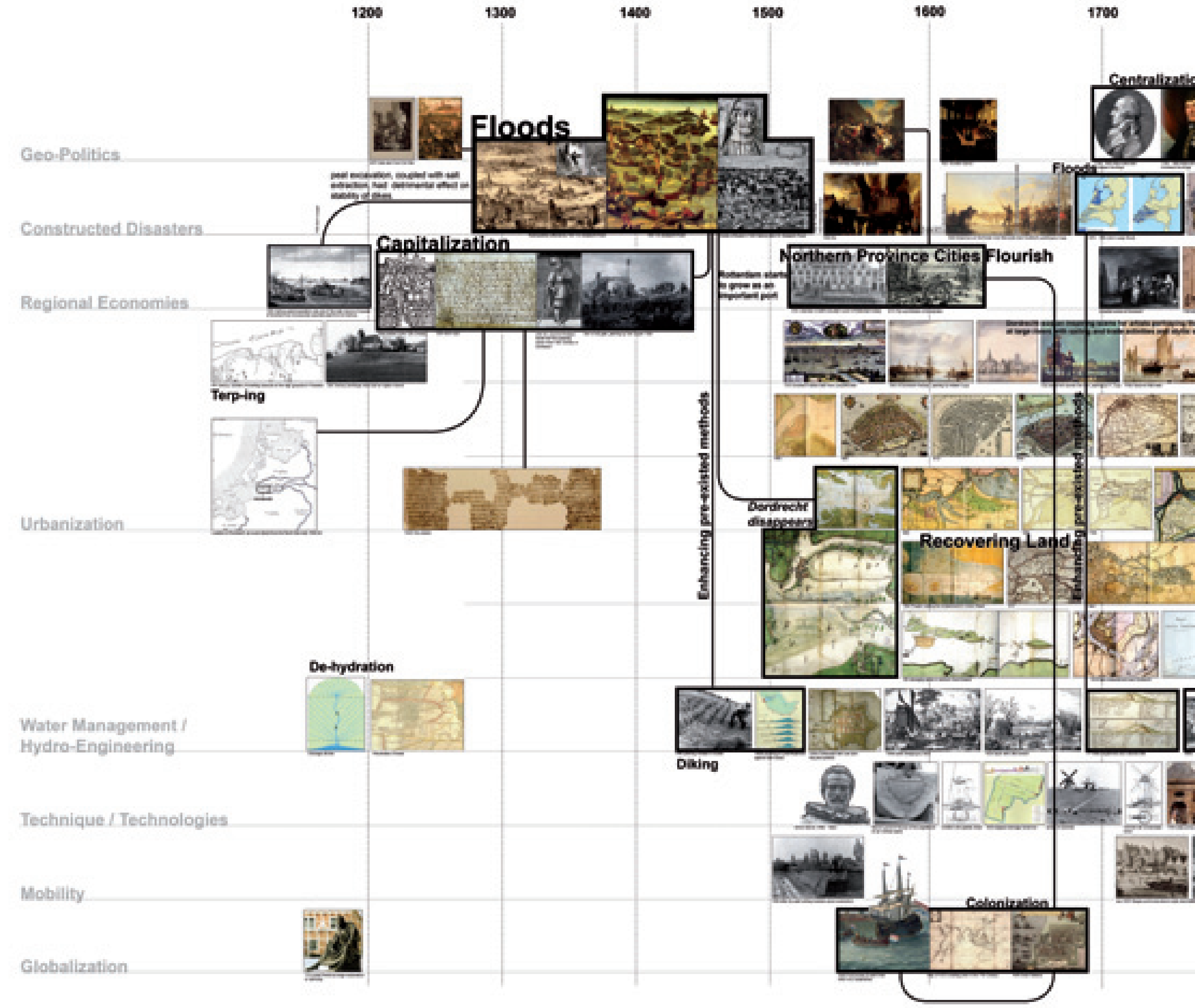


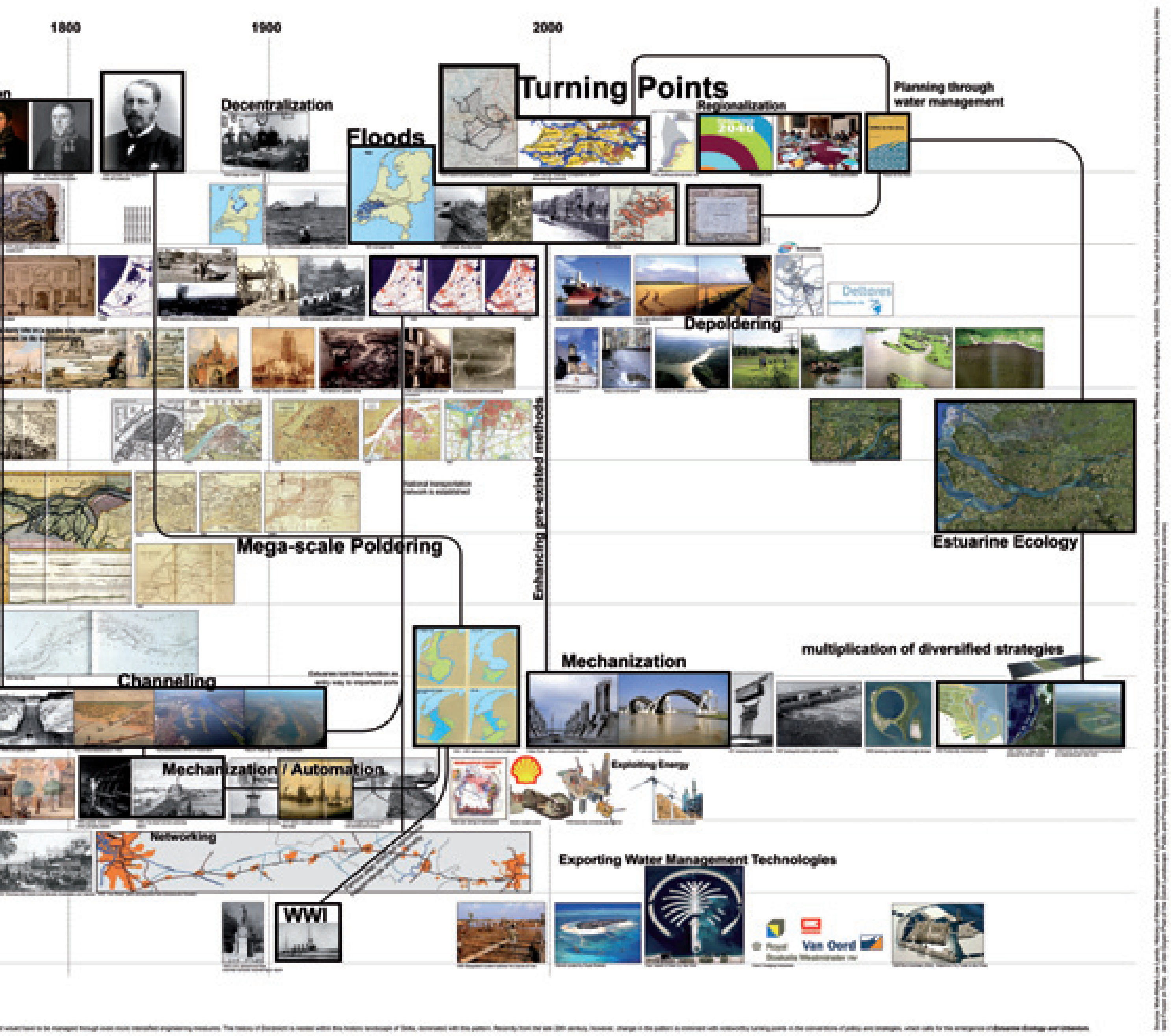
Figure 21 Delta as estuary: water-land diagram summarizing the interventions and effects

Figure 22 Ecology as Industry: speculative view of the SW delta of the Netherlands as estuaries

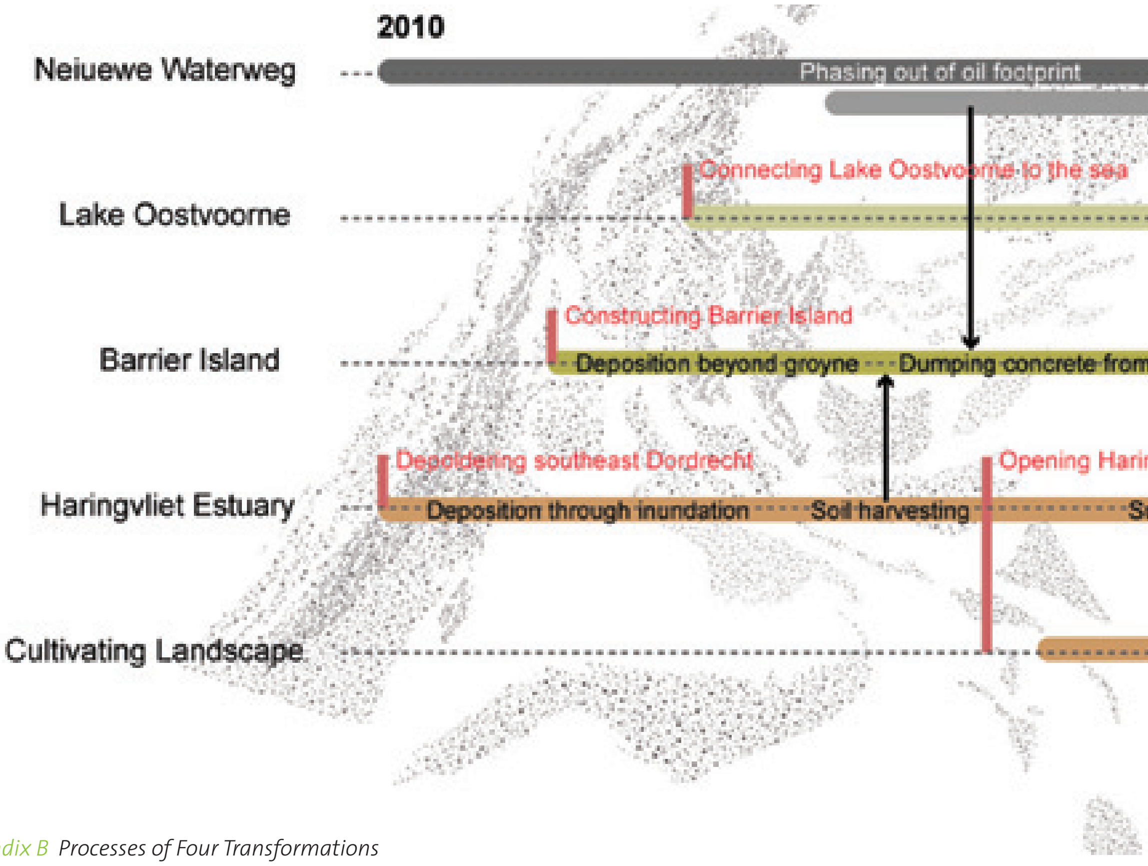


Landscape of History of Delta

Appendix A *Landscape and Dutch History*

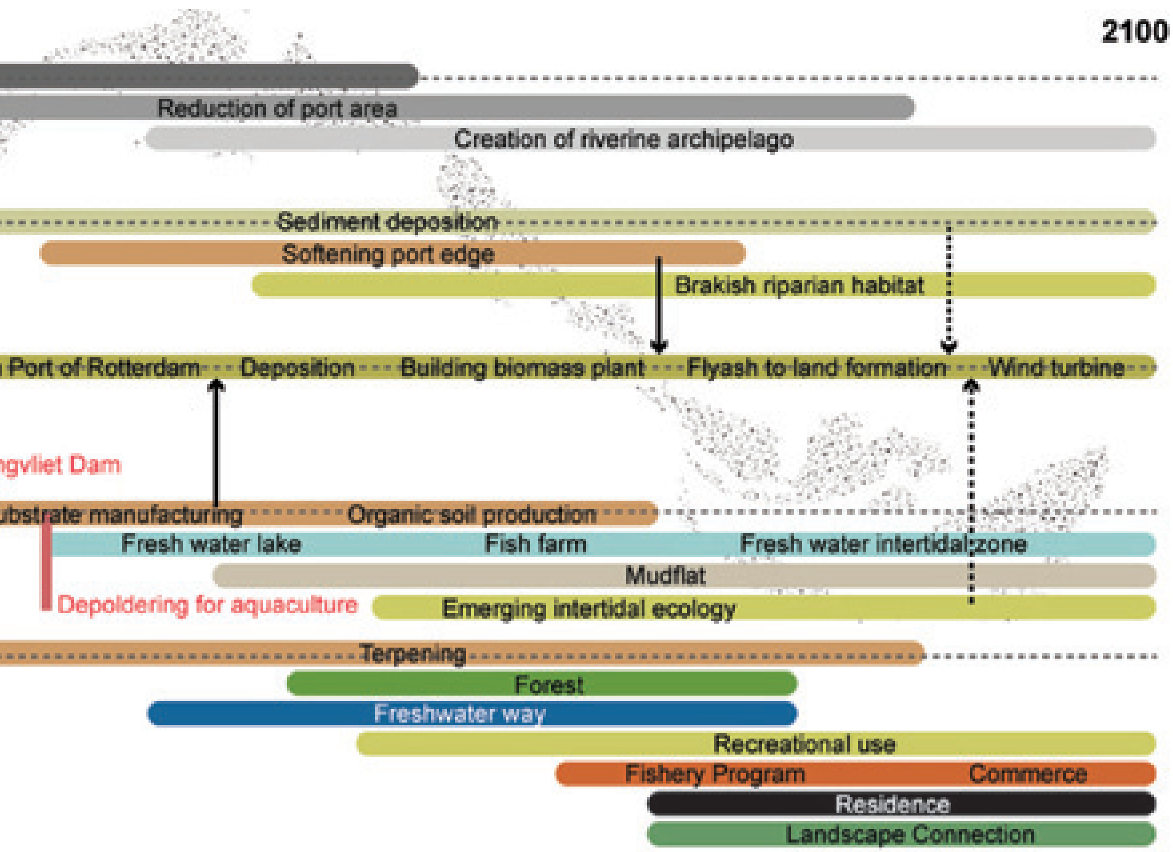


1800
1900
2000
Decentralization
Floods
Turning Points
Regionalization
Planning through
water management
Depoldering
Deltares
Enhancing pre-existed methods
Mega-scale Poldering
Estuarine Ecology
Channeling
Mechanization
multiplication of diversified strategies
Mechanization / Automation
Exploiting Energy
Networking
Exporting Water Management Technologies
WWI
Van Oord



Appendix B *Processes of Four Transformations*

Appendix C *Illustrative Plan*



Appendix D View E from the barrier island looking toward the new Port of Rotterdam

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GROUNDWATER ZONING AS SPATIAL PLANNING IN SEMARANG

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Abstract

Significant disasters of sea level rise, land subsidence and floods occur in coastal areas in sub-watersheds of the Garang watershed, and the North and East Semarang sub-watersheds, due to the complex factors such as population growth, land use change, climate change and groundwater extraction. Continuous groundwater extraction will lead and accelerate the further destruction of the environment. Groundwater resource protection can be used as an adaptation option for decreasing environment degradation. By groundwater zoning based on discharge and recharge areas for spatial planning, groundwater resources and environment in this area can be protected from further degradation.

Numerical MODFLOW model processed within PMWIN-MODFLOW was used for the groundwater flow model in North and East Semarang sub-watersheds, Semarang. Borehole data, topography map, geomorphology map and hydroclimatology data were used for modeling groundwater flow. Secondary groundwater level measurement was assigned for calibration of the model. Moreover, land subsidence, sea level rise and groundwater exstraction rates were used for modeling groundwater protection. The groundwater flow model can be used for defining land use spatial planning in this area.

Intensive groundwater extraction occurs in the coastal area of Semarang. It can be clearly shown from the groundwater flow direction and cone depression of groundwater that focuses in this area. Spatial planning in this area is divided into three zones that are Zone I, II, and Zone III. Zone I is placed in the southern part that is almost close to the sea. Zone II is located in the middle of the sub-watershed and the last zone is located in the recharge area of the groundwater.

INTRODUCTION

Background

A delta is shaped when sediment input from river is surpassed by sediment removed by tides and waves. This process is influenced by climate, elevation, and geomorphology of the catchment area and hydrodynamic of the coast where the river is flowing (Akoumianaki and Nicolaidou, 2007). Sea level rise rate, rainfall pattern and temperature due to global climate change will alter the delta ecosystem (Day Jr.,et.al.,2005). The delta faces the critical problem of land subsidence that contributes to sea level rise (Sãnchez-Arcilla,et.al., 1996). Sea level rise will accelerate in duration and frequency of marsh flooding and accelerate average salinities (Snedden, et.al., 2007). Therefore, the delta can be managed in terms of sea level rise and its changes by using appropriate natural processes especially based on a natural ecosystem function (Snedden, et.al., 2007).

The mouth of the Garang River Catchment Area clogs due to sedimentation in the coastal area of Semarang City that forms the delta. This area encounters serious problems in respect to sea level rise, land subsidence, and coastal floods. Coastal floods in this area derived from local flood inundation, river floods and sea water tidal floods that will get worse if the climate change occurs (Marfai and King, 20071). Land subsidence due to groundwater exploitation and construction load exceeds 16 cm per year (Marfai and King, 20072). Therefore, it is necessary to manage the groundwater resources from further degradation.

Land use influences groundwater resources by recharge changes and by water demand changes (Lerner and Harris, 2009). Appropriate land use and its management will protect groundwater from degradation and further environment destruction. Groundwater recharge and discharge zoning can be used to protect ecologically valuable areas (Batelaan,et.al., 2003). Therefore, spatial planning of land use for groundwater and environment protection is required.

Study Area Description

The mouth of the Garang River Catchment Area in Semarang City, Central Java, is one of small deltas that exist in this world (Snead, 1980 in Viles and Spencer, 1995). This catchment area is spatially situated in the essential city where the capital city of Semarang exists. According to the Ministry of Public Works (2009), this catchment area is known as the Garang Watershed. This watershed has four sub-watersheds that are West Semarang, Mangkang, North Semarang and East Semarang. The low land and coastal area of two sub-watersheds in this watershed, North Semarang and East Semarang, incur complex problems such as land subsidence and sea level rise. Administratively, there are about 7 districts in the low land and coastal area that are Semarang Barat, Semarang Utara, Semarang Timur, Semarang Selatan, Gayamsari, Genuk, and Pedurungan. Over 768,236 people live in these areas (Indonesian Statistical Bureau, 2009). Half of the population in Garang Watershed lives in low land and coastal areas. Therefore, these areas are widely developed. Many important public buildings and infrastructures exist in this area such as the harbor, station, commercial and industrial buildings and the urban heritage of Semarang that lay on material sedimentation from the river that will accelerate land subsidence in this area. This area will be vulnerable for the population and buildings that exist in this area.

Land subsidence occurs about 5 cm/year in the south to 9 cm/year in the north of Semarang City (Ministry of Public Works, 20081). The high rate of land subsidence to the south of Tanjung Mas harbor is 9 cm/year. Increasing groundwater extraction rate in this area results in significant land subsidence. Gradually increasing groundwater extraction from 0.4 million m3/year in 1990 to 35.7 million m3/ year in 1998 accelerated land subsidence (Marfai and King, 20072). Furthermore, groundwater extraction rates per month in the land subsidence area are obviously high and there is a relatively short distant from one well to another well. The Ministry of Public Works, 20081 stated that the highest rate of groundwater extraction is 2160 m3/ month. It can be clearly shown in Figure 1. Annual sea level rise in the Semarang Coast area is 8.86 mm/year (Prihatno, et.al., 2010). Moreover, land use change due to an increase of paved area and population growth leads increasingly to the frequency and severity of flooding events (Ministry of Public Works, 20082). Most of the low land and coastal area is paved area and many forests in the hilly area are converted to unpaved areas (Indonesian Statistical Bureau, 2008). Landuse changes in this area will lead to a more critical disaster problem in this area such as sea level rise, land subsidence, and floods. Therefore, it is necessary to plan the use of land in this area.

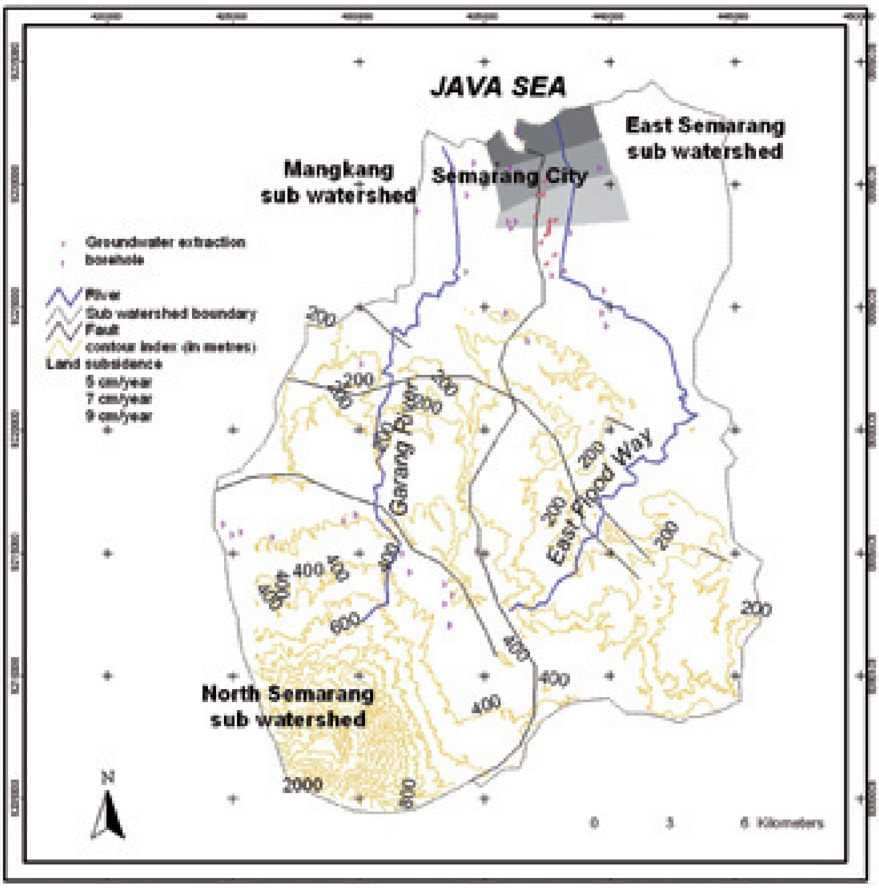

Figure 1 *Study area location*

The study area is bordered by two main streams that are the Garang River, and Banjir Kanal Timur (East Flood Way).

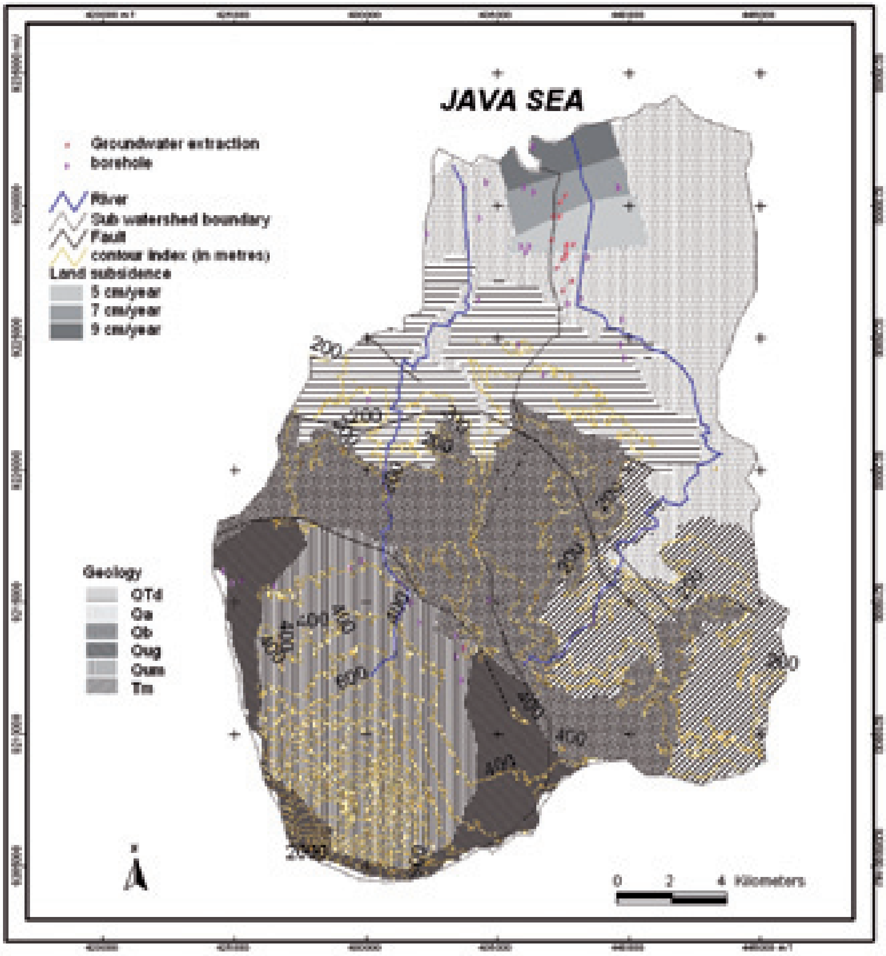

Figure 2 Geology of the study area

Figure 2 shows the location of the study area. Hydrogeology characterization is explained in term of transmissivity, hydraulic conductivity, storage coefficient and aquifer thickness of the groundwater basin in correlation with the groundwater potency. The study area is included in the groundwater of Semarang-Demak and Ungaran. These basins have a high potency of groundwater. Surface-water hydrology in the study area comprises the Garang, Babon, and Banjir Kanal Timur (East Flood Canal) rivers as primary drainages, numerous tributaries such as the Pengkol. Based on rainfall data over more than 30 years, minimum annual precipitation in this watershed reaches 1950 mm and 3650 mm for maximum annual precipitation. The precipitation increases from 1950 mm in the north of the catchment up to 3650 mm in the southwest. The spatial average precipitation in this watershed is 2511.45 mm.

Topography of approximately 442.72 km2 study area is described as five distinct regions: flat (nearly level), undulating, rolling, hilly and mountainous areas. Half of the region is flat area of about 225.31 km2. The general geology formation consists of alluvial sediment (Qa), marine sediment (Tm), volcanic breccias (Qb), basal olivine-augite flows (Qum), lava flows of andesitic hornblende augite (Qug), and tuffaceous sandstone, conglomerates, volcanic breccias and tuffs (QTd). Alluvial sediment formation consists of sand, clay, and gravel that is located in the northern of this study area. Volcanic breccias formation comprises of volcanic breccias, lava flows, tuffs, tuffaceous sandstone, and clay stone. Tm formation is dominated by clay stone, napal, sandstone, and limestone. Soil type in these sub-watersheds based on the Ministry Public Works (2009) consists of alluvial, andosol, complex Mediterranean and grumusol, latosol, meridian and ulfisol. Alluvial is situated in the low land of these sub-watersheds due to the sedimentation process from the river. This sedimentation flows to the Java Sea that creates the delta. Andosol and latosol spread in hilly and mountainous areas of the watershed in the southern part. Complex Mediterranean and grumusol is found in the structural-denudational hilly area of the Garang watershed. Based on geology, soil and topography maps, it can be explained that the major landforms in this area are volcanic landform, structural-denudational landform, and fluvial landform. Fluvial landform and marine landform create alluvial plains, coastal-alluvial plains and deltaic plains particularly in the northern area of the Garang watershed. Structural-denudational landform is especially located in the middle of this area. Some faults exist in this area. Volcanic landform is placed in the southern area. The volcanic material from Mount Ungaran is dominated by the existence of material in this area. Figure 2 describes the study area in terms of geology, land subsidence and groundwater extraction location.

METHODOLOGY

Conceptual Model

Groundwater modeling is recently known as the best way to support groundwater resources management (Lubczynski and Gurwin, 2005). MODFLOW is applicable for groundwater modeling (Winston, 1998). MODFLOW is a modular three-dimensional finite difference groundwater flow model that is published by the U.S. Geological

Survey (Mc Donald and Harbaugh, 1996). Peralta et.al. (2007) stated that MODFLOW can be used to study the planning and policy development process of groundwater extraction. The numerical MODFLOW model processed within PMWIN-MODFLOW for pre- and post-processing is used for modeling groundwater flow (Lubczynski and Gurwin, 2005). The proposed methodology was applied to define the recharge and discharge areas of the East and North Semarang sub-watersheds for spatial planning in Semarang. Future scenarios for spatial land use planning based on future land subsidence and sea level rise rates for modeling groundwater flow to discharge or recharge areas. Recharge and discharge areas to determine the land use planning in the East and North Semarang sub. watersheds was adopted from Batelaan, et.al. (2003).

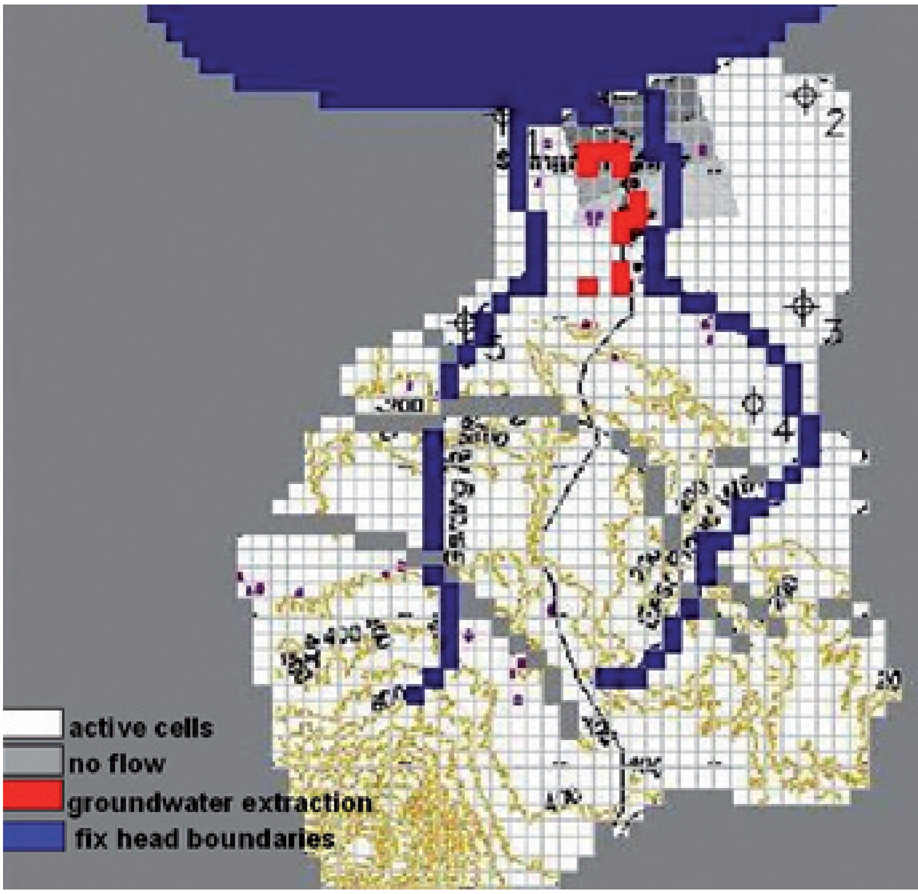

Figure 3 Boundary condition and grid condition

Boundary Conditions

No flow boundary (Q=0) was assigned for the watershed boundary. Fix head boundaries consist of the river and the sea. The river head was calculated from a river gauging station in the study area. Due to a lack of water level of river measurement of tributaries drainage in this area, only the main streams of East and North Semarang sub-watersheds were assigned as a fix head boundary, Garang River and East Way Flood. Figure 3 describes the boundary condition and grid assigned in the study area. Average mean levels of these rivers were determined from 1986-2001 due to the lack of available data. Some faults across this area were defined as a no flow boundary. The average fix head of the Java Sea was calculated from secondary data measurements from the period 2003-2009.

Hydrostratigraphy units

Integrated data sources of the geological map consisting of lineament location and borehole data were used to define hydrostatigraphy boundaries. A two-layer of model grid of 60 x 60 m was applied. The horizontal grid square of the model is not the same due to the line of fault in this area. The first layer is defined as the unconfined aquifer and the second layer is assigned as the confined aquifer. The basement of the second layer is the impermeable layer of breccias rock. Hydrostratigraphy boundaries of these permeable and impermeable layers as well as the groundwater table and piezometric surface were determined by these integrated data sources.

The digitized contour lines of the 1:25.000 topographical map were used to determine the surface of the top of the first layer. Then the thickness of each layer and unsaturated zone were defined from the interpolation of the point data of the borehole and the topography map. The thickness of the unsaturated zone and each layer were assigned based on average values from the point data calculation. Moreover, the area where land subsidence has occurred would be taken into account in defining the recent surface of the top of the first layer, the thickness of each layer and the unsaturated zone.

Hydraulic conductivity and storage coefficient

On the basis of borehole data, aquifer properties in the East and North sub-watersheds were calculated. Spatial distribution of hydraulic conductivity (K) and storage coefficient (S) were accounted for by the average point measurements of K and S obtained from boreholes. Point data of S and K were plotted, then the average value of K and S become the value of K and S for each landform. The spatial value of K and S was converted from GIS software for inputting into MODFLOW.

Recharge

Groundwater recharge is calculated using the water balance technique. Seiler and GAT (2007) stated that groundwater recharge (D_g) in humid and cold areas is:

$$D_g = P - ET - (D_o + D_i) \pm \Delta S$$

where ΔS can be neglected, P is annual precipitation (mm), PET is evapotranspiration (mm/year), D_o+D_i is run off. ET is estimated from P (precipitation) and T (temperature) using Turc (1954). The Thornthwaite approach can be

shown in the equation below:

$$ET = 1{,}6\left(\frac{10T_{month}}{I}\right)^{a} [mm/month]$$

with

$$I = \sum_{1}^{12}\left(\frac{T_i}{5}\right)^{1.514}$$

and

$$a = 6{,}75.10^{-7}I^3 - 7{,}71.10^{-5}I^2 + 1{,}792.10^{-2}I + 0{,}49239$$

The runoff is estimated from previous research by the Ministry of Public Works (2009). Due to the lack of data set, the estimation of annual temperature was based on 6 years of data. Next, the annual temperature in this study area is 27.50C. Then the annual precipitation is 2511.45 mm, and the evapotranspiration 182.78 mm/year. Next, run off estimation is 677.6 mm/year. Therefore, the groundwater recharge is 1651.07 mm/year.

Model calibration

The calibration of the groundwater model was made using 36 head measured points. Moreover, a transmissivity aquifer is included in the calibration process. The calibration process was used as a steady state condition. The discrepancy between the measured and the calculated heads was used in the calibration process.

Groundwater extraction model

Groundwater extraction rate data was collected in the area where land subsidence obviously occurs. There are 14 wells that extract groundwater in this area.

Spatial land use planning

Spatial land use planning was defined from the groundwater recharge and by determining the discharge areas. The groundwater flow model can be used to establish the flow direction of the groundwater so that the discharge and recharge area of the groundwater can be zoned. The groundwater flow condition due to the extraction rate, land subsidence and sea level rise were assigned as the spatial zoning of groundwater for land use policy in the East and North sub-watersheds.

RESULT AND DISCUSSION

Groundwater Zoning

The groundwater condition in this area is a critical problem due to over-exploitation. This can be shown from the groundwater flow direction in this area. All flows of groundwater are concentrated in the area where intensive groundwater extraction exists. Figure 4 shows the groundwater direction from the south to the north. The sharp concave shape of the groundwater contour clearly shows that in this area the groundwater is extracted intensively. Therefore, a focus will be placed on the groundwater protection zoning for spatial planning in this area.

Groundwater protection zoning in this area is divided into three groups: Zone I, Zone II and Zone III. The area where there is intensive groundwater extraction and significant cone of depression includes heavy protection that is Zone I. The area of Zone I is close to the sea or in a coastal area. This area is not only vulnerable because of land subsidence but also because of sea level rise. Zone II is in the middle of these two sub-watersheds, East and North Semarang. This area experiences relatively less intensive groundwater extraction than that in Zone I. Zone III is located in the southern part of these two sub-watersheds. It is clearly shown in Figure 5.

This zoning can be beneficial for designing groundwater protection in this area. The area which is very vulnerable such as Zone I can be adjusted as the primary focus to protect groundwater resources in this area. Moreover, from this zoning, further degradation of the environment due to groundwater extraction such as land subsidence can be maintained properly.

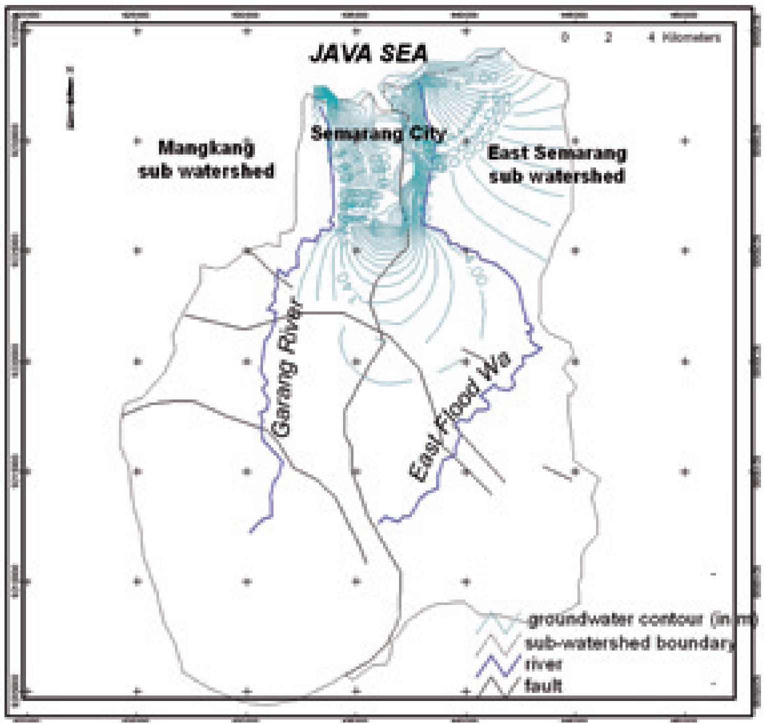

Figure 4 *Groundwater contour shape due to over abstraction*

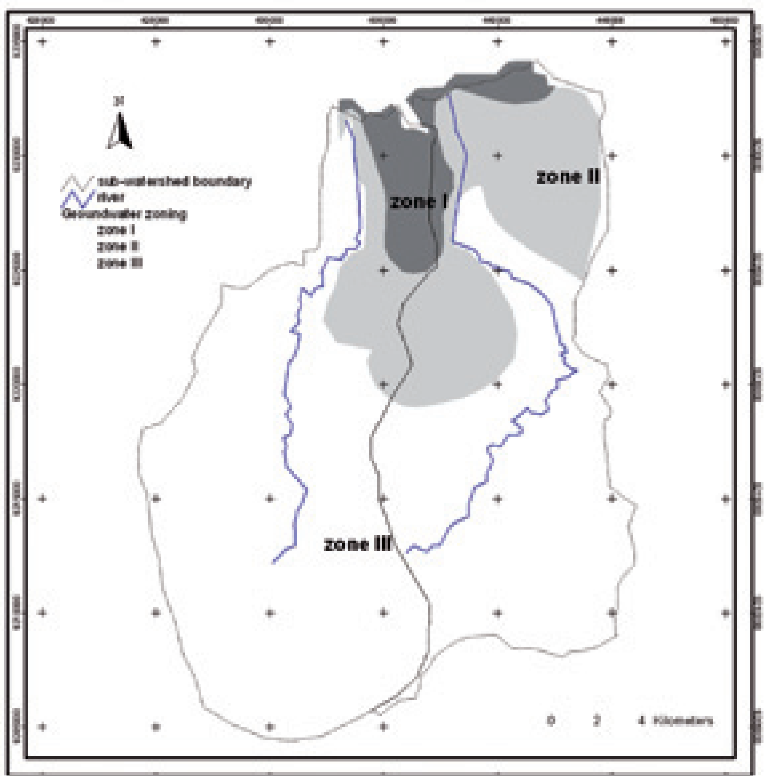

Figure 5 *Groundwater zoning as spatial planning*

CONCLUSION

Groundwater zoning can be used as a tool for spatial planning to protect groundwater resources. Zone I is very vulnerable due to groundwater extraction that is located in the northern part. Zone III is a relatively light area because of degradation due to groundwater extraction.

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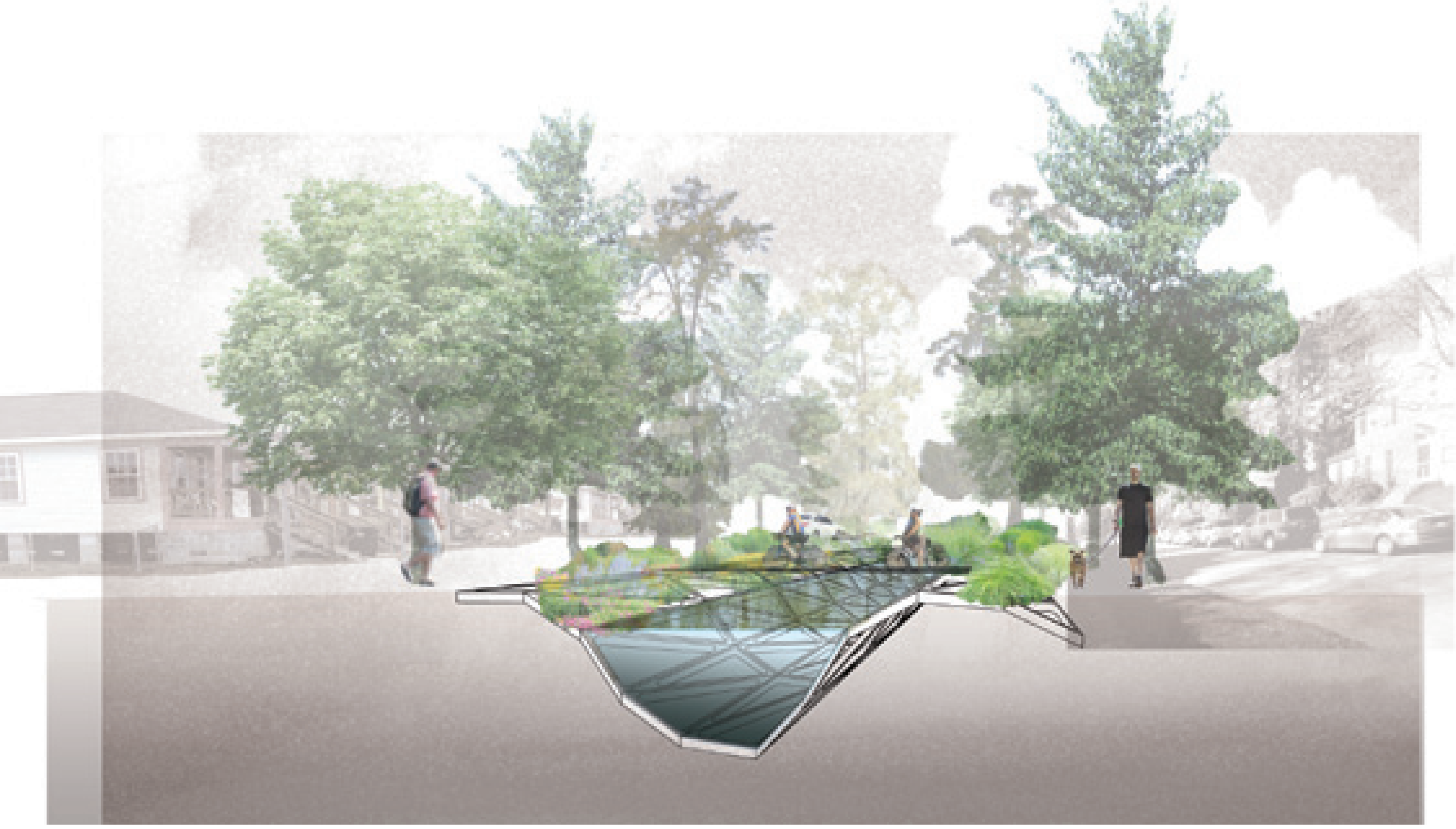

THE BIG LEAK

Adaptive responses to New Orleans' land subsidence crisis

WINNER

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Project Statement

The BIG LEAK addresses the Crescent City's land subsidence crisis, proposing an adaptable stormwater conveyance system that modulates the ground to allow for varying infiltration conditions. New Orleans' existing stormwater conveyance network primarily consists of underground pipes, canals and culverts. Replacement of this system with parametrically derived surface canals would act as an exfiltrating infrastructure for strategically recharging NOLA's water table. This water table recharge process could stop or reduce NOLA's rate of land subsidence.

THE PROBLEM: LAND SUBSIDENCE

Until the last 200 years, the area now comprising the city of New Orleans lay at or above sea level. The deltaic plain of the Mississippi River was a constant land building machine, where a high water table and regular phases of sedimentation ensured safety from the sea. However, the processes that resulted in land building are not conducive to human settlement. Each new engineering solution that allowed for settlement of increasingly larger land tracts in and around New Orleans, has resulted in future peril to its culture and residents. Today, forces of erosion and subsidence have resulted in half the city's land now lying as much as 10-15 feet below sea level.

Land subsidence may result from both natural and man-induced causes including:

- Tectonic motion and sea level rise,
- Heavy withdrawal of groundwater, geothermal fluids, oil, and gas,
- Extraction of coal, sulphur, gold and other solids through mining
- Underground construction (tunneling), or
- Hydro-compaction of loosely deposited sediments, oxidation and shrinkage of organic deposits.

A combination of sea level rise, groundwater withdrawal and shrinkage and compaction of soil contribute to New Orleans' land subsidence crisis.
There is a direct correlation between the water table level and subsidence rate. The lower the water table, the faster the subsidence rate.

Land subsidence has consequences beyond water intrusion and flooding. Subsidence results in buckling and potholing of city streets, cracked building foundations, and threatens infrastructure such as "gas pipelines, sewer and water lines, bridges and interstates, and industrial facilities." Buildings have been known to explode as a result of broken gas lines in New Orleans.

One of the engineering infrastructural insertions that enables human habitation in even the lowest parts of the city is the storm water conveyance system. New Orleans' existing stormwater conveyance network primarily consists of underground pipes, canals and culverts. Its primary purpose is to remove stormwater from the city as quickly as possible. This, however, creates an additional problem: rainwater is pumped out of the city before it has a chance to infiltrate and replenish the water table. Further, leaks in the below ground stormwater management infrastructure causes the removal of additional groundwater from the water table along with stormwater, resulting in further land subsidence. And as mentioned previously, the lower the water table, the faster the subsidence rate.

Ironically, another broken engineering system, the drinking water distribution system, may counter-act some of the negative effects of the storm water conveyance network. As much as half of the drinking water distributed in New Orleans may leak directly back to the water table. Theoretically, this may reduce the negative impacts of the stormwater conveyance network. This dichotomy is the basis for the BIG LEAK.

Figure 1 *Representation of the ground condition at the time of first European settlement (LEFT), then the compacted ground condition that exists today (MIDDLE).The Site (RIGHT).*

SOLUTION: THE BIG LEAK

The BIG LEAK addresses the Crescent City's land subsidence crisis, proposing an adaptable stormwater conveyance system that modulates the ground in order to allow for varying infiltration conditions. Replacement of the existing underground system with parametrically derived surface canals would act as an exfiltrating infrastructure for strategically recharging NOLA's water table. Intentional 'leaking' results in an addition to, rather than a subtraction from the city's water table.

Site

The BIG LEAK is a scalable solution with applications for the entire city. This initial site exploration examined the area along the Orleans Outfall Canal, bordering the Lakeview neighborhood to its west and the cultural landscape, City Park, to its east. Sections of this area lie as much as 14 feet below sea level, as a result of land subsidence.

Process

First, parametric design applications were used to create a series of abstract models of the ground condition that were responsive to variable water flows. These models represent the ground as an urban grid of columns: as the desired range of ground porosity increased, the columns parametrically decrease in 3-dimensions. The resulting form describes a structural gradient that creates low, porous areas for canals, and high, dense areas along the natural levees. The porous ground model was used to propose a series of abstract constructs that act as an exfiltration infrastructure for strategically recharging NOLA's watertable.

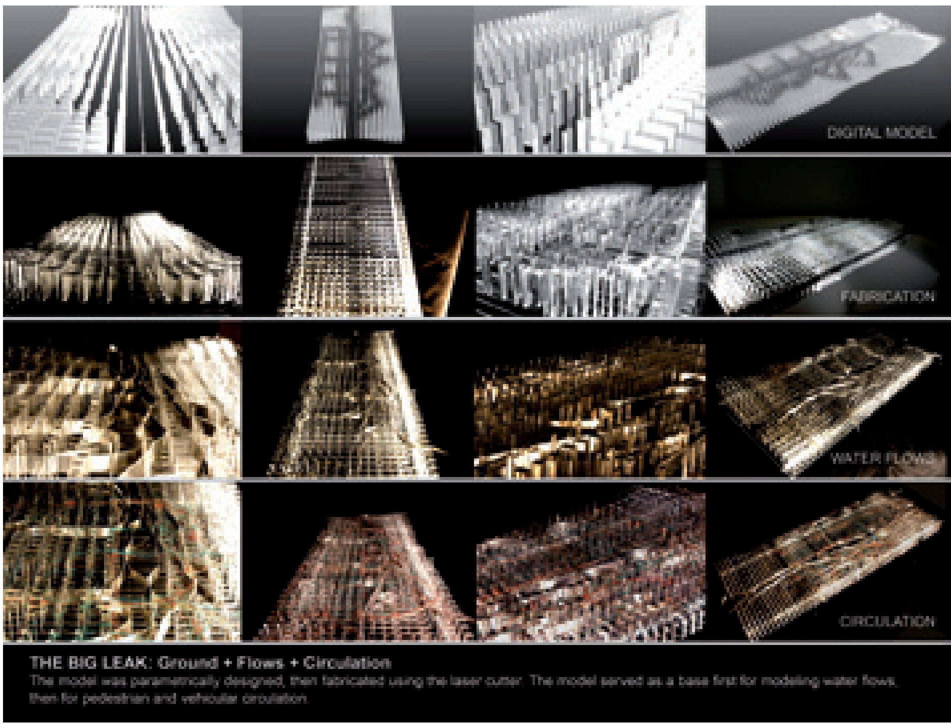

Figure 2

Existing Network

Stormwater for these areas is currently directed through underground canals and culverts to pumping station #7 which is located 2 miles inland from Lake Pontchartrain. Pumping Station #7 pumps the stormwater into the above-grade Orleans Canal where it flows the 2-mile distance to Lake Pontchartrain. Although the Orleans Canal did not breach during Hurricane Katrina, other outfall canals in the city did, as a result of the storm surge from Lake Pontchartrain. These canals have been identified as a major weakness in NOLA's hurricane defense system.

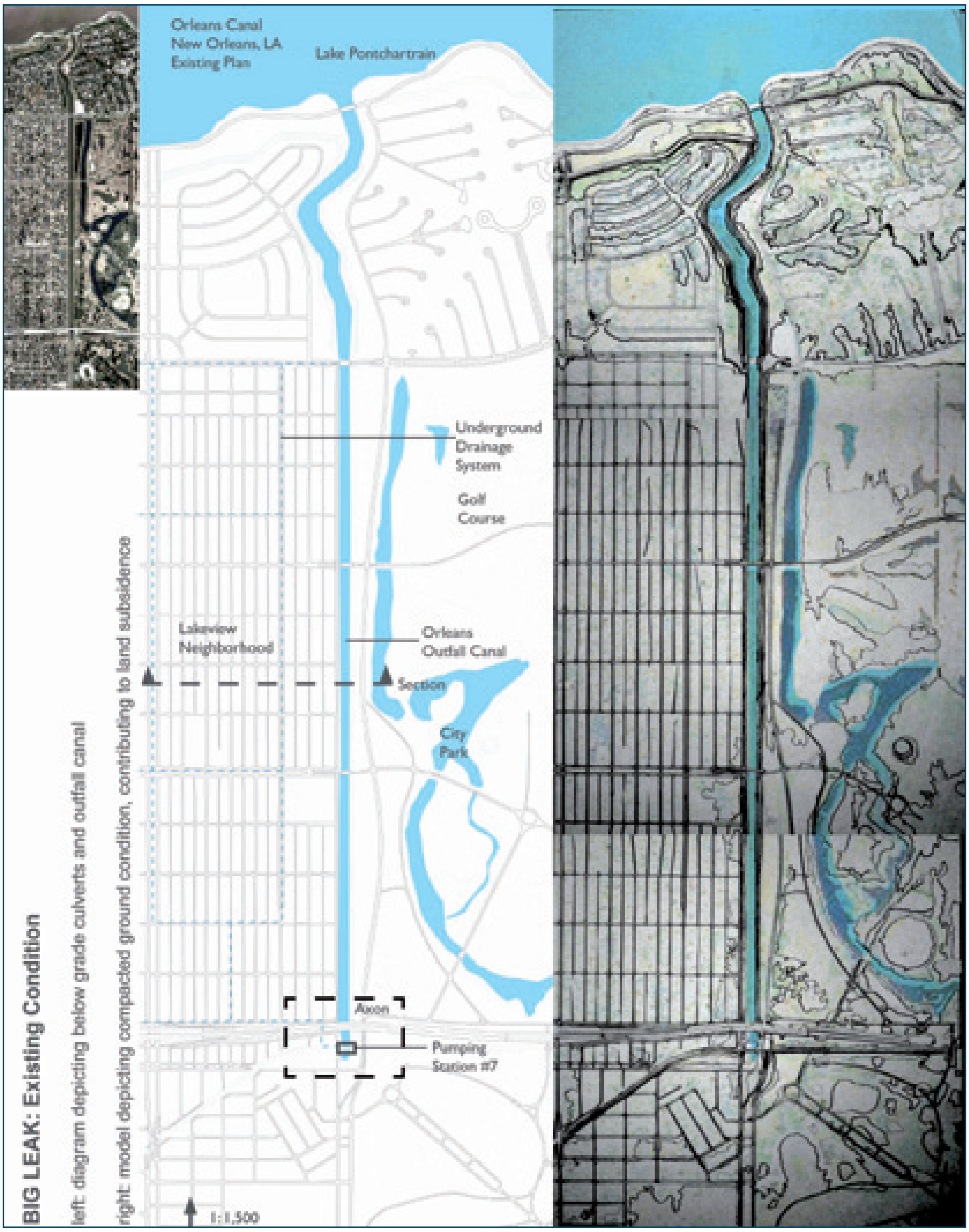

Figure 3 Existing condition

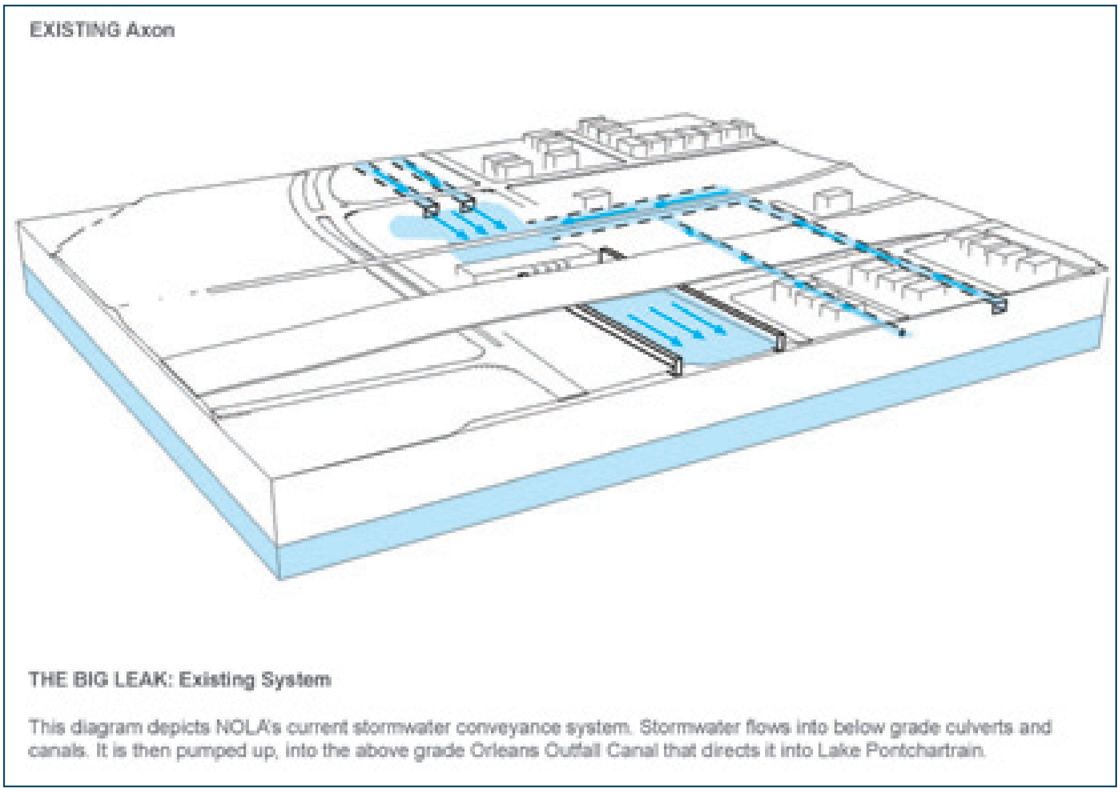

Figure 4 *Existing axon*

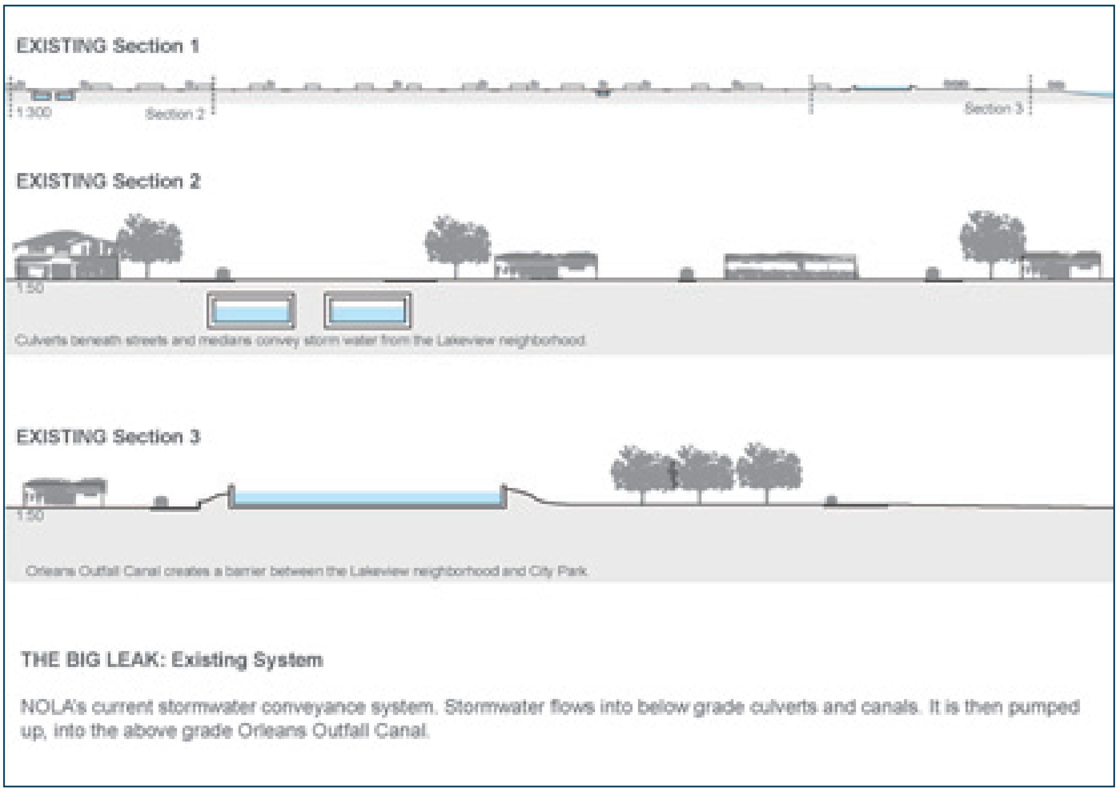

Figure 5 *Existing sections*

Proposed Network

The Army Corps of Engineers proposes installing new pumping stations at the shore of Lake Pontchartrain to supplement the existing pumping stations and outfall canals, leaving the existing infrastructure in place. However, public stakeholders from NOLA have advocated decommissioning the current pumping stations and moving primary pumping responsibility to new pumping stations along Lake Pontchartrain.

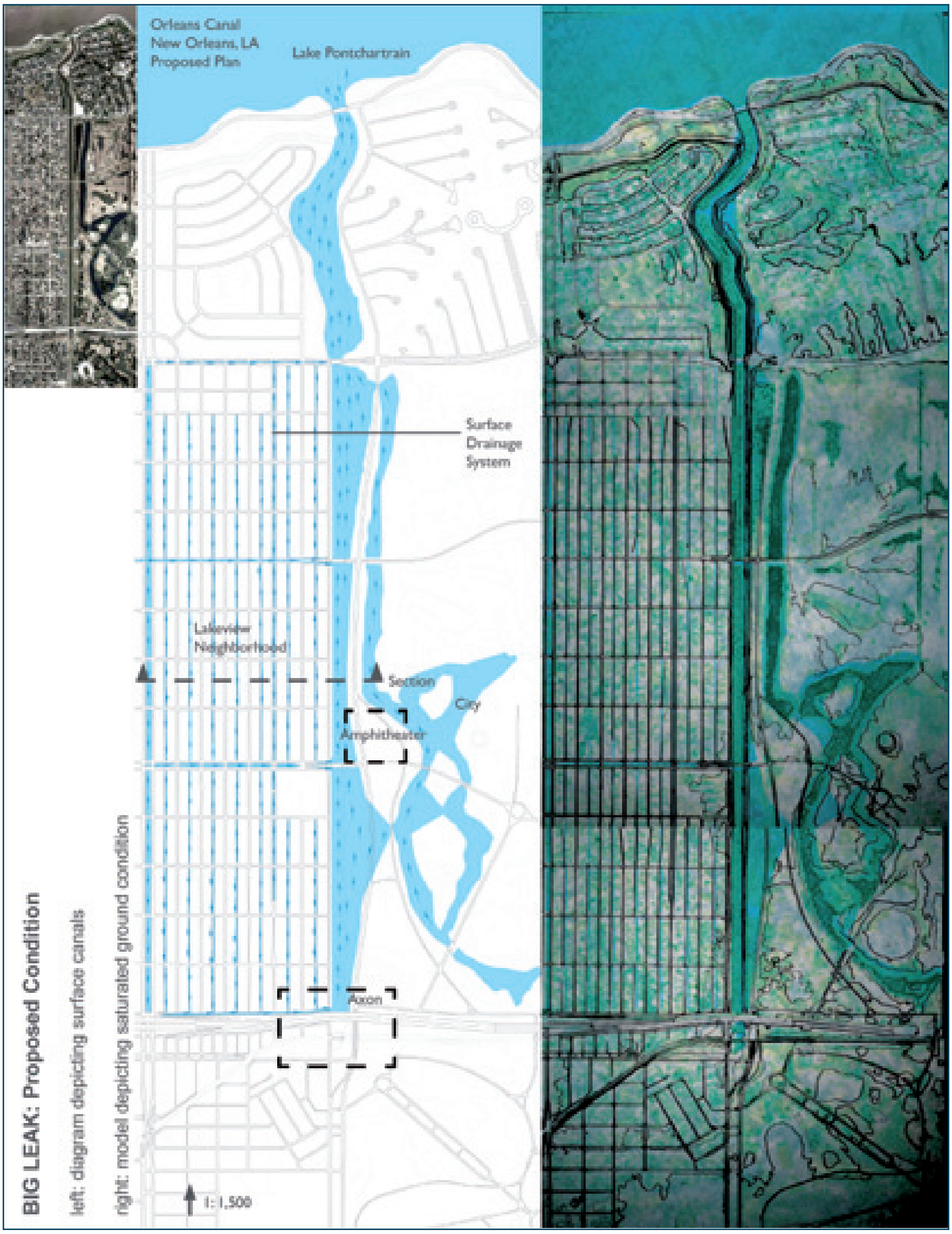

Figure 6 Proposed condition

This provides the opportunity to convert the above-grade outfall canals that create walled barriers between communities, to a surface system that serves multiple purposes.

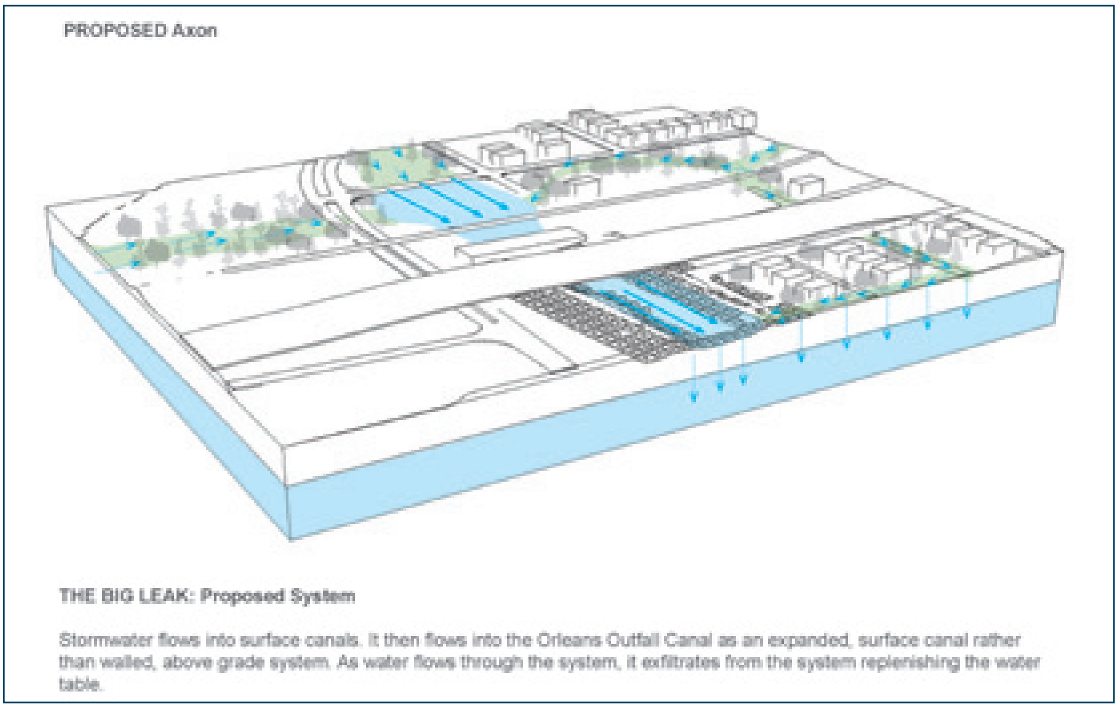

Figure 7 *Proposed axon*

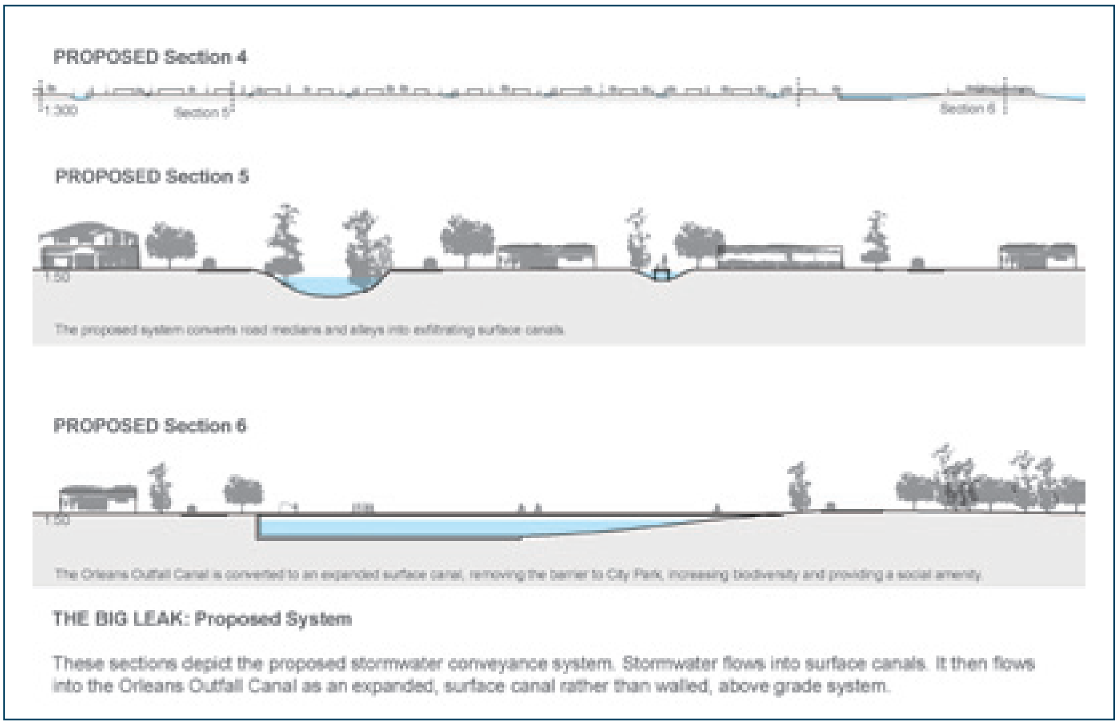

Figure 8 *Proposed sections*

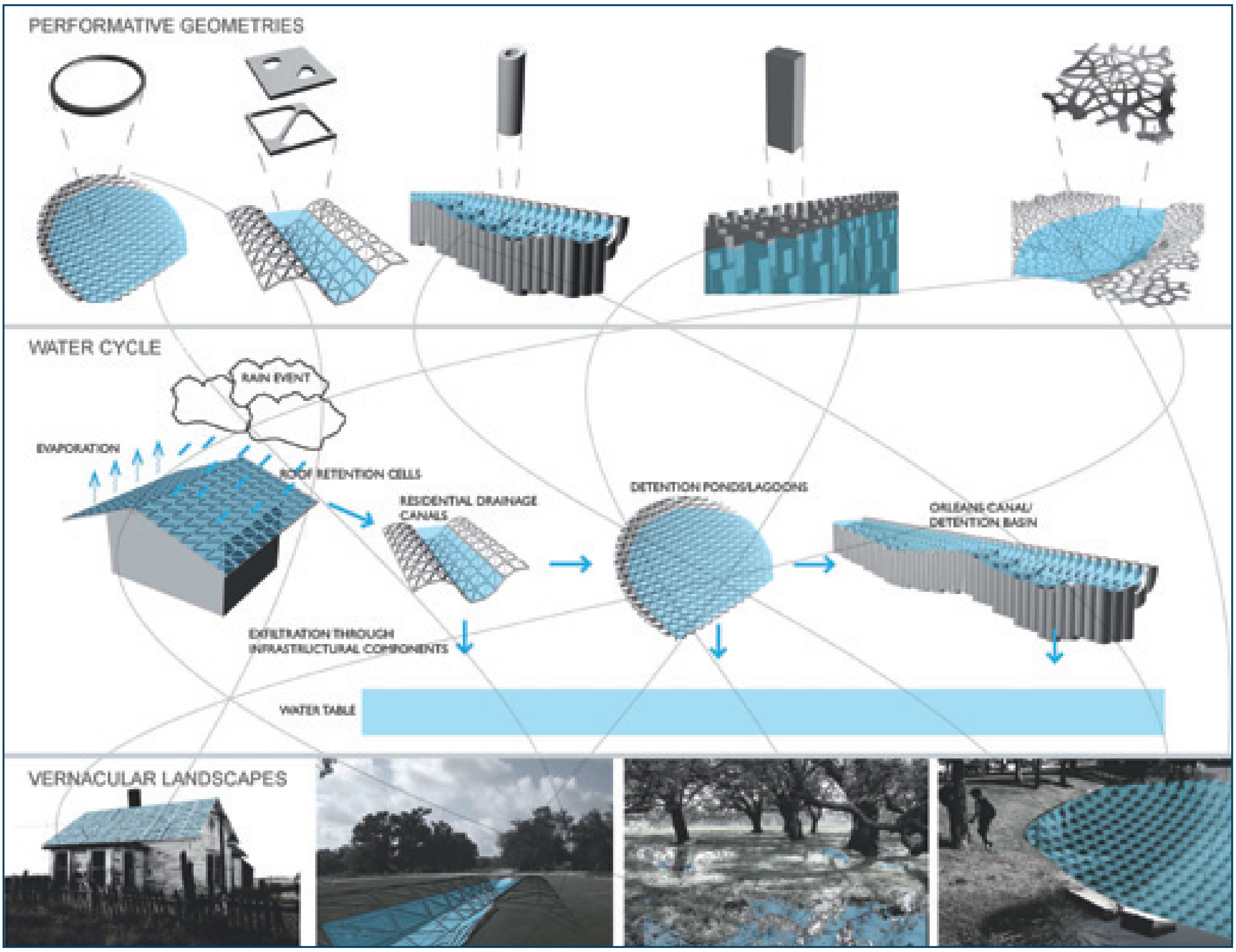

Figure 9 Parametric exfiltration

Parametric Exfiltration

Today, it is commonly believed that exfiltrating systems can adequately perform in low intensity rain events, but that conventional sub-surface, non-porous systems are still required to handle high intensity storms, such as those experienced in New Orleans during a hurricane. This project proposes a system that can be customized to allow for groundwater infiltration via stormwater conveyance model exfiltration, while also maintaining the necessary water velocity to negate flooding risk.

In designing a stormwater conveyance system one must consider the hydrologic cycle and the relationship of rainfall and the drainage basin over which it falls. Rainfall that is caught by vegetation before hitting the ground is referred to as interception. Some rainfall will infiltrate into the ground, while some will be trapped in depression storage. The remaining water is referred as direct surface runoff. An objective of any stormwater conveyance model should be to reduce direct runoff as much as possible. Direct runoff is calculated as:

$$D_r = D_p - D_{li} - D_i - D_s - D_e$$

Where:

D_r = total depth of direct runoff
D^p = total depth of precipitation (rainfall)
D_{li} = total initial loss, sometimes called initial abstractions
D_i = total depth infiltrated after initial losses
D_s = total depression storageDe = transpiration and evaporation losses

Stormwater conveyance modeling software analyzes each of the components of the hydrologic cycle based on the physical construction and surface conditions of a drainage basin to calculate the resulting direct surface runoff and its capacity for the drainage basin.

This proposal advocates a porous, supporting structure for the conveyance system that could be filled with a filtering material (organic or manufactured.) The aperture size of the structural components can be parametrically adjusted based on the specific soil type of the drainage basin, the desired infiltration rate, and the porosity of the fill material. These systems directly increase the Di (total depth infiltrated after initial losses) and Ds (total depression storage) of the overall drainage basin, thereby reducing the Dr (total depth of direct runoff.)

This parametric exfiltration system reduces the load on pumping stations to remove direct stormwater runoff during rainfall events and provides capacity to retain water during non-rainfall (dry) conditions to allow additional time for rainfall to infiltrate into the water table. As state previously, raising the water table in this way results in a reduction in the rate of land subsidence.

Social Barrier to Social Asset

In many cities around the world, water canals and systems are accessible and celebrated. However, in New Orleans they are hidden and their importance often forgotten. The Orleans Outfall Canal is currently a 20-30ft. barrier between the Lakeview neighborhood and the cultural landscape, City Park.
Converting the Orleans Outfall Canal from an above grade barrier to a surface canal and retention basin seams neighborhood with park, creating a social and bio-diverse asset for the community. Likewise, surface canals at the neighborhood scale become community intersections of activity. There may even be moments where this parametric form emerges from the ground to create in habitable spaces in City Park, such as an amphitheater.

Figure 10 *Neighbourhood Canal*

Figure 11 *Orleans Canal*

Figure 12 *Park Amphitheater*

CONCLUSION

There is no one solution that will solve the issues facing delta cities around the globe. It will take many tools at multiple scales to make these safe and inhabitable places for humanity and wildlife. This proposal purports these results:

- Removing stormwater from the city,
- Re-charging the water table,
- Increasing biodiversity, and
- Creating social assets.

These results ultimately come together in a solution that will abate land subsidence in the city of New Orleans

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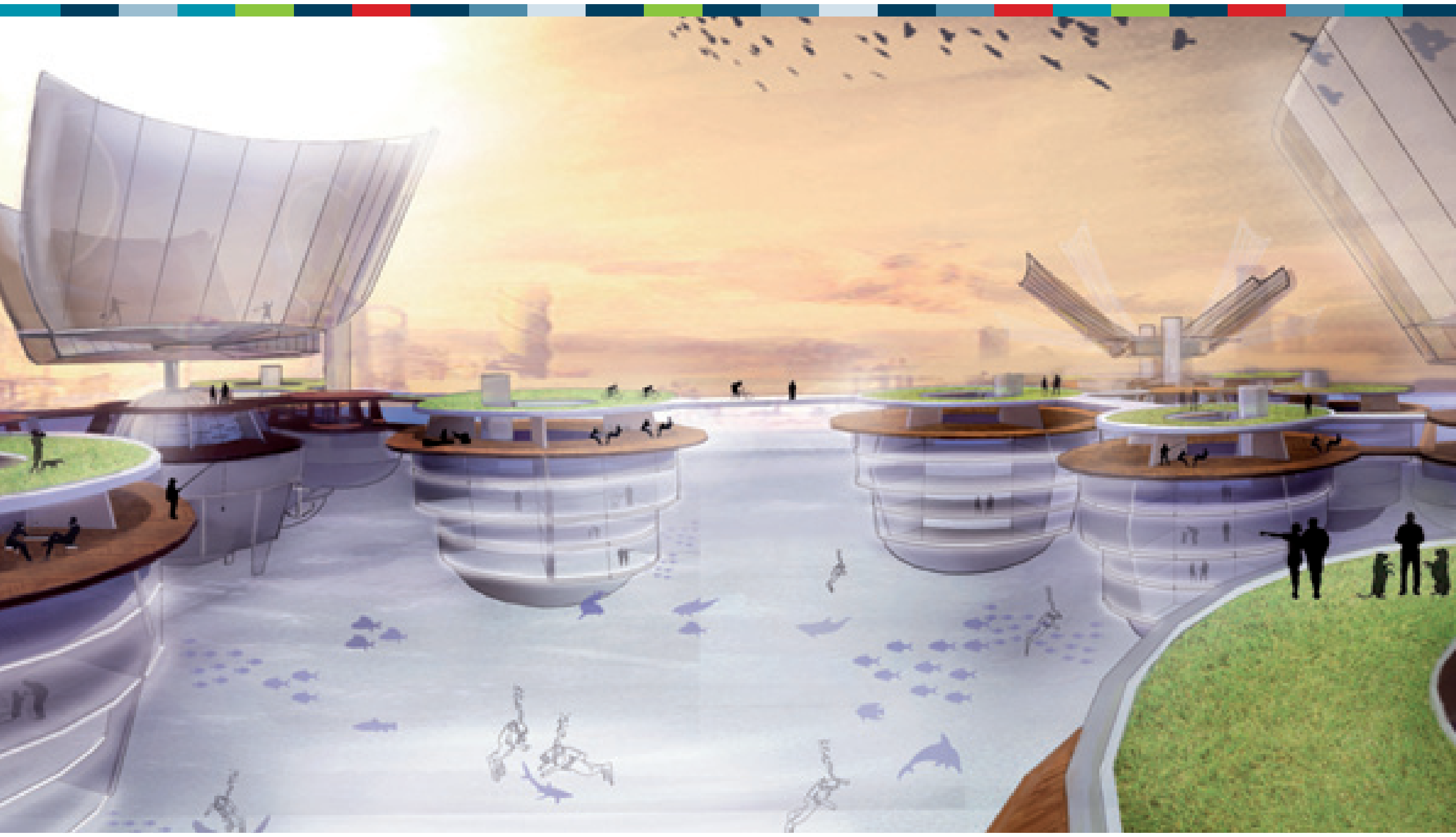

NYMPHAEA

RUNNER UP

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The Future

Our future seems bleak, or not? We envisage a future where delta cities reinvent themselves for the massive changes of the coming century. Confronted by countless adversities, faced with a drastic sea level rise, increased population figures, and mounting pressures for self-sustainability.

The urgency of the situation requires a re-look into existing means of living and the creation of new cross-programmed infrastructure, urban and architectural typologies to address the pressing issues of water, food and energy security

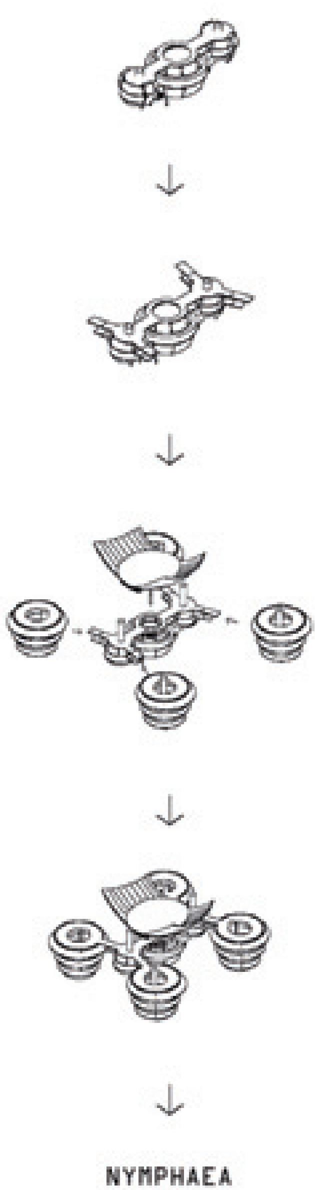

Figure 1 *Vortex Induced Vibrations oscillate objects in fluid current*

My project, Nymphaea, examines the possibilities where energy harvesting, high-density living and fish farming could co-exist to form synergistic relationships between them. A new lifestyle is proposed in the future where we all live underwater!

Nymphaea would be largely dependent on energy harvested from water currents, which range from speeds of 1.74m/s to 3.1m/s on average. VIVACE (Vortex Induced Vibrations Aquatic Clean Energy) 1 is a machine that effectively converts slow moving water currents with speeds as low as 0.51m/s into energy. Currently, most aquatic turbines require wave speeds of at least 2.57m/s to operate. Professor Michael Bernitsas, from the University of Michigan, revealed that a one and a half square kilometer field of these cylinders, combined with water current at 1.54m/s could yield enough energy to serve 100,000 homes.

Wind power can also be harnesesed with the use of wind turbines attached to Nymphaea. With the constant fluctuations of wind direction at the deltas, the revolving wind catchers are utilised to capture and direct winds to the wind turbines, which in turn drive the generator. The wind catchers help to increase the wind speeds and the overall energy generated by the creation of a 'Venturi effect'.

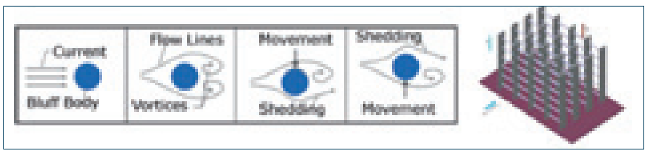

Figure 2 *Vortex Induced Vibrations oscillate objects in fluid currents*

In the master plan, a series of walls will be built to create channels of varying widths for the water currents to flow through. Based on the Venturi effect, the water currents would increase in velocity upon flowing through a constricted section, thus increasing the efficiency of the VIVACE devices. The walls will also serve as a barrier to prevent the existing built up environment from flooding.

In the initial phase, the walls are first erected with the deployment of the basic unit of Nymphaea consisting of just the generator component. As residential demands increase, the residential pods are subsequently transported to site and assembled on site.

Effectively, the distribution of Nymphaea units corresponds with areas having faster current speeds. Development will grow in a similar manner, having areas of higher density concentrated nearer to the constricted channels and gradually spreading outwards.

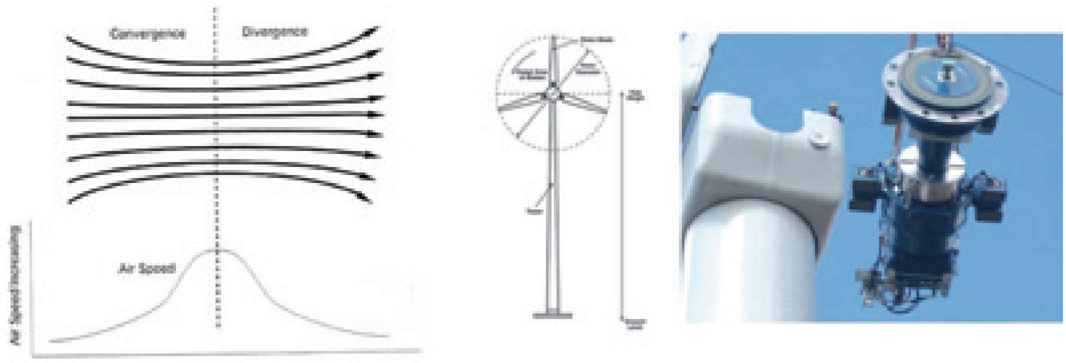

Figure 3 The Venturi effect (left) Wind turbines (Centre and right)

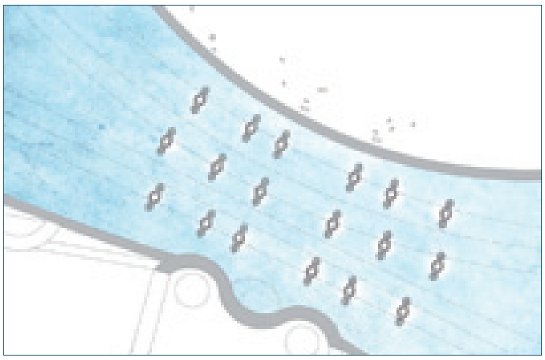

Figure 4 Master plan Phase 1/ Erection of protective seawall and harvester unitss

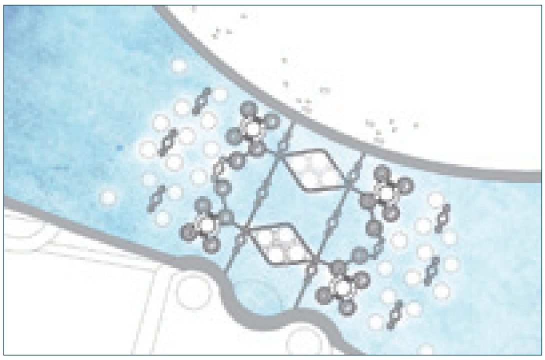

Figure 5 Master plan Phase 2:/ Residential components are attached to the existing harvester units

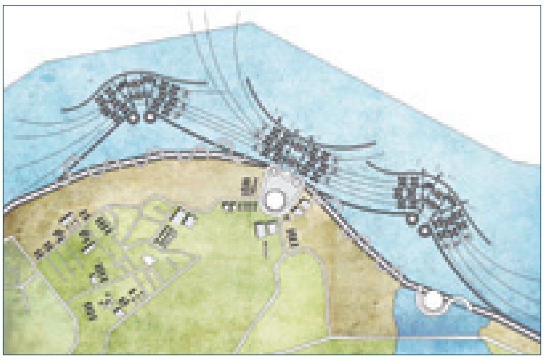

Figure 6 Master plan Phase 2:/ Residential components are attached to the existing harvester units

With rising sea levels due to adverse changes in weather, there arose a need for a flexible and portable architecture with the ability to be relocated. Nymphaea was thus conceptualized as a floating unit capable of harnessing current energy while providing comfortable living spaces. Close to a zero footprint was achieved with the use of anchors to tie down the floating submersible.

Designing towards a type of portable architecture was essential in allowing for easy erection and assembly on a site remote from any main form of infrastructure. Nymphaea was conceived in several parts, the primary body consisting of the harvester unit that houses the energy harvesting equipment, and the secondary

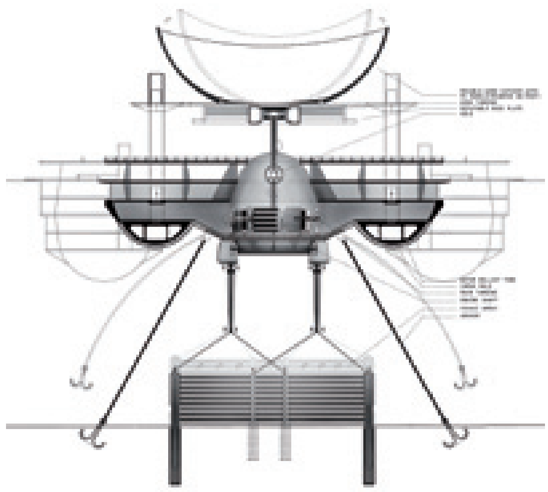

Figure 7 *Generator room and Nymphaea anchoring system*

housing units that can be plugged into the main body. The parts can be transported in one piece via ship or air for instant use once they arrive at their location. This method also allows maximum flexibility for adaptation to different layouts and facilitates phasing during construction.

Structure

The design of Nymphaea poses many problems not encountered with land-based systems: for example, normal pressures are very large, and many structural elements are extremely sensitive to initial geometric imperfections. According to studies done in the design of submarines2, for a uniform pressure the ideal pressure vessel geometry is a sphere. Next to a sphere, the most efficient pressure hull structure is that of a right circular cylinder with domed enclosures at either end. The cylindrical shell was thus adopted as it gives better volumetric efficiency in that most

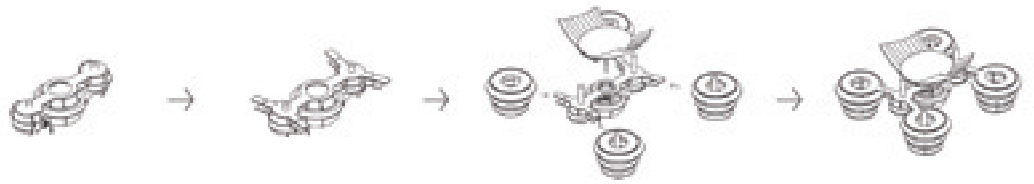

Figure 8 *Assembly of Nymphaea*

rectangular space can be included within it than a sphere of the same enclosed total volume. It is simpler to manufacture because the cylindrical hull has single curvature and so plates can be rolled. Exploring deeper into the buckling deformations of shells, at each point around the circumference there is a compressive loading applied between the elements of the circumference. The circumferential hoop can be regarded as an infinitely variable length strut and so there are many mode shapes in which it may buckle. Thus, ring stiffeners fairly closely spaced along the length of the cylinder were used to provide radial stiffness to the cylinder.

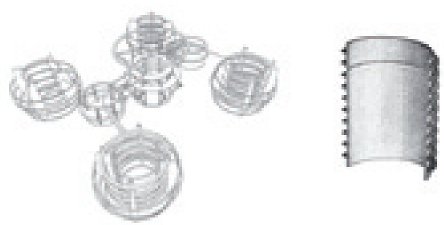

Figure 9 *Ring-reinforced cylindrical shell*

TransHab3 was a concept pursued by NASA to develop the technology for expandable habitats inflated by air in space. Its structure is a hybrid system that incorporates both inflatable and hard technologies to fulfill the peculiar, conflicting requirements of portability versus resistance to extreme environmental conditions. It thereby combines the safety and compatibility advantages of the rigid structure with the packaging and mass/volume efficiencies of the inflatable structure. The structural core consists of a hexagonal shaped tube made of composite columns that connect to a tunnel unit at one end. These are braced by isogrid shelves that help the core resist loads. After launching, these shelves can be repositioned by inflation.

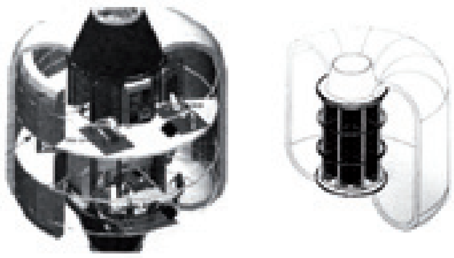

Figure 10 ISS TransHAB central core structural system

Ideally Nymphaea could develop along this direction with both the use of soft and hard technologies. The outer shell could be conceived as a layered system, inflated by air to help resist the outside pressures. Moreover, an inflatable skin could substantially reduce the total weight of the unit, allowing for greater ease during transportation.

Material-Lightness

Aiming for lightness was one of the key concerns as it affects cost and ease of transportation. It also promotes sustainable use of materials by using as little material as possible to achieve its maximum potential. There is a marked indication that striving for lightness strongly needs development of knowledge on building things out of lighter materials.

Plastics, over the past 50 years, have grown at an incredible pace until becoming part of nearly all the areas of human activity. They are light simply because their main building stones are the lighter atoms: hydrogen, nitrogen, oxygen and carbon and they can be composed into materials of great strength. Being non-biodegradable, otherwise seen as non-environmentally friendly, it is also this very characteristic that makes plastics durable and resistant to chemical and organic deterioration what makes them so tough on the environment.

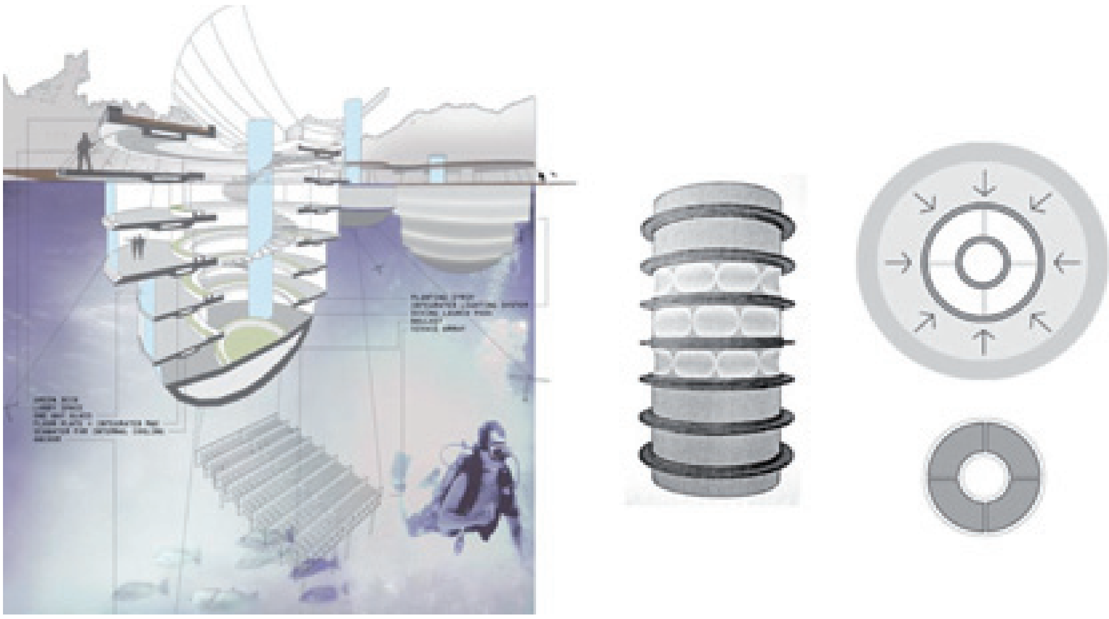

Figure 11 Force diagram showing floor plates acting as strengthening element

The internal walls and floor plates of Nymphaea were intended to be constructed with plastic composites for the above reasons to serve as a strengthening element by forming a rigid structure together with the steel ring frames. Moreover, the use of plastic floor plates/walls can allow for M&E and other services to be integrated into the structure itself.

Figure 12 *Fiberglass kayak*

The design of the residential component in Nymphaea sought for a transparent skin that offers maximum frontage out into the sea and also to provide strength to resist the hydrostatic pressures. Fiber-reinforced plastic (FRP) commonly known as fiberglass was chosen as the choice of material. It is a combination of glass fibers and polyester resin combined into a material that is usually filled or sanded and then painted to remove and hide imperfections. Fiberglass provides high strength to weight ratio and high flexural strength and pound for pound fiberglass can be stronger than steel and sheet metals. Fiberglass is extremely malleable, allowing a high degree of design. It can easily be bent into a continuous curve to suit the required curvature whilst remaining cost-effective. Moreover, being exposed to constant seawater and corrosion, Fiberglass - chemically inert and corrosion-resistant, is able to combat these problems. This amounts to low maintenance cost associated with repairing or replacing these damaged components.

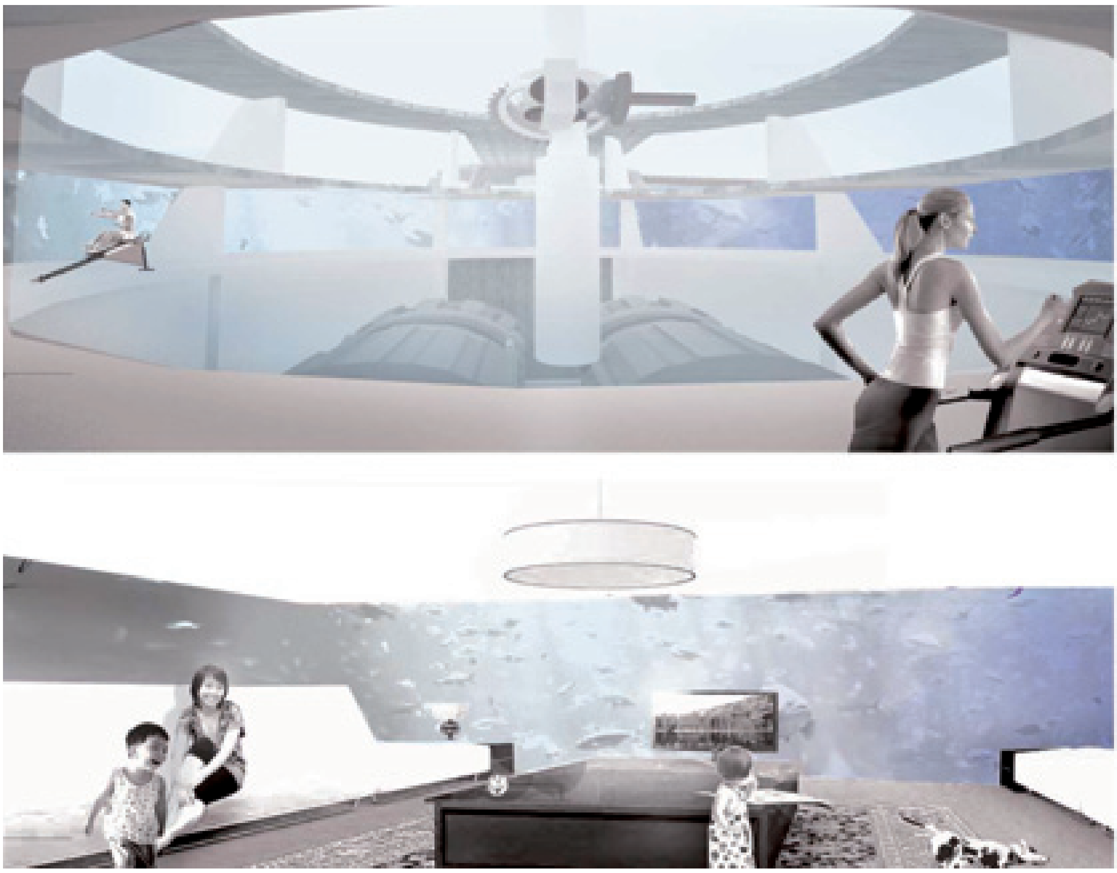

Figure 13 *Interior View from gym overlooking generator room (Top), Interior perspective of living room (bottom)*

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A WORKING LANDSCAPE FOR NEW ORLEANS

RUNNER UP

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Abstract

This paper studies how strategies aiming at working landscapes can simultaneously improve stormwater resiliency and spatial quality in two suburban neighbourhoods in New Orleans that were hard hit by hurricane Katrina in 2005. A spatial strategy mitigates stormwater flooding problems during a 1/10-year storm event and explores the potential of water as an amenity in the city.

The paper identifies the need for a new approach by quantifying problems concerning (1) hydrology, (2) vegetation and (3) vacancy. Based on topography, subsidence rate, problems with rain flooding and the original appearance of the landscape, 4 landscape zones are distinguished that provide basic concepts for interventions on all scale levels, addressing the 3 problems stated above. A new water plan for the area based on retain-store-discharge principles and a robust network of native vegetation form a new landscape framework. By utilising the empty space(s) due to vacancy following the hurricane to serve as water storage, this problem turns into an opportunity to re-create attractive residential areas with high quality of life.

The results of this study illustrate how preparation for the future and a changing climate poses challenges, but also offers opportunities for the creation of attractive delta cities.

INTRODUCTION

Deltas are highly dynamic landscapes, and subject to constant change. As a result, human intervention and innovation has always been necessary to safely live and work in deltas. The location of an urban region in a delta brings prosperity and economic wealth, but at the same time there are disadvantages and challenges to overcome. Being low-lying areas, deltas are prone to flooding by the rivers that form them, large volumes of rainfall - typical of coastal climates -, and storm surges from the adjoining seas. The rapid urbanization of the world's delta puts natural resources at risk and amplifies possible consequence, both economical and psychological, in case of disaster (McGranahan et al., 2007). The recent concerns about climate change and socio-economic trends of progressing urbanisation and continuing investment make life in the urban delta even more complex, and a sustainable strategy for dealing with water in urban deltas all the more relevant.

New Orleans, located at the mouth of the Mississippi river (see figure 1), is a typical urban delta city. Like many delta cities around the world, historically the city has a two-fold relationship with water as both resource and threat. Since Hurricane Katrina devastated the city in 2005 the Dutch Dialogue workshops – initiated by local architect David Waggonner and the Royal Dutch Embassy - US and Dutch professionals have engaged in a knowledge exchange aiming for new harmony in the landscape, equally inspired by Dutch water cities and love for 'the big easy'. Continuing on Dutch Dialogues II (please refer to Meyer et al., 2008) and providing input for Dutch Dialogues III (April 2010), this paper explores how a transformation of the New Orleans' storm water system can increase stormwater resiliency, provide a climate-adapted future, and at the same time contribute to the revival of the city.

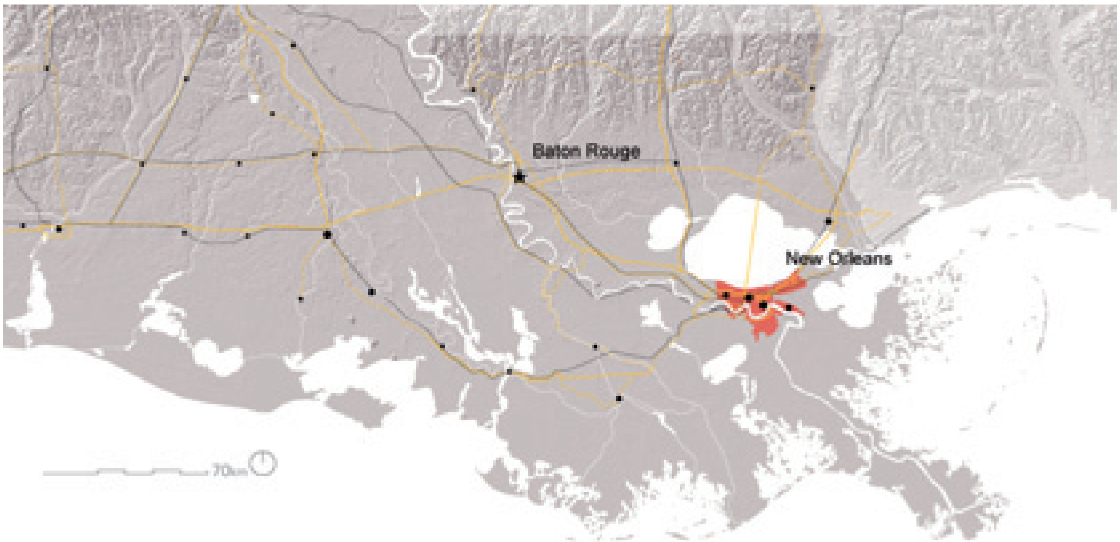


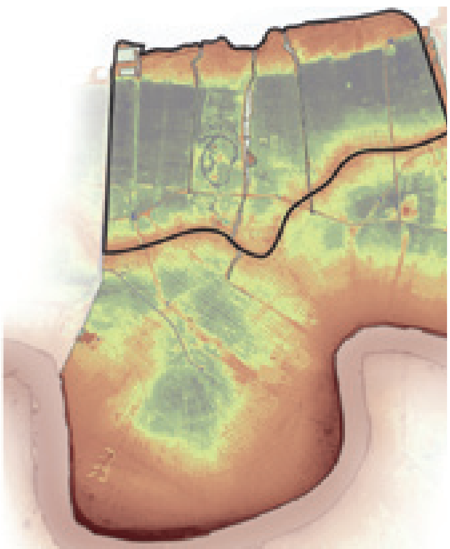
Figure 1 *Louisiana and the Mississippi deltaic plain*

Today's state of affairs in New Orleans

It has now been well over 4 years since Katrina struck the South Louisiana coastline near New Orleans, flooding 80% of the city up to 3m (Campanella, 2008), and forcing virtually all citizens to evacuate. Since 2005 15 billion dollar has been invested in a hurricane risk reduction system on the perimeter of the city, built by the U.S. Army Corps of Engineers. Once completed in 2011 it will provide protection against 1/100-year storm events, and is designed to withstand a 1/500 year storm event without catastrophic failure (USACE, 2008); a better than ever before safety from hurricane threats. These considerable investments however, do little to improve the day-to-day quality of the living environment for the residents of New Orleans, which varies greatly related to topography. Behind the dikes a two faced city can now be observed:

The historical parts of the city, located on higher grounds, again do well. Flood elevation levels were low here and population reaches close to pre-Katrina levels. Again the same lively, festive and easy-going atmosphere is buzzing through the streets. These neighbourhoods provide the lush greenery, rich experiences, colonial architecture and bustling nightlife; all that New Orleans is famous for. However elsewhere large parts of the city are by all means still severely damaged and lack landscape quality. It is in the low-lying suburbs, the former back swamp of New Orleans, that the city's problems concentrate, the lack of landscape quality is most manifest and interventions are most needed. The Gentilly and Lakeview neighbourhoods are typical examples of such low-lying areas and form the focus area of this study (see images below).

Figure 2 (left) *61,310 Residential addresses (29%) vacant or unoccupied (GNOCDC, 2009*
Figure 3 (right) *Study Area and topography (LSU, 2000)*



Lack of landscape quality

Being landscape architects we have tried to tackle four main problems in these areas, which together determine this landscape quality: rainflood events (1), subsidence (2), the permanent consequence of vegetation loss (3), vacancy, and its resulting changes in atmosphere of the neighbourhoods (4).

1) In New Orleans extreme precipitation events - with interior floods as a consequence - have occurred frequently in the past decades (Faiers et al., 1997; NASA Earth Observatory, 2007). The city has a sub-tropical climate; average monthly temperatures in the city range from 12 to 28 °C and average annual precipitation is approximately 1572 mm (1961-1990). Rainfall is extremely intensive; rainfall in excess of 75 mm in 24 hours, or 100 mm in 48 hours is an almost annual event in the city (Stuurman in: Meyer et al., 2009). The effects of climate change mean that New Orleans has to prepare itself for even more intense rainfall events - based on in situ observations Groisman et al. (2004) observe a linear trend of an increase of 26% during heavy precipitation events - separated by longer periods of drought (Boesch, 2002).

Figure 4 *Lack of landscape quality*

Already today, the large volumes of rain in short time periods often exceed the capacity of the outdated and broken storm water system in the city, inflicting large amounts of property damage, and sometimes even casualties (US Army Corps of Engineers, 2009, NWSFO, 1997). Figure. 4 shows the floodwaters during a 1/ 10-year storm event which can rise up to 60cm in the study area (BCG Engineering, 2003).

2) With an at-the-time world-class drainage system the swamps and marshes at the fringe of the city were drained at the beginning of the 20th century. Since then, fast discharge, a deep drainage regime and only small amounts of open water result in a low groundwater table, dry soils and consequently subsidence of these now urbanised, former 'backswamp' lands (USACE, 2006). Originally slightly above sea level these lands have fallen up to 3m below sea level, causing them to suffer the worst from Katrina's floodwaters (Campanella, 2008). The subsidence resulting from soil settlement complicates the draining of the city and worsens existing water problems by shifting subsurface drains and canals, loosening joints and causing leaks, breaks, and bottlenecks in the system. Also subsidence causes substantial damage on roads and sidewalks.

3) Both the strong winds and the brackish flood waters of Katrina destroyed 70% of the urban canopy, an estimated total amount of 100.000 trees. The loss of the urban canopy leaves the city far more susceptible to storm water and wind damage during future storms, and negatively impacts the microclimate through a lack of shade during hot summers. The remaining fragmented green structure and barren and deserted looking suburban landscape offers little to no opportunities for local fauna. Additionally the hurricane decimated the tree stock and nurseries in all of South-Louisiana, hampering recovery (Ierardi, 2008; HikeforkaTREEna, 2009).

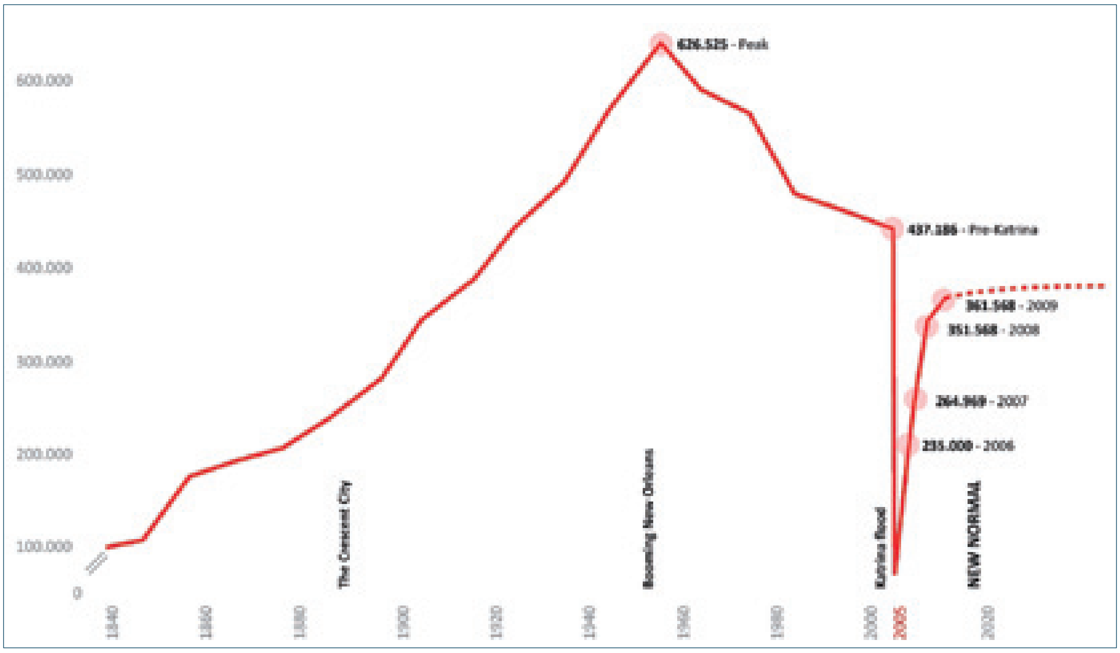


Figure 5 *Stagnating rates of return. (Campanella, 2008; Times Picayune 2009)*

4) Heavy emotions after Katrina and unsupported plans for urban renewal led to a 'laissez-fair' policy following the storm; a strategy focussed on short-term recovery. Today, 20% of the New Orleanians have not returned (Times-Picayune, 2009) and it is questionable whether they ever will, as people have rebuild there lives elsewhere in the U.S., leaving their lots empty, overgrown or in ruins in what were once thriving middle class suburbs. The resulting striking image of a perforated urban tissue with closed schools, unreturned grocery stores, and scattered inhospitable structures has a detrimental effect on aesthetics. Large numbers of inactive plots give parts of the area a feeling of neglect and desertedness. In this condition the poor urban environment not only provides limited possibilities for natural life, but also fails to inspire humans, and does not offer reason to pass time in the public space. As vacancy is strongly related to topography it is most significant in the lowest area's which sustained the most damage during the storm. In Lakeview and Gentilly over 30% of the residential plots are currently unoccupied, with some neighbourhoods close to a 50% loss of inhabitants (GNOCDC, 2009).

New normal conditions

It is important to realise that the situation New Orleans faces today are 'New Normal' conditions, no longer solely related to the recovery from Katrina (Campanella, 2008; GNOCDC, 2009). The stabilising rates of return (see figure. 5) imply the perforated tissue will not heal on its own accord and needs a structural rethinking. At the same time they also offer opportunities for changes in water management.

21st Century Urban Water Management

A paradigm shift can be observed regarding the way we relate to water. Since the 80's and 90's of the 20th century new developments regarding ecology, global climate change, and risk management have created a shifting approach towards water management. While traditional water management focused purely on safety through technical interventions, a much broader approach that incorporated ecology and spatial planning has become dominant. In this '21st century water policy' it is increasingly recognised that an integrated approach towards the disciplines of water management and spatial design together can address water-related problems more adequate and at the same time enhance spatial quality. Instead of seeing water solely as threat, the potential of water as a tool to create a sustainable environment with high spatial quality is acknowledged (Commissie waterbeheer 21e eeuw, 2000).

Figure 6 Westersingel Rotterdam. The city brands itself as a delta city (Photograph by authors, 2009)

Next to integration in spatial planning, challenges associated with a changing climate require 21st century water management to be flexible in order to withstand unexpected events in the future. Therefore the aim is to reserve enough space for water, maintain sweet water reservoirs and oppose drought through working with what nature has to offer. Inclusion of ecological processes is strived for, and technical interventions are proposed only when 'soft solutions' are not adequate or possible' (Commissie waterbeheer 21e eeuw, 2000). One of the ways this paradigm articulates itself in relation to storm water is the 'three-stage-strategy':

1. Retain stormwater as close to the source as possible. This relieves area's elsewhere and opposes water shortages in dry periods,
2. Store water that cannot be retained in retention area's such as ponds, swales, wetlands or other water bodies, where it has additional purpose,
3. Only when retaining and storing capacities are no longer adequate the water
4. should be discharged from a local water system into a regional water system.

Instead of a static system which confines water to be removed quickly from the city, these principles illustrate a dynamic strategy and physical environment in which there is more room for water to move, and water levels are allowed to fluctuate. Water is guided to where we want it to have additional purpose. One of the best examples of such an approach is the Waterplan 2 for the city of Rotterdam (Municipality Rotterdam et al., 2007). The document combines possible solutions for Rotterdam's water challenges for both for short-term problems, and the adaptation on the long run to the consequences of climate change, with the ambition to make Rotterdam a more attractive place to live. The city brands itself as a delta city in which the water is part of a (renewed) identity. People feel more comfortable in an identifiable environment with a sense of place to which they can relate (Norberg-Schulz, 1980). Additionally, such readable landscapes engage people with the landscape and its issues, and the processes and systems shaping it. By bringing people in close contact with their natural environment, public awareness and community support can be created for the substantial transformations our cities will have to undergo in order to adapt to complex environmental issues such as climate change. Nassauer (1995) and Saito (2007) among others, therefore plead for the uncovering of invisible ecological processes in an active representation for human experience. Landscape is a tool to achieve such social engineering and this is another reason for delta cities to combine the benefit of open water with the necessity to provide more room for stormwater in the city's fabric.

Water management in New Orleans

Compared with an average store/discharge ratio of 9:1 in the Netherlands (Hooijmeyer et al., 2005) the drainage system in New Orleans - with a 1:1 ratio - is highly dependent on discharge. The system is still mainly made out of the historical system put in place in the beginning of the 20th century and aims for an as-fast-as-possible discharge of its storm water through heavy-duty pumps with enormous capacities (up to 350m3/s (USACE, 2008). The pump stations in place are not able to fully utilize their enormous pump capacities though. The pumps can theoretically pump 0,77" – 1,13" of storm water out of their catchment areas per hour (USACE, 2007), much higher numbers than the 0,5"/h of the commonly applied rule regarding discharge of the New Orleans drainage system (USACE, 2009). This implies frustrations in the system upstream of the pump. Furthermore the torrential rainfall in New Orleans is of such magnitude that even if the storm water could be delivered to the pumps without frustration, the peak discharge of the first hour exceeds their capacity, see table 1 (USDC Weather Bureau, 1961).

The frequent rain flood events prove that the strategy based on discharge is unsuccessful. In this sense the technocratic system not only functions inadequately, but is also conceptually outdated for it relies on fast discharge and hard tech civil engineering alone. Measures aimed at retention and storage of water, combined with an ecological approach to water management, do currently not play a part in the technocratic system of New Orleans

Figure 7 Technocratic watermanagement: subsurface drains, deep drainage regime, discharge dependend system, floodwalls. (Sewerage and Water Board of New Orleans, unknown date; Hooijmeyer et al., 2005; USACE, 2009)

(see figure 7 above). Practice in New Orleans today is thus noted to be different from the trend in contemporary water management as outlined above. It belongs to a paradigm characterized by a fight against the water and nature in general, this in contrast to contemporary thinking which is increasingly common in the Netherlands and abroad, and seeks to work with nature, aiming at mutual benefit and to profit from open water as quality in the city's public space (Commissie waterbeheer 21e eeuw, 2000).

Because virtually all drainage infrastructures in the main metro polder of New Orleans are submerged, covered, or hidden by floodwalls, water is barely visible to residents. Large parts of the city can be characterized as consisting of nearly 0% open water, providing little to no resemblance to the native habitats of a delta city. This in contrast to Dutch delta cities where discharge/storage proportions mean that by law up to 11% of the land can be required to be open water (Hooijmeyer et al., 2005). With few or no links to their natural environment, citizens in New Orleans become detached and unaware of the landscape they live in.

Future Perspectives – A working landscape

Four and a half years after the storm the unique situation in New Orleans means that it is now time for a long term and integrated strategy for the revival of the city. Major disasters cause devastation on one hand, but create opportunities on the other. Hurricane Katrina in this sense was also an eye-opener. The reconstruction of the resulting perforated urban fabric now makes it possible to structurally transform the New Orleans water system. While flooding problems are far from uncommon in delta cities, the unique situation in New Orleans represents a chance to structurally improve the city's storm water resiliency and at the same time contribute to its revival.

To this end the huge amount of space left vacant after hurricane Katrina should be considered both a necessity and a chance to introduce extensive surface water and green structures of native and storm proof vegetation in the Lakeview and Gentilly neighbourhoods. By creating more room for water and reforesting the city, both the city' water problems can be addressed and its living environments—and thus attractiveness for residents—can be improved. This paper proposes a transformation process aimed at a working landscape with as its backbone a re-envisioned storm water system based on contemporary 21st century water management (Commisie waterbeheer 21e eeuw, 2000). Such a working landscape works two-fold:

Perform: In working landscapes, the aim should be on the inclusion of landscape processes, with as target a healthy and vital system that prevents nuisances and is productive. This means the cooperation with and use of these processes in a symbiosis, without the blocking or frustrating of them, with environmental problems as a result.

Inform: A working landscape should engage in interaction with the human perceiver, and trigger the human imagination and creativity. A design must not only be beautiful in aesthetic sense, but also enrich people with facts, stories and thoughts, by revealing richness and dynamics in the landscape. As such landscape is a tool to create a sense of belonging and identity.

A working landscape in this way may turn these low-lying areas into attractive and distinctive suburbs that New Orleans and its inhabitants so rightly deserve.

Research by design

The landscape architectural design forms an important part of this research, for only the creation of a design allows for conclusions whether the introduction of surface water in the perforated urban fabric is both possible and sensible, and thus is a valid concept.

The proposed strategy for New Orleans finds its inspiration in the richness of the surrounding original landscapes of the Mississippi delta, which are structured by a topographical gradient. Hardwood forest is found along the higher grounds of (former) riverbanks, followed by brackish bald cypress and tupelo swamp forests with saline marshlands closest to the sea. In the suburban area of Gentilly and Lakeview four landscape zones are revealed that refer to those original landscapes, and are further based on topography, subsidence rate, and problems with rain flooding. A fourth zone consists of a manmade landfill in the north of the study area. The zones provide basic concepts for interventions on all scale levels, addressing the problems stated above. Each landscape zone has its own strategy regarding hydrology and vegetation. In the lowest area's more space is reserved for open water in large surfaces and branching networks, while at the higher grounds infiltration in wadi's (swales) and a higher building density are the main principles. An integral approach towards spatial development ensures that investments work towards more than one end at the same time.

Waterplan

A vital part of the transformation is a new strategy regarding water management, advocating an interconnected surface water system based on the three-stage-strategy's: store-retain-discharge principle. The ratio between storage and discharge of a drainage system is a choice. New Orleans needs either a higher discharge capacity or a higher storage capacity to oppose its rain flood problems. As discussed above, for this design the retain-store discharge principle is favoured over the fast-discharge principle that is currently applied since it is more flexible and resilient towards the future. Additionally it offers possibilities for water to serve as an amenity in the city and opposes subsidence by creating a higher ground water level.

Dutch standards (Van de Ven, 2009) regarding freeboard and the allowed water fluctuation (dH max) are applied and tested in this study (see table 1) according to the following formula:

$I(t) * C - Q(t) = S$

A reduced drainage regime at a proposed freeboard of 0.9m counters subsidence and drought by moistening the soils. A generally allowed water fluctuation of 0.5m creates storage capacity in new canals and ponds strategically located in vacant space—voids, plots and medians varying in size (see figure 8)—within the working landscape structure. New Orleans' large City Park, covering more acres than New York's Central Park and located in the centre of the study area, is re-envisioned as a water machine that can store 852.500m3 of water during rain events.

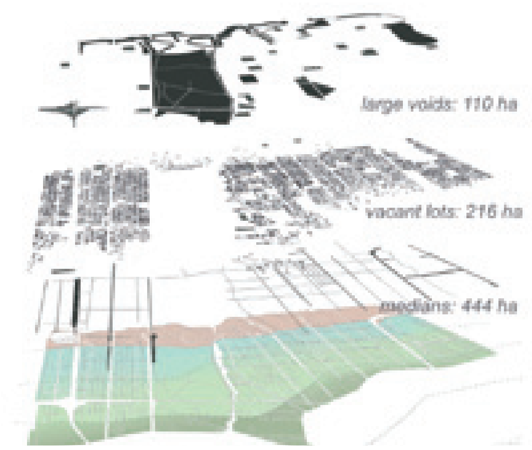


Figure 8 Design space and landscape zones

By combining LIDAR terrain data (LSU, 2000) with the flood depth and -area data (BCG Engineering, 2003) a floodwater volume of 1.200.000m3 for the residential areas of Gentilly and Lakeview was derived with GIS-tools. It was found that transformation of 20% of the gross available design space in the total neighbourhoods, together with the proposed design for City Park can solve 89% of the stormwater during a 1/10-year storm. Gross available design space is shown in figure 8 and is defined in this calculation as the combined area of empty lots, larger voids and unused medians which sums up to 771 ha. The amount of water that can be stored in the design space is dependent on the area and height of the available water fluctuation. Not all of the gross available design space is available for water due to a desire not to use all vacant plots for water retention, losses in for example embankments and provisions necessary for maintenance. Apart from the lake, a smaller portion of the water system of the park is assigned to mitigate storm water run off from the park itself, but is only sufficient to mitigate 26% during a 1/10-yr storm. The result is that during extreme storm events flooding would in this way concentrate in City Park, while residential areas are spared.

Landscape framework

The park will function as an anchor point and showcase for the new landscape structure in the neighbourhoods and demonstrates how an interpretation of the former appearance of the landscape can provide a connection with place and nature, and enrich the character and identity of the city.

Starting point of the design in residential context should be a pattern analysis of the urban fabric, by which opportunities for water storage and urban design can be discovered. The open surface water can offer multiple living environments related to water, and contribute significantly to the storage assignment. The exact scale of the transformation depends on the results of this analysis as well as the ambition level and priorities of the city. Hazards regarding health issues and water quality can be counteracted by critically designing slopes and borders according to technical design principles which include the prevention of stagnant water through guaranteed flow and ecological mosquito management (Metzger, 2004; Norris, 2004; Walton, 2003).

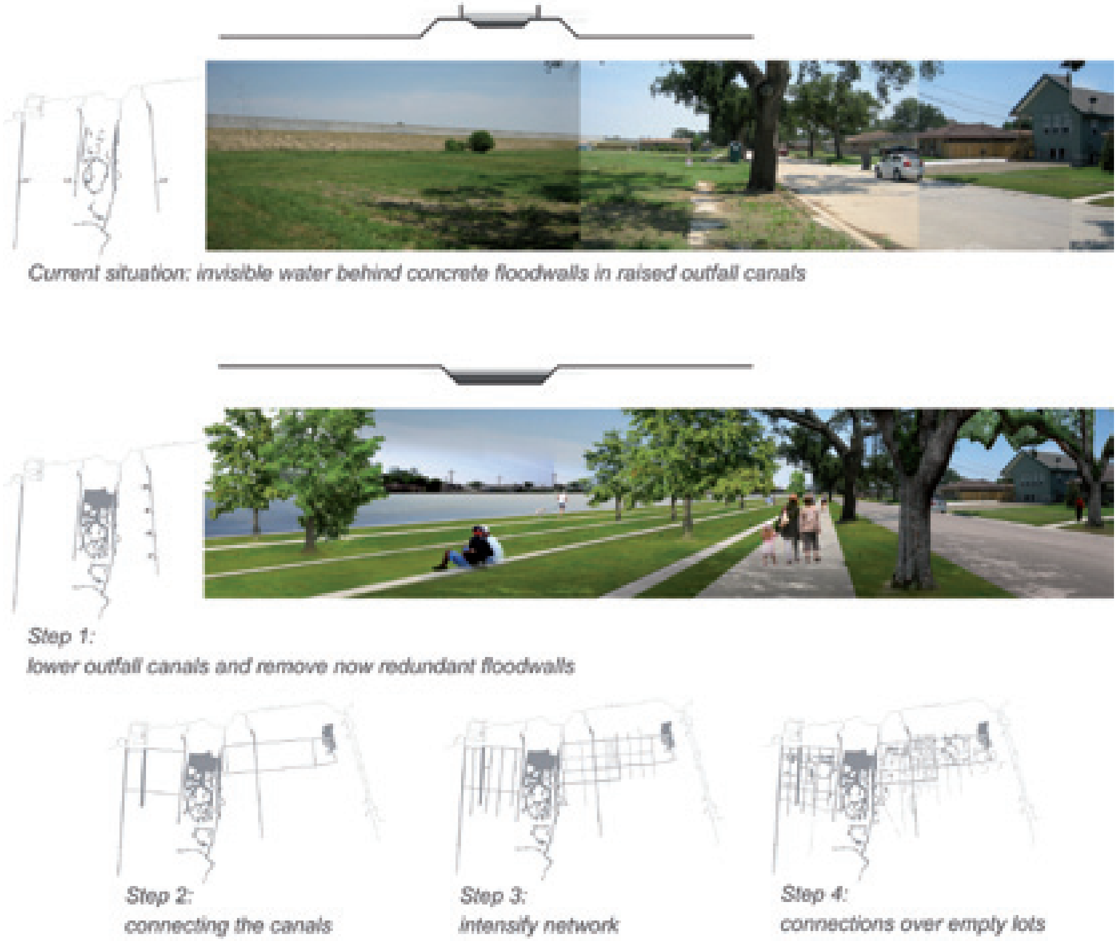


Figure 9 *Waterplan based on store/retain/discharge principles. A growing network of canals improves stormwater resiliency, reduce subsidence and bring water as an amenity in the neighborhood*

Typical native plant and tree species associated with the ecosystems in each landscape zone form the main character within the landscape framework, while accent species bring identity in different neighbourhoods within those zones. Native species ensure robustness to local climate (extreme winds and downpours) and additionally provide habitat to local fauna. The trees introduce shade in the public space and therefore positively influence the microclimate of the city during Louisiana's hot summers. Temporal functions reserve space awaiting development. Tree nurseries can be one of those functions, fulfilling the need for seedlings to reforest the city on-the-spot, as well as occupying and bringing meaning to neglected land. In a future stage these functions can give way for water bodies that will act as buffer zones and are designed as beautiful amenities within the neighbourhoods.

The flow and dynamic of water are the life that runs through the city's new veins. The prominently visible open water system educates residents about the fact that they live in a delta city where they have to live with water, which can act both as a resource and a threat. People have to realize that also initiatives on their private property (rain barrels, native vegetation, permeable materials) are needed to cope with the rainwater problem in the future. Through incentive planning, the community can and should be engaged with such interventions on plot level. All together this study shows how canals, grass lined swales, nurseries and retention ponds can be developed in order to not only function well but also look good; truly water as an amenity for the great city of New Orleans.

Figure 10 *Water as an amenity in New Orleans*

CONCLUSION

Preparation for the future and a changing climate poses challenges, but also offers opportunities for the creation of attractive delta cities. Four and a half years after the storm the unique situation in New Orleans means that it is now time for a long term and integrated strategy for the revival of the city. The strategy based on 21st century water management proposed in this paper mitigates rain flood events by reducing peak discharge, offers conditions for native, sustainable vegetation and provides attractive public space.

The results of this research indicate that strategies aiming at attractive working landscapes have much potential to offer a soft and sensible solution to the water challenges in New Orleans, and at the same time improve landscape quality.

Landscape architecture, contemporary water management and urban planning together can build a city that learnt from its past and will be more resilient and climate adapted in the future. A city with a vibrant and truly unique atmosphere that can have an exemplary function for other delta cities in the world in terms of approach to storm water system adaptation. Also by revealing landscape processes to the residents they will be more engaged with landscape issues, generating increased awareness and support. Let us not wait for another disaster to trigger such a relation with water and landscape, but let us start today with the creation of climate adapted and attractive delta cities in the world.

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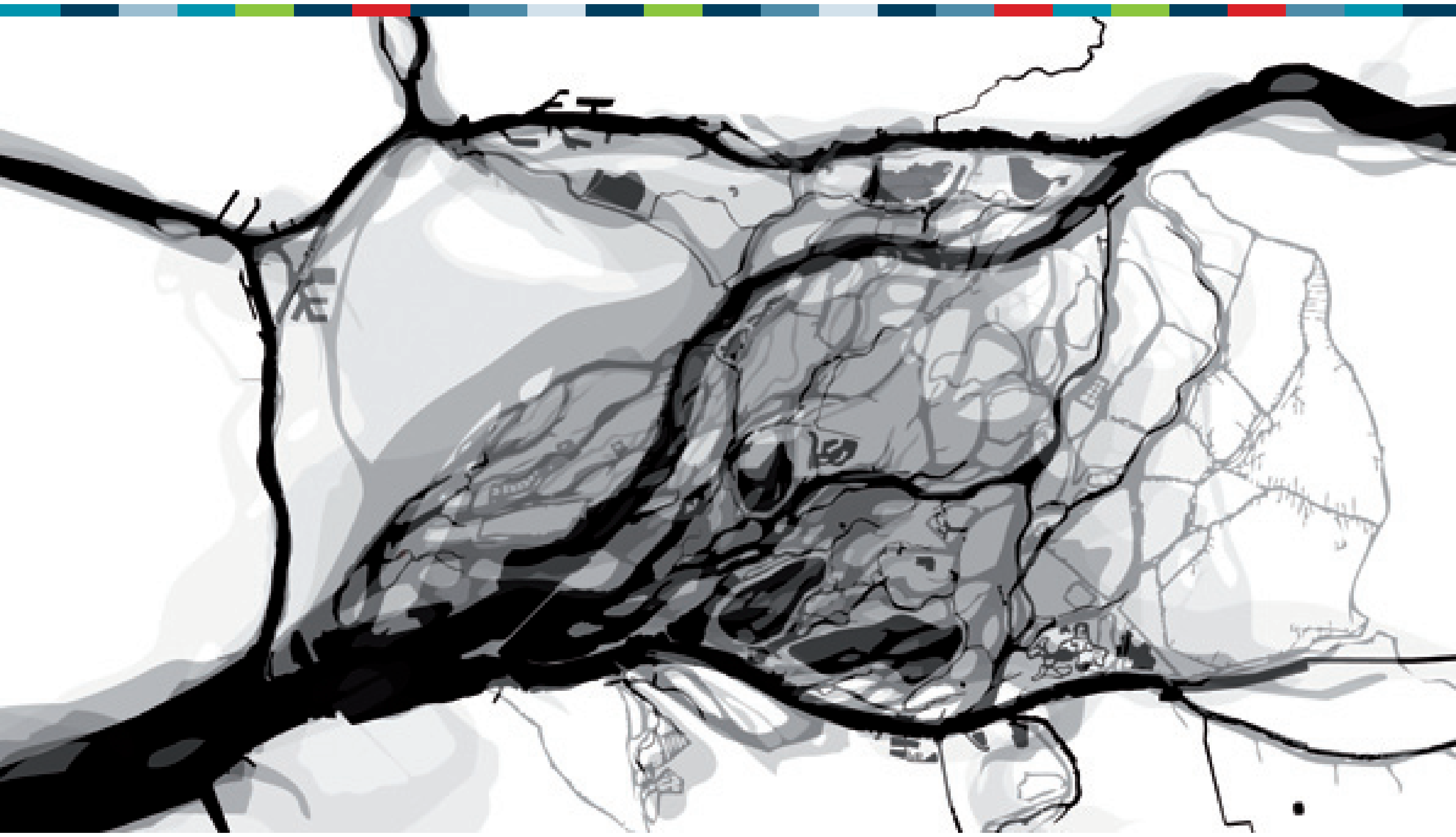

DEDAMMING URBANISM

RUNNER UP

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Abstract

In response to the failure of current engineering strategies to manage complex deltaic systems in the Netherlands, our strategy involves the opening of the Haringvliet Dam to introduce the exchange of salt and freshwater for the reclamation of estuarine ecologies. Through the research of ecological shift that have occurred throughout the last 700 years resulting in mono-ecologies and land use patterns, we introduce the Dynamic Nomaal Amersterdam Peil (DNAP) as a concept strategy to establish a shift from dry-land agriculture to aquaculture, in order to reintroduce a bio-system similar to the historical gradient that once existed. The establishment of mud flats will generate bivalve economies altering urbanization patterns inside and outside the dike and, more importantly, we will illustrate how these changes in land uses will position Dordrecht as a global player.

The point of departure for this change is the latent ecology of the delta's estuary, one of the world's most diverse, complex and fragile biotopes. In this scenario, Dordrecht becomes an island of islands at the epicentre of an urban archipelago; the junction of a watershed and a coast, amidst a mixing zone squeezed in between saline waters of the North Sea and the fresh waters of Europe's longest watercourse, the river Rhine. As a result, the future of Dordrecht - like the future of the Netherlands - is inseparable from the future of the estuary In turn, the future of the delta is inseparable from the future of the North Sea. In the space of this geographic convergence and ecological systematization, a new aquatic habitat provides ground for proto-ecological processes to emerge and proto-urban conditions to spin-off. Closed, linear and engineered controls make way for the flexibility of soft systems. Here, the ground is transformed with the accretion of the estuary's most vital resource: mud. Together with tidal dynamics, silt and sedimentation of the mud flats enable reefs that build up and accumulate, hosting the colonization of thousands of bivalve species, one of the basic building blocks of intertidal ecologies. The benthic and pelagic foodshed begin to thrive: plankton and bacteria, clams and crabs, smelt and salmon beavers and seals, reeds and cattails, willows and poplars. It is a landscape where the dichotomies of wet and dry, sweet and salt dissolve, making room for an ecological gradient to emerge. Every living species co-exists, co-operates and co-develops across a range of hydrological zones, shoreline territories and intertidal time-scales. Ecology becomes infrastructural.

INTRODUCTION

Over seventy percent of the GDP in the Netherlands is produced below sea level. To uphold this submergent economy, the Netherlands must spend 2 billion Euros annually on flood defense, an amount equivalent to the United States' per capita spending on military defense. With dwindling reserves of natural gas in the North Sea, Dutch energy demands, which include water pumping systems and flood control structures, rely on the import of 976 thousand barrels per day, mostly from the Middle East. To withstand the projected sea level rise between now and the 22nd century, flood infrastructure in the Netherlands must be raised by 1.3 meters this century and an additional 4 meters subsequently, while groundwater simultaneously drops 1.75 meters. When we talk about climate change and sustainability, what exactly are we trying to sustain? Should we fear sea level rise or exploit it? Should we shore up the Netherlands or let it flood? How do we deal with depleting energy resources and population pressures? Can design preempt challenges that don't yet exist?

The future of the Netherlands is clearly inseparable from the future of energy, engineering and ecology. Responding to the current call for re- armoring coastal defenses across the Netherlands, this project takes on the double bind of climate change and urbanization with a design research project which addresses the regional challenges of the Maas-Rhine River Delta, an aqueous terrain of subsiding land, squeezed in by rising sea levels and increasing flood waters.

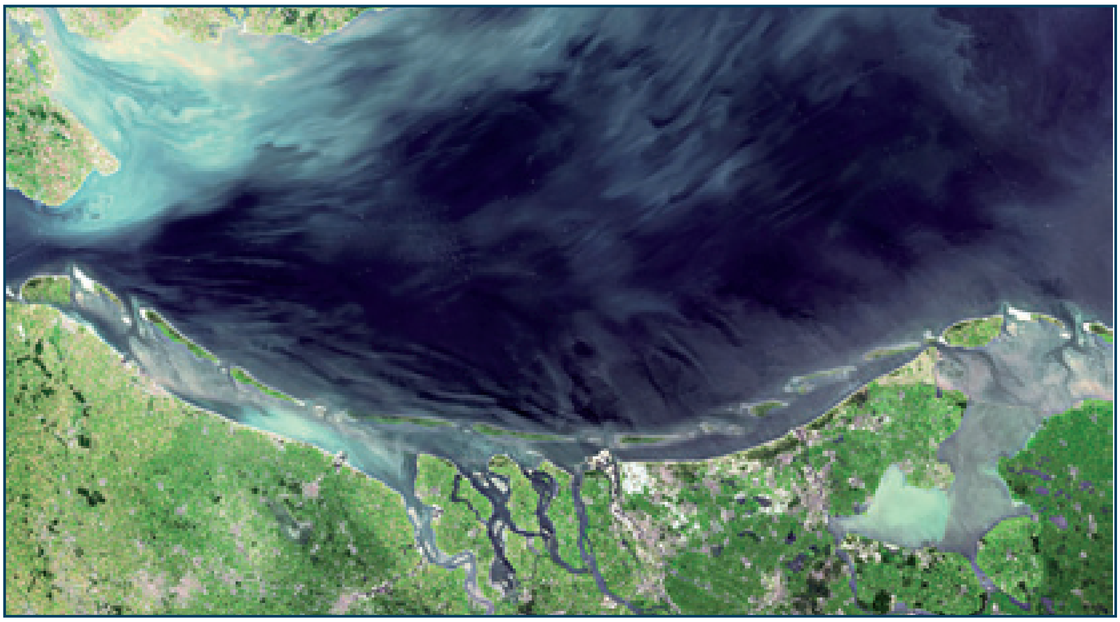


Figure 1 *Aerial view of the Netherlands coastline and delta. © 2004 European Space Agency*

Dordrecht: City or Urban Island?

Nowhere is this challenge more pressing than in Dordrecht, a 1000-year old city located on an urban island in the Rhine-Waal watershed of the delta region of the Netherlands. From its early beginnings as a peat bog mecca for fuel in the 12th century to a global cargo terminal for shipping in the 15th century, Dordrecht is the first city ever to be chartered in the Netherlands, enjoying considerable growth during a golden age of economic development that lasted well into the 16th century. As a major market city trading in wood, wine and grain, the geography of protected polders and ring dikes in South Holland strategically positioned Dordrecht at the center of the national shipping toll system and, as the national mint for monetary currency. Its prominent role as a geo-economic hub came to an abrupt end, however, with the Great Flood in 1421, a sea surge that killed between 2,000 and 10,000 people in South Holland, flooded salt fields and peat farms, and turned the mainland of Dordrecht into an island. With the growth of the Dutch East India Company (the world's first multinational corporation) in the next three centuries, Dordrecht's staple economies were supplanted by other, more competitive cities such as Rotterdam in the wine trade, and by Amsterdam for grain and wood from the Baltic region.

Decline, Development, Decentralization

Overcoming a series of religious reforms, wars, plagues and epidemics from the 16th century onwards, the City of Dordrecht grew and diversified its economy by expanding its land base. Using well-known techniques of endikement and drainage, reclamation of submerged land was undertaken to annex and amalgamate neighboring islands into a super- island of shipping logistics and cash crop agriculture, known as the Groote Waard. The last remaining canals of the city were filled in during the 19th century, creating a centralized underground sewage system to avoid further outbreaks of cholera and dysentery. Using the signature poldering process of Dutch military engineering, the Merwede, South, Alloyzen and Wieldrecht Polders were created as a megasize fortification reliant upon endikement, drainage and water pumping, thereby averting future risk during periods of massive flooding in the 20th century.

Climate Capitalism

More than 50 years after the Big Flood in 1953 which precipitated the mega-projects in the Delta Works Projects (Deltawerken), a series of contemporary challenges are now facing Dordrecht and the Delta region. Located in the estuarine epicentre of the delta, the future of Dordrecht as an urban island is now confronted with a triple threat: rising sea levels and growing risk of sea surges from the west, rising incidence of river flooding to the east, and continuing land subsidence inside the perimeter of the polders. As part of the most urbanized region of the Netherlands, known as the Rijnmond Region, Dordrecht faces a series of pressing questions according to city officials from Gemeente Rotterdam:

Is the current system of dikes, flood barriers and dams capable to face expected future climate changes like sea level rise and peak discharges from the rivers? Is there a new way to reconsider the functioning of the Dutch delta system of the Dutch model of water control and engineering? Should the strategy involve a superdike or a delta archipelago? Should the strategy be closed and controlled, or open and flexible?

Responding to these complex conditions, the Dutch Ministry of Transport, Public Works and Water Management has decided to lower the dikes and widen the floodplains in about 40 polders as an alternative to the conventional heightening of the dikes. While the Dutch Delta Commission has proposed a series of new mega-waterworks to fortify the coastal region, a remarkable change of attitude, tantamount to a strategic reversal in policy, is occurring. Faced with the increasing incidence of winter rain and impermeable surface cover in the Rhine and Meuse watersheds according to climate-change models, and in response to high water warnings that are projected for the coming decades, the prevailing model of Dutch civil engineering is being questioned and rethought. In a nationwide project known as the "Room for the River," forty strategic plans worth over 2.5 billion Euros in forty different cities - including the City of Dordrecht are being developed in the Delta Region between 2010 and 2015.

Plan for Failure, Design for Destruction

Furthermore, the City of Dordrecht has leveraged the organization of the "Drecht Cities," a group of riverside towns (Alblasserdam, Dordrecht, Hendrik-Ido-Ambacht, Papendrecht, Sl ied recht, Zwijndrecht) bordering the Oude Maas, Noord and Beneden-Merwede to overcome similar economic and social challenges that have resulted from the vacuum created by the gargantuan infrastructure of the neighboring Port of Rotterdam. Combining flood management, transportation infrastructure, biophysical systems and urban development, cities are now being prepared and retrofitted for flooding from a regional perspective. Instead of raising existing dikes, planning projects are currently alleviating risk and relieving pressure from existing polders farther down river by widening the floodplain, especially when upstream river levels rise. From mandatory swimming lessons at the age of 5, to the flood-proofing of building interiors, to the mandatory flood planks and the incidental swapping of land rights for farms to flood, a wide array of spatial strategies and ecological policies are now being innovated and deployed in the Delta Region. After a thousand years of trying to hold the waters back, this national policy shift represents a new, contemporary cultural paradigm. Historically portrayed as the "enemy", waters of the delta region and coastal zone are now being re-conceived as the "agent" in a complex, fluid, dynamic landscape that underlies the future of the economy, the healthy ecology, and the livability of the Netherlands.

Ecology as Economy

The economic future of Dordrecht, the City of Dikes, is clearly inseparable from its ecological future. Its complex geography is an ecological registration of the 1000-year legacy of civil engineering, commercial trade and industrial development. Capitalizing on these emergent conditions, the City of Dordrecht is now seeking to position itself as a frontrunner in the discourse on cities and climate change. In an initiative known as the Urban Flood Management Project, the City of Dordrecht has teamed up with venture capitalist Bax & Willems from Spain to develop new urban economies and new spatial models of urbanization.

In tandem with the cities of London and Hamburg, Dordrecht is seeking a series of design strategies that function at both the scale of urban economy and regional ecology. In other words, Dordrecht is confronting its urban ecological future by rethinking its historic relationship with Rotterdam, Amsterdam and Utrecht in the Randstadt, and moving towards positioning itself as a prototype for urbanization in flood-prone deltas - regions where, according to the United Nations, almost two-thirds of the global population will live by the middle of the 21st century. Proposing a series of ecological interventions for the Delta Region, the ultimate objective of the project is to develop contemporary design methods that go far beyond flood mitigation or passive adaptation, and in effect, to capitalize on the climate conundrum of the future.

Engineered Delta

Over the last seven hundred years, the Dutch have formulated several techniques and strategies to combat floods, storm surges, land subsidence and sea level rise. Primary techniques and strategies have included embanking (inland) and damming (coastline). Although such strategies have proved successful, severe flood events have remained a constant threat to the Netherlands, calling for large-scale strategies. As a result (after the 1953 flood), the Delta Works Projects were developed—a series of large-scale engineering projects along the Netherlands' coastline (reference diagram on page 5). One of the effects of the Delta Works Projects is the morphology of the Netherlands' marshlands. Historically, marshlands existed along the coastline but, due to various engineering interventions (primarily damming), the marshlands have transformed the Netherlands' coastal marshlands into a thin line, concentrated at the Wadden Sea (a UNESCO World Heritage site).

Engineering efforts have also been implemented inland to control the riv¬ers. Channelization and dredging, along with pollution, have altered the hydrology network immensely. One of the most critical changes occurring inland is the damming of the rivers, altering and disrupting water flows in and out of the North Sea, resulting in hampered fish migrations, loss of the nursery function for marine fish species and an increase danger of passive fish drift into the sea at peak discharge.

Figure 2 The red boundary represents the current perception of the delta region (USGS). Expanding beyond the current perception of the Netherlands delta, we find the Netherlands is a ***deltaic nation****. The Dutch delta is a product of human engineering and natural processes that functions within a constant state of flux. In reality the delta extends beyond this boundary, comprising 67% of the surface area of the Netherlands. Located at the confluence of the Rhine-Meuse-Schidlt rivers, the delta region spans a 7000 km river system and transverses 7 countries.*

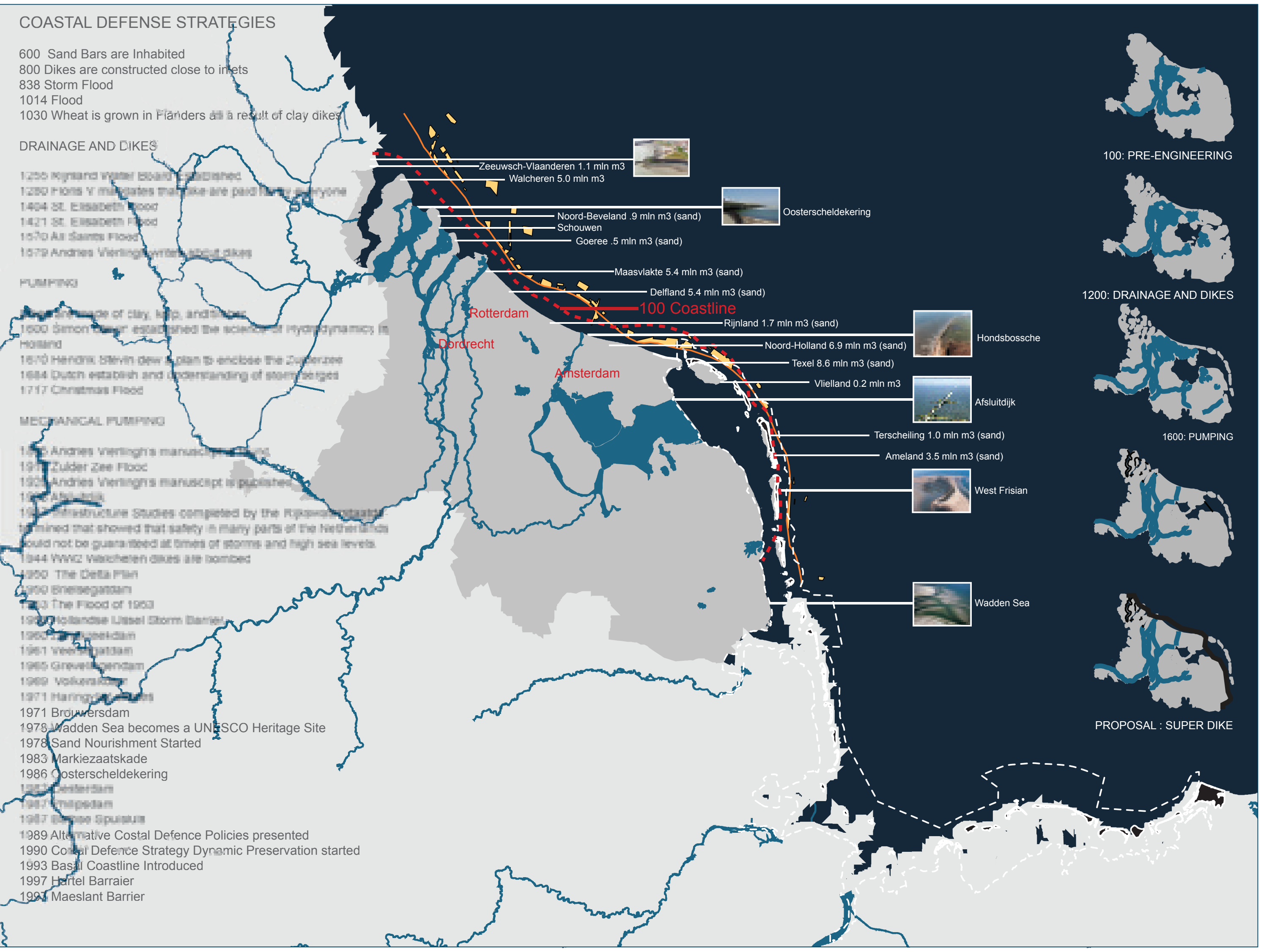


Figure 3 *Coastal Defense Strategies*

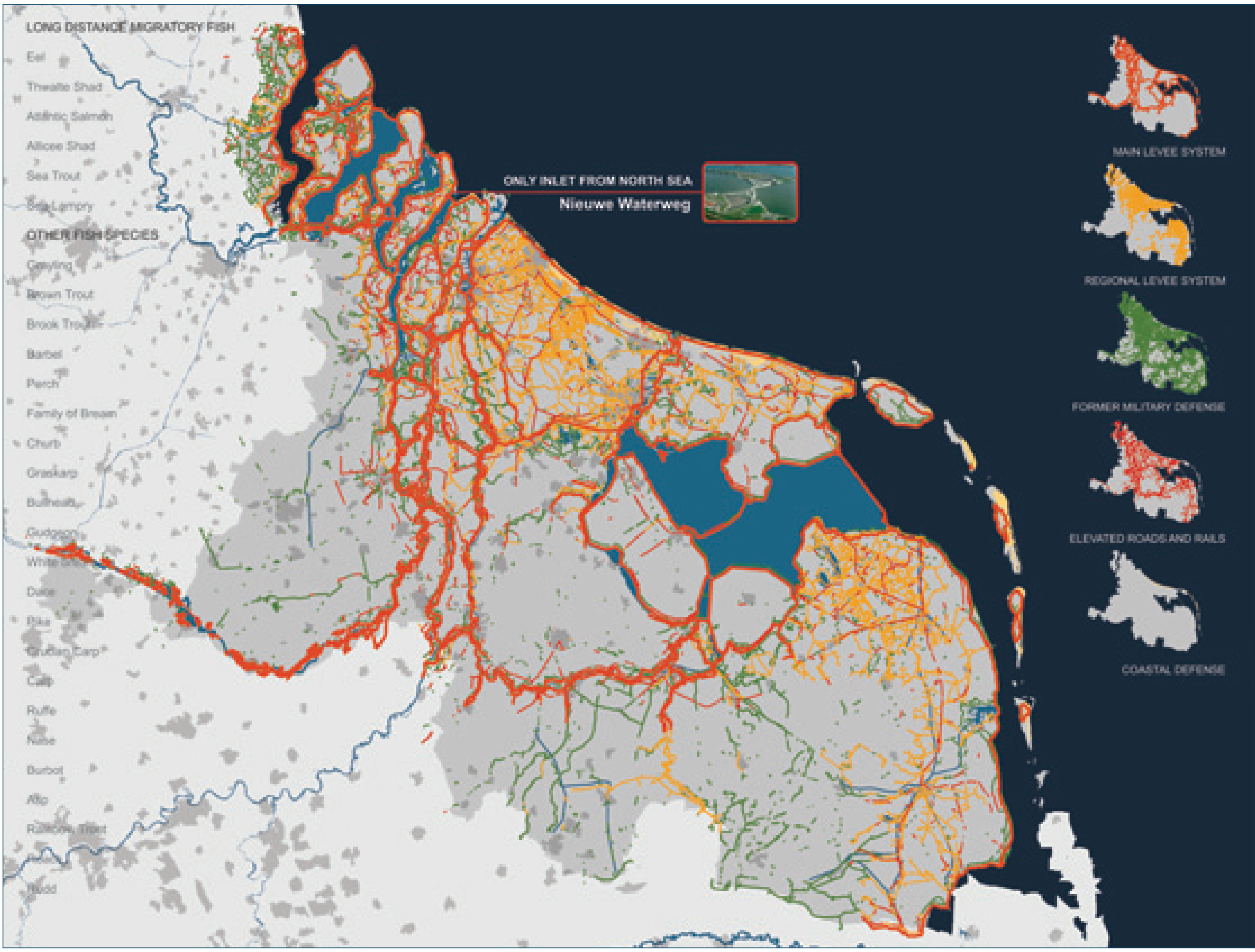


Figure 4 Controlling the river

Dynamic Normaal Amsterdams Peil (dNAP)

For example, due to the closing of the Haringvliet Dam (once a gateway and primary shipping channel to the (former) port of Dordrecht), a large portion of the river water now flows through the Nieuwe Waterweg (see figure 3), injecting fresh water into the North Sea and altering the salinity levels along the Dutch coastline. This nitrogen rich water (from dry-land agriculture) has contributed to the eutrophication problems in the Wadden Sea—ultimately impacting eco-systems from the Netherlands to Germany. The damming of the coastline to protect against floods has resulted in the following ecological phenomena:

- Disturbed silt balance
- Accumulation of contaminated sediments
- Disappearance of intertidal zone
- Increased flat formation in outer delta
- Disappearance of nursery functions for fish and invasive species
- Disappearance of fish migrations

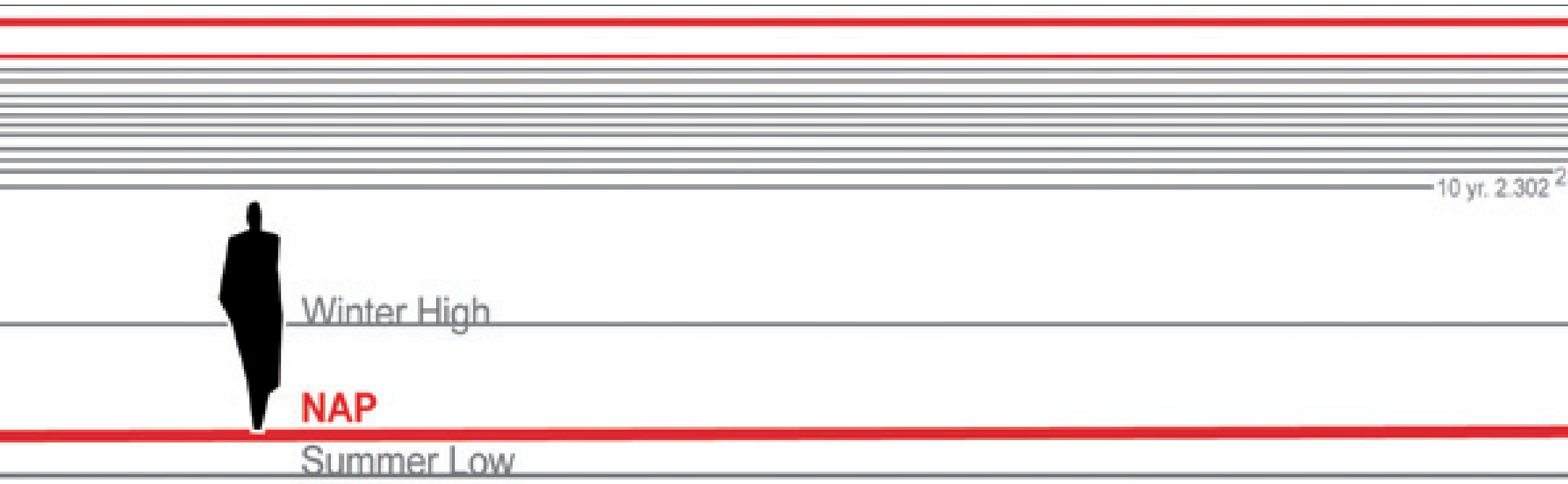


Figure 5 Dynamic Normaal Amsterdams Peil (dNAP)

Reconceptualizing the NAP as DynamicNAP (dNAP)

Despite a history of coastal defense strategies, the Dutch coastline has eroded 5km in four centuries. Strategies ranging from kelp dikes, to Delta Works Projects, to sand nourishment strategies have been efforts to hold a line between the land and the sea. Specifically, the damming of the shoreline has drastically altered the ecology of the delta. An estuary that once exchanged fresh and salt water has now been transformed into a fresh water basin. Such strategies have formed a binary relationship between land and water—this binary thinking is a product of the Nomaal Amsterdams Peil (NAP). The NAP is a vertical datum in which to gauge water level rise, and it represents one set level: "normal." Established in 1675, this datum has been integrated into Dutch culture and exported internationally, and is recognized as sea level rise. The concept of the NAP has established policies, regulations and laws.

Above are various designed flood plains, with the 1953 flood at the top. This diagram illustrates the various water level changes that have occurred throughout the estuary, representing water level gradients, not as one set level. The right diagram illustrates the hydrological configurations of the Rhine-Meuse River over the past thousand years. The configuration showcases a bio-system in a constant state of flux, reinforcing that the delta does not have one set level or configuration, as proposed by the NAP.

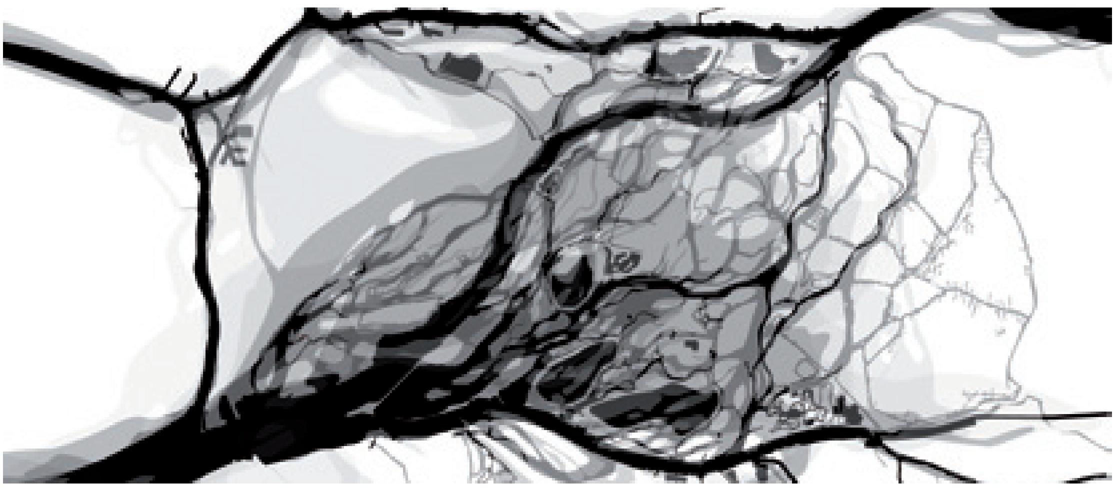
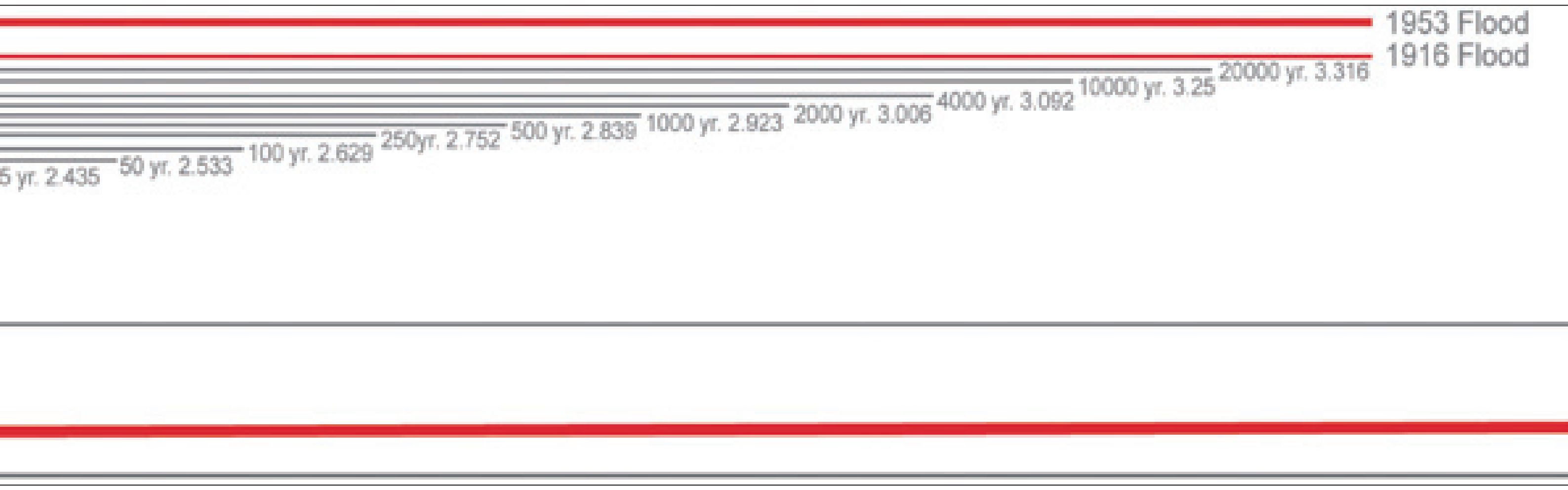


Figure 6 Poldering and Depoldering of the Dordrecht Region: The Diagram illustrates the hydrological configurations of the last 1000 years



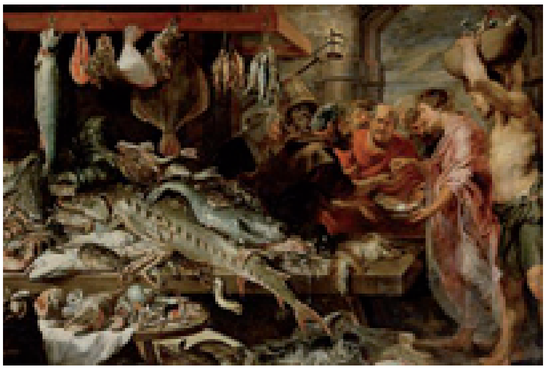


Figure 7 *Frans Syndera, 1621*

The NAP has not only altered ecologies but has transformed economies. During the Middle Ages, the Dutch economy was generated by the estuary, an economy that was aquaculture based. The following painting depicts female fishmongers and the robust fish ecology that once existed. Today, the Netherlands imports a majority of its bivalves that once were locally cultivated from France, Italy and North America.

deDamming Urbanism

In response to the failure of current engineering strategies to manage complex deltaic systems, our strategy involves the opening of the Haringvliet Dam (reference diagram to the right) to introduce the exchange of salt and freshwater for the reclamation of estuarine ecologies. Through research of the ecological shifts that have occurred throughout the last 700 years resulting in mono-ecologies and land use patterns, we introduce the Dynamic Nomaal Amersterdam Peil (DNAP) as a concept strategy to establish a shift from dry-land agriculture to aquaculture, in order to reintroduce a bio-system similar to the historical gradient that once existed. As a concept strategy, it is imperative that this model be translated as a dNAP, one that reflects a gradient, not a set line.

The Netherlands landscape is homogeneous in land use types, primarily comprised of dry-land agriculture. Sustaining dry-land agriculture is a polder landscape: a series of low-lying tracts of land enclosed by embankments (dikes). In order to sustain a dry-land agricultural economy, the Dutch must rely on embankment strategies. Moreover, with sea level rise, these embankments must be maintained and elevated. In response to unsustainable strategies to maintain a dry-land agricultural economy, our project redirects sources of economy by recalibrating the delta's engineering and ecology, with the introduction of an aquaculture-based economy.

Vital Gradients: Mud flat Ecology

Through the establishment of estuarine conditions, several ecological processes will develop. One ecological process and vital gradient will be the creation of mud flats. Studying robust estuarine conditions, mud flats are a keystone ecology within the gradient between land and water. Resulting from the deposition of estuarine silts, clays and marine animal detritus in intertidal zones, mud flats serve as vital coastal wetlands for coastal erosion control, estuarine economies and coastal bird habitat. As a priority habitat and ecology across the North Sea for the European Union, the Netherlands currently spends 30 to 40 million Euros on engineered coastal defenses each year. Looking at the keystone gradient of mud flats, we targeted keystone species that create bio-diverse environments, while acting as a bio-filter to improve water quality (i.e. the eutrophication of the rivers and coastal waters as a result of damming strategies).

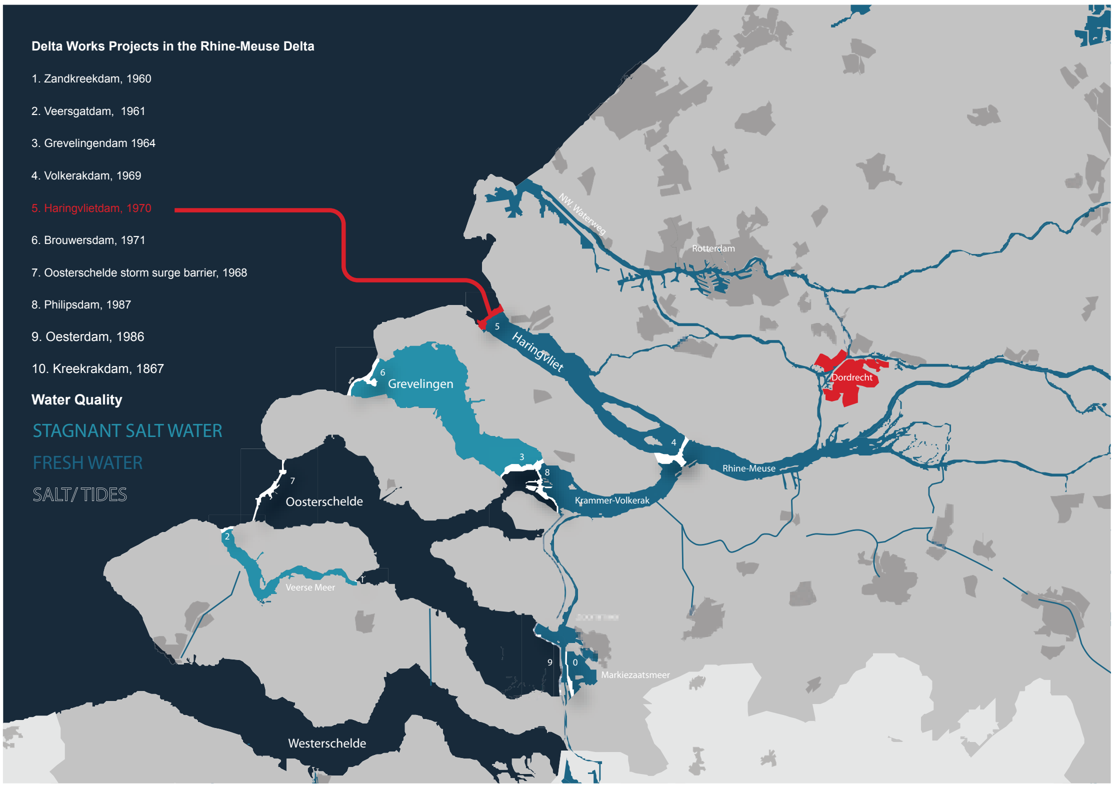


Figure 8 The diagram above illustrates the various dams along the Netherlands coastline and their respective water body types.the last 1000 years.

Bivalves are marine and freshwater mollusks. There are over 30,000 species within the bivalve family, including scallops, clams, oysters and mussels. As part of an estuarine ecology, a bivalve reef habitat bears the potential for supporting over 300 different species of fish and invertebrates of commercial value. Of this ecological gamut, the Netherlands currently produces only one species: mussels. Studying the make-up of bivalves, the oyster in particular has the ability to intake pollutants such as nitrogen and phosphorus to generate clean water. In addition to the ecological benefits bivalves inherently possess, bivalve reefs have the ability to attenuate waves. Bivalve reefs act as wave breaks along the river's edge, aiding in the reduction of storm surges. There are several techniques that can be implemented to establish a bivalve reef, ranging from a submerged rope system, concrete balls, to waste products such as tires. Significantly, bivalves have the ability to generate new economies. As previously noted, during the Middle Ages the Dutch economy once thrived on the delta. The establishment of bivalve reefs would enable the habitations of a larger bio-system, including salmon, flounder, oysters and mussels.

If we focus on the economic importance of the oyster, full economic value goes beyond dockside value. In addition to primary sales of raw, unshucked products, there are economic benefits from secondary services such as: shucking and packing houses, transport and manufacturing of prepared oyster products and retail sales. The shell itself is used in several different products, from 'oyster shell calcium' to 'oyster shell concrete.' More interestingly, the city of Dordrecht can utilize the oyster and the intertidal zone to generate a pearling industry. Mud flats will generate bivalve economies altering urbanization patterns inside and outside the dike and ultimately will position Dordrecht as a global player reef, ranging from a submerged rope system, concrete balls, to waste products such as tires. Significantly, bivalves have the ability to generate new economies.

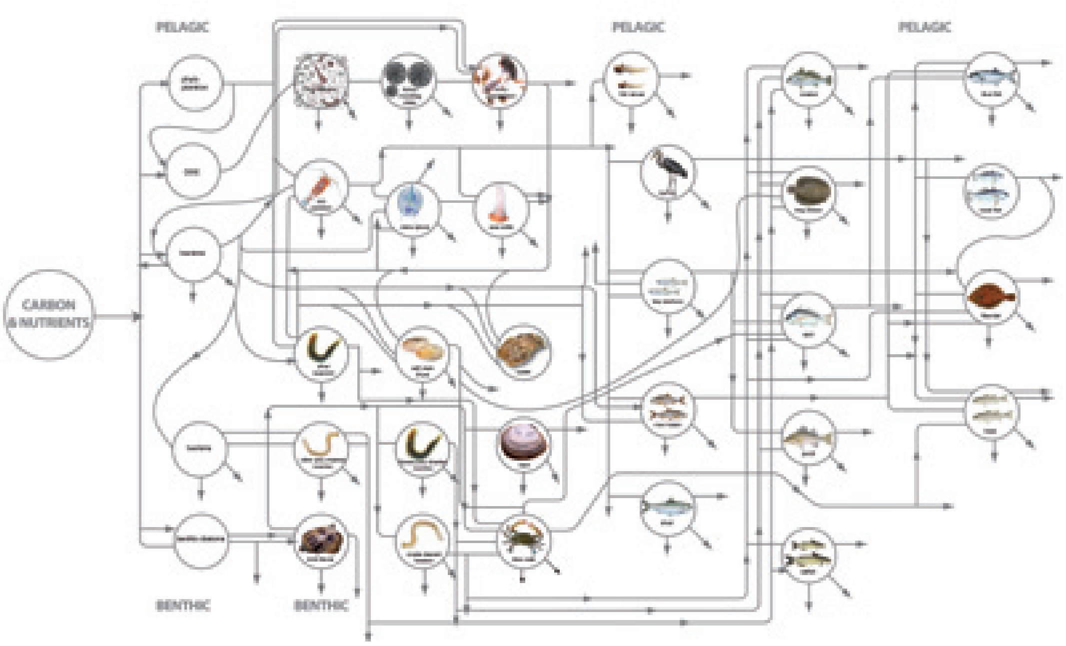


Figure 9 Estuarine species

CONCLUSION

The response to Dordrecht's hermetic condition requires more than a mere technical, scientific, or social solution. It involves a longitudinal strategy that is both systemic in nature, and regional in scale. Undoing seven centuries of the world's most advanced engineering controls or rebuilding the attenuated ecologies of the estuary requires incremental yet protracted transformation over time.

The point of departure for this change is the latent ecology of the delta's estuary, one of the world's most diverse, complex and fragile biotopes. In this optic, Dordrecht becomes an island of islands at the epicentre of an urban archipelago; the junction of a watershed and a coast, amidst a mixing zone squeezed in between saline waters of the North Sea and the fresh waters of Europe's longest watercourse, the river Rhine. As a result, the future of Dordrecht - like the future of the Netherlands - is inseparable from the future of the estuary. In turn, the future of the delta is inseparable from the future of the North Sea. In the space of this geographic convergence and ecological systematization, a new aquatic habitat provides ground for proto-ecological processes to emerge and proto-urban conditions to spin-off. Biophysical processes, whose most basic and fundamental is tidal exchange, can generate future urban economies. Closed, linear and engineered controls make way for the flexibility of soft systems. Here, the ground is transformed with the accretion of the estuary's most vital resource: mud. Together

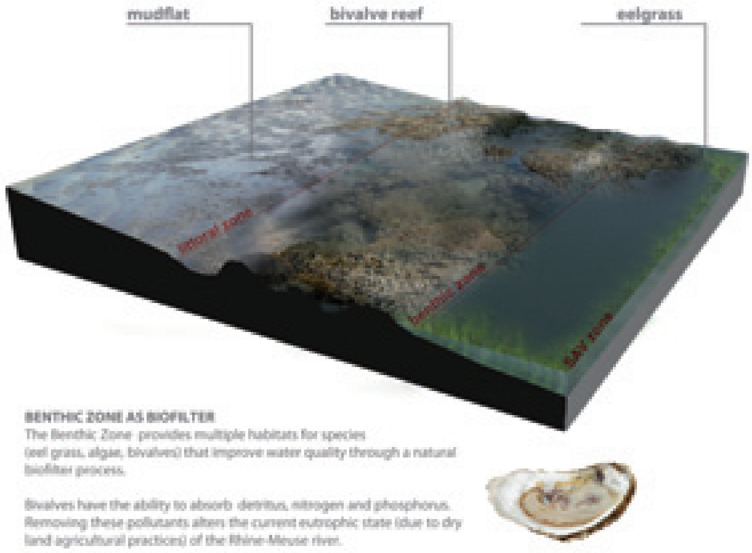


Figure 10 Benthic Zone as Biofilter

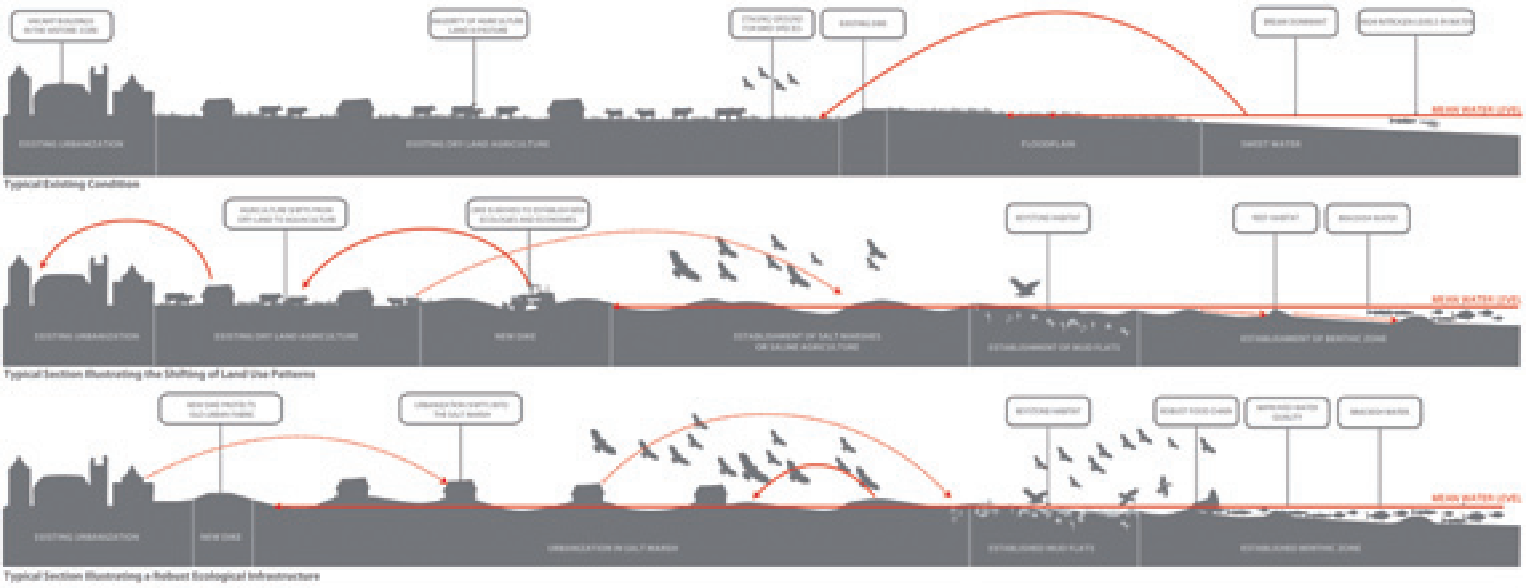


Figure 11 Typical sections: 1) existing situation (above), 2) shifting land-use (middle) and 3) robust ecological infrastructure

with tidal dynamics, silt and sedimentation of the mud flats enable reefs to build up and accumulate, hosting the colonization of thousands of bivalve species, one of the basic building blocks of intertidal ecologies. The benthic and pelagic foodshed begin to thrive: plankton and bacteria, clams and crabs, smelt and salmon, beavers and seals, reeds and cattails, willows and poplars. It is a landscape where the dichotomies of wet and dry, sweet and salt, dissolve making room for an ecological gradient to emerge. Every living species co-exists, co-operates and co-develops across a range of hydrological zones, shoreline territories and intertidal time-scales. Ecology becomes infrastructural. From this cultivated ground, the ecological catalyzes the economic. Every aspect of urbanization is tweeked, transformed, and tuned to enact secondary and tertiary functions, that are essential and operative. Freed from symbolism, buildings function as dikes, topography functions as terps, streets become floodplains, shorelines become slopes, rivers become habitats and cities become hubs. Urban fabric, whether historic or contemporary, becomes geo-cultural, like the stratification of sediments destined to become archaeology or myth.

In a remarkable reversal of historic tensions, cultural oppositions break down, opening a new horizon of unfettered collaboration across provincial and national boundaries. But, to plan ahead requires more than a shortsighted 10- or 20-year outlook. In the shadow of uncertainty and indeterminacy, Dordrecht becomes a complex estuarine prototype designed and deployed with an ecological intelligence over a prolonged period and extensive geography. As part of a vast urban archipelago, new regional morphologies can absorb or anticipate future risk, and avert disastrous hazards, with adaptive measures, resilient flexibilities, preemptive programs and opportunistic synergies that compound and aggregate between now and the next century.

ACKNOWLEDGEMENTS

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TRANSFORMATIVE SHIT

RUNNER UP

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Julia Price

University of Virginia, USA

Transformative Shit

Hurricane Katrina's sweeping blow to New Orleans was not an isolated incident, but was preceded and multiplied by subsiding soil, inflexible infrastructure, and a damaged protective wetland. A successful rebuilt urban form must respond to all of these challenges. Transformative Shit builds on existing City initiatives to bolster wetlands with sewage effluent, and expands the plan to retain sediment, lessen the burden on weakened infrastructure, and rebuild neighborhood fabric in the Lower Ninth Ward.

SYSTEM

FLUCTUATING LAND

Delta land is a fluctuating cycle of accretion and dispersion of mass. Sediment and organic matter are collected from upstream erosion and deposited in the slower, shallower coastal delta. This deposition results in a rich, fertile soil in the delta floodplain, which is kept lofted with organic content by the constant growth and decomposition of wetland

vegetation. Delta land shifts and erodes from passing ocean currents and storms and subsides through decomposition. The cycle of addition and subtraction results in a changing location but relatively stable amount of land.

THE MISSISSIPPI DELTA

The Mississippi Delta has been built over thousands of years by the deposition of the Mississippi River, which collects water and sediment from the third largest drainage basin in the world. Over the past two hundred years, dams and floodwalls have been erected along the river and its tributaries to harness the water's power and control flooding. These structures have had the unintended consequence of lessening the sediment load bound for the delta. In the delta, floodwalls have had the opposite effect — they prevent floods that would deposit sediment.

This Delta's other land ingredient, decomposing vegetation, has traditionally come from freshwater bald cypresses, which annually deposit their deciduous canopies. Cypress swamps have been eaten away by a combination of logging and saltwater intrusion from dredged shipping channels.[1,2]

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NEW ORLEANS | OUTSIDE THE FLOODWALLS

In addition to building land, dense cypress swamps form a spongy buffer that soaks up the impact of storm surges. To the west of the floodwalls of New Orleans, a cypress swamp called the Central Wetland Unit had been a crucial buffer in limiting the impact of storm surges. In the 1960s, the dredging of the Mississippi River Gulf Outlet Canal (MRGO) allowed salt water from the Gulf of Mexico to penetrate deep into this freshwater swamp, killing the cypress. The area is now mainly open water.

The storm surge from Hurricane Katrina came directly up the MRGO Canal, losing little of its force along the way. Had the protective wetlands been there to take the initial impact, it is likely that floodwalls and levees would not have broken. A storm surge barrier has been built on the MRGO to block future storm surges, but this needs to be done in tandem with efforts to rebuild the larger wetland buffer. [3]

NEW ORLEANS | INSIDE THE FLOODWALLS

Early settlement in New Orleans was focused on the higher, sandy natural levee at the bank of the Mississippi, leaving the low cypress back swamp to absorb storms, produce organic matter and support an abundant fishery. The advent of a drainage system and enclosure within a constructed levee allowed the back swamp to be drained and settled. Without the replenishment of deposited organic matter, the highly organic soil of the back swamp began to subside from decomposition. This lowered land leads to surfacing groundwater, which is then pumped out from the polder, causing further subsidence.[4]

As the land inside decomposes and settles, it exerts pressure on the brittle metropolitan drainage and sewerage system of metal pipes and concrete culverts. This infrastructure was cracked and leaking before Katrina, and its damage is far worse after. An estimated 63% of treated drinking water was lost through cracked pipes in 2006.[5]

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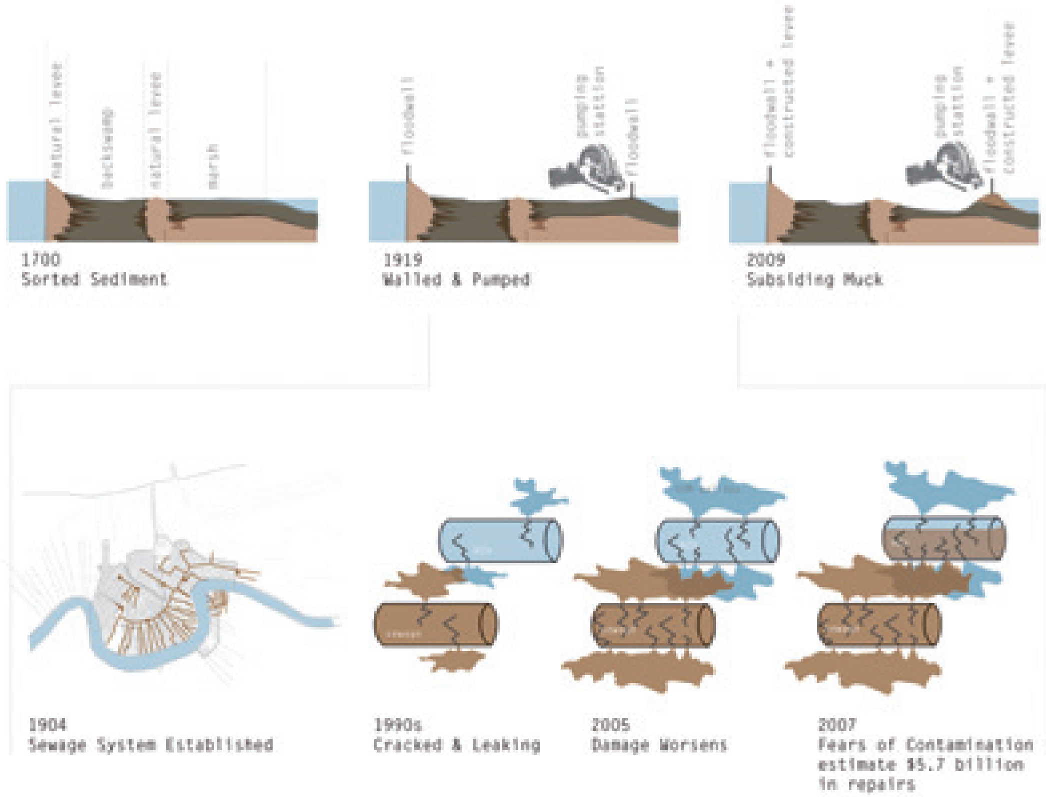

This has the beneficial effect of recharging the groundwater and decreasing subsidence, but in a highly inefficient manner. Additionally, there is danger that sewage may leak into the drinking water system.[6]

THE NINTH WARD

Surrounded by floodwalls and levees, the Ninth Ward can be understood as an uneven polder that sinks to its most subsided point in the former back swamp. Separated by the Industrial Canal from the rest of the city, and bordered by the Cypress Triangle section of the Central Wetland Unit, this neighborhood historically relied on the swamp for protection, sustenance and as a backyard. With the loss of this cultural landscape to salt water intrusion, recent neighborhood activism has focused on swamp restoration. The additional decimation of the neighborhood by Hurricane Katrina has galvanized this movement with an understanding of the swamps buffering function.[7]

EXISTING INITIATIVE

THE WETLAND ASSIMILATION PROJECT

The current sewage treatment system sends solids to the incinerator or off-site landfills, and pumps nitrogen-rich effluent to the Mississippi, which deposits it in the hypoxic Gulf of Mexico Dead Zone. The New Orleans Metropolitan Sewerage and Water Board is currently experimenting with using this effluent to decrease salinity in the Central Wetland Unit and aid in swamp restoration.[8]

6. "New Orleans Sewer, Water Board to Reinstate Program in Wake of Hurricane Katrina." Underground Construction 1 Apr. 2010. Print.
7. Staff, Editorial Page. Help Holy Cross. Web. 22 June 2010. <http://www.helpholycross.org/>
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We see an additional opportunity to expand this initiative to retain some of the sediment and nutrients within the floodwalls, thereby decreasing pressure on the sewage system and producing even cleaner effluent for swamp restoration.

PRECEDENTS

In researching alternative sewage treatment systems, we came across two major strategies — small scale in-situ treatment (Sidwell Friends School)[9] and large scale ex-situ treatment (Arcata, CA)[10]. New Orleans called for an amalgam of the two — an urban scaled treatment strategy that would keep the sediment and nutrients close to where they were created.

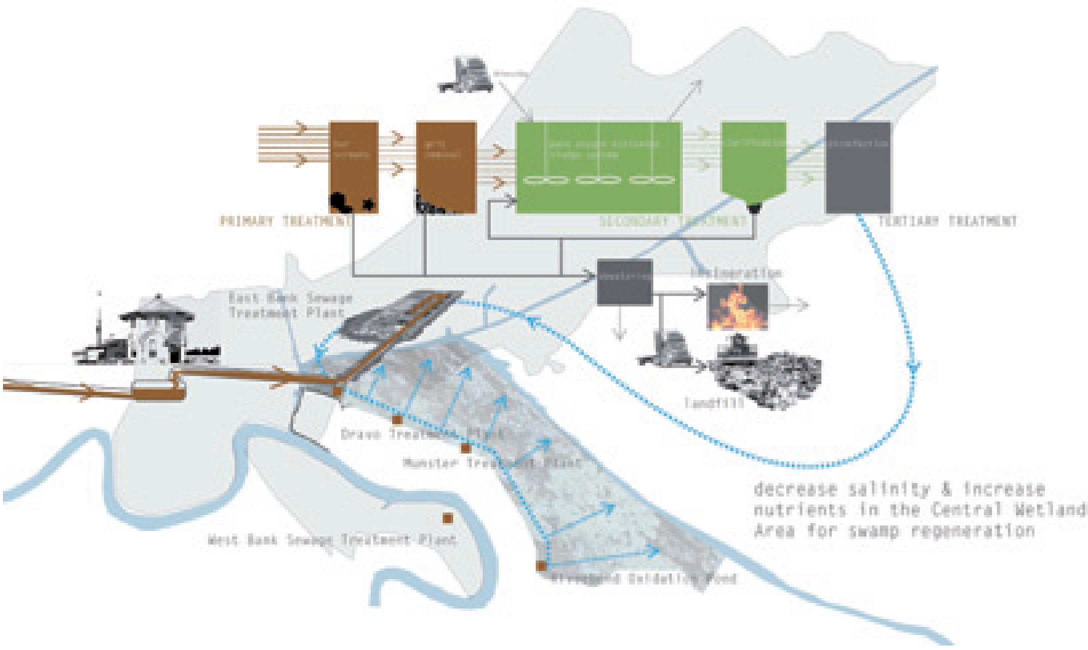
PROPOSAL

Transformative Shit is a decentralized sewage treatment system as the foundation of a new neighborhood form that recalls the historic back swamp landscape of the Lower Ninth Ward.

SITE SELECTION

The Lower Ninth Ward is ripe for an in-situ treatment system for four major reasons:

1. The ward slopes down to the swamp and the current sewage treatment plant, with the exclusion of the levee, allowing for a gravity fed system with a minor pump component.



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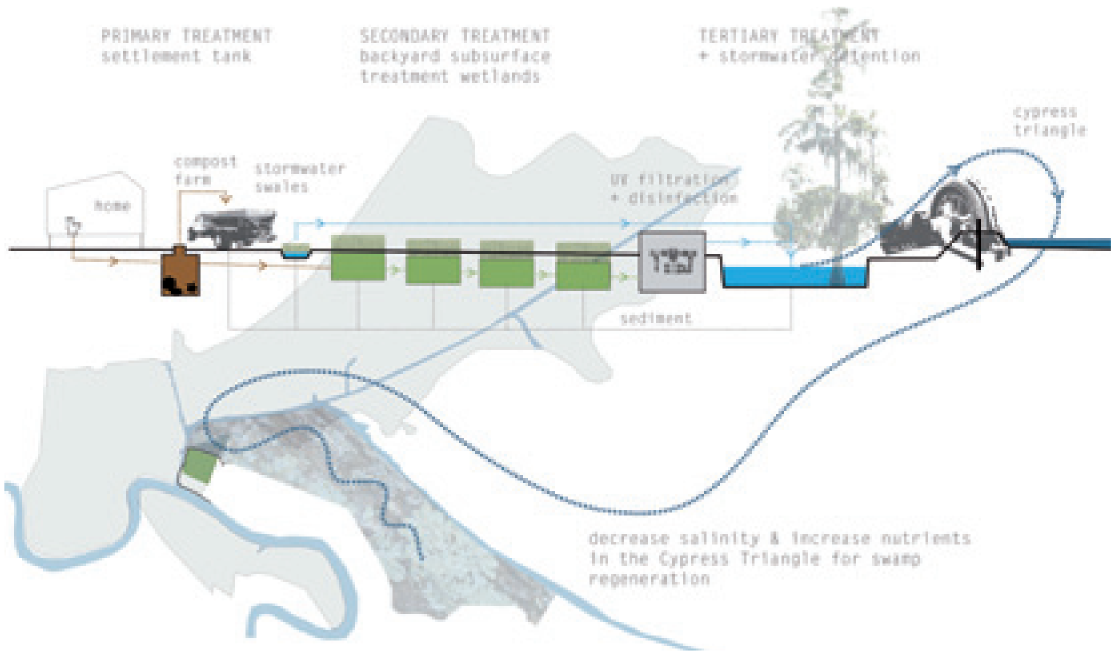


2. The neighborhood was decimated by Katrina. A major infrastructural project would give residents belief and support in rebuilding.
3. The relatively lower expected return rate of landowners is an opportunity to reconfigure lots to support such a system.
4. The swamp, particularly the area called the Cypress Triangle, has been an important cultural landscape in the history of the neighborhood, as a fishery and backyard. There is strong interest and support for restoring the swamp in the returning residents.

SYSTEM

PRIMARY TREATMENT

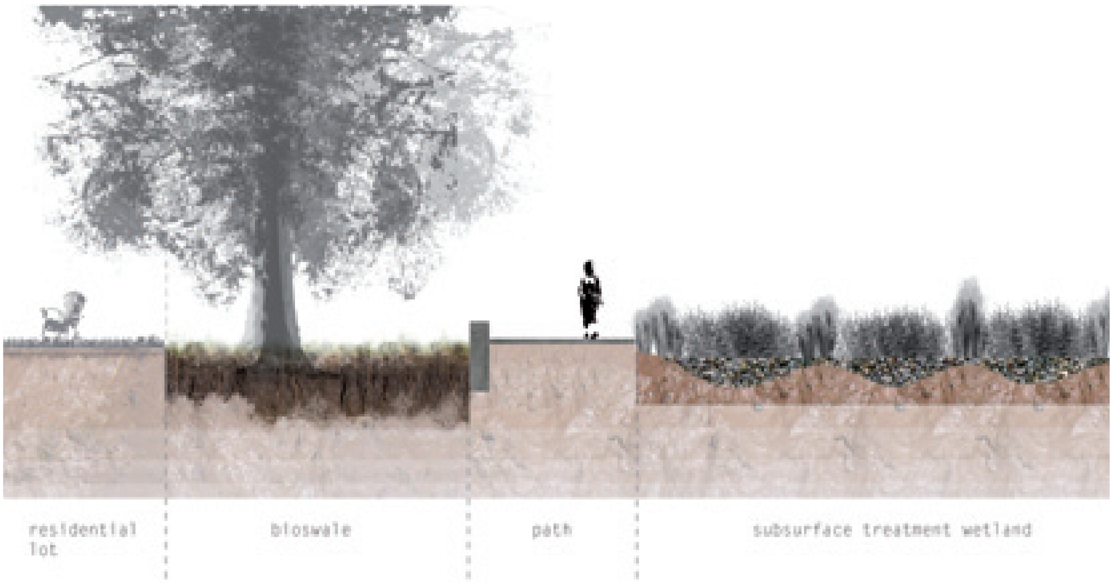
Sewage is collected at the block scale using traditional lateral and trunk pipes. The trunks deposit into underground settling tanks that collect sediment. This sediment is picked up by trucks and brought to a compost site. The resulting decomposed biosolids are used to build up ground as needed throughout the city.

SECONDARY TREATMENT

Lots are strategically landbanked to create alleyways in which a comprehensive system of subsurface treatment wetlands, the Lower Ninth Ward Marshways, are gravity fed from the primary treatment tanks. These wetlands are lined to prevent seepage of sewage effluent into groundwater. Atop the liner, a corrugated clay layer channels

effluent into parallel flow paths, increasing the contact between effluent and plant roots. This layer is covered with a layer of gravel, in which is planted a combination of Typha angustifolia and Carex louisianica. The channels are funneled together into a culvert and redistributed at every street crossing, which maximizes root/effluent contact.[11].

11. Kadlec, Robert H., and Scott D. Wallace. Treatment Wetlands. Boca Raton, FL: CRC, 2009. Print.



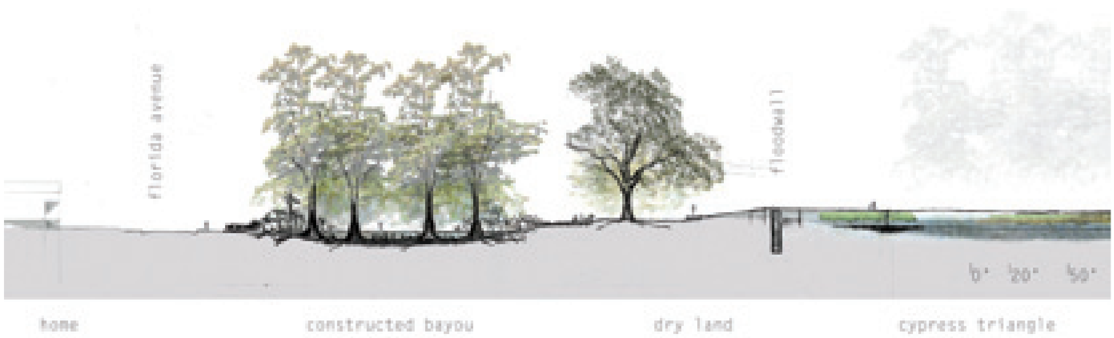
The resulting surface is safe to the passerby on paths that bracket the wetlands. As a further precaution, the path is extended into a seatwall that can increase the storage capacity of the basin in the event of storms. Between the seatwall and the residential lot is a bioswale with Taxodium distichum and other freshwater swamp plants. These bioswales collect rainwater to recharge groundwater. Both wetland swales, treatment and swamp, produce organic matter through vegetative growth. This material is used to build up ground either on the inner side of the bioswale or in needed areas throughout the city.

In addition to treating sewage and retaining sediment within the neighborhood, these marshways direct municipal funds to a public landscape that anchors existing housing and forms a new community porch and pedestrian network. This grounds a neighborhood identity for existing residents while the neighborhood is still returning. New residents can hook into existing wetlands and provide for incremental growth of the system.

TERTIARY TREATMENT

The treatment wetlands drain north, to a UV filtration station. After UV treatment, the effluent is clean enough to join with the collected stormwater in the Florida Avenue Bayou, carved into the lowest strip of the Lower Ninth Ward bordering the northern floodwall. This freshwater swamp, constructed within the floodwall, recharges groundwater and produces organic matter within the polder. Excess water is subject to a final polishing in this swamp before being pumped out to the Cypress Triangle using the existing pumping station.
Once in the Cypress Triangle, it performs the desalinifying functions outlined in the city's Wetland Assimilation Plan.

This treatment wetland is the civic front yard of the Lower Ninth Ward, a public recreational amenity that connects to the Cypress Triangle swamp restoration. Taxodium distichum shade and protect the adjacent levee, which remains the high and dry path in storms and the vantage point to see inside and outside the floodwall. The Florida Avenue Bayou prefigures the protective swamp outside the floodwall and restores the community connection to the swamp.



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SURVIVING DELTA CITY

Response to Global Warming (Case: Semarang City, Center of Java, Indonesia)

RUNNER UP

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Abstract

Semarang is one of the largest cities in Indonesia, which suffered the greatest threat from the impacts of sea level rise. Since the beginning, Semarang has been a city that has been facing many problems, especially disaster, such as flash floods, tidal floods (rob), seawater intrusion, land subsidence, shoreline retreat, etc. The sea level rise issue hots up when the predicted number of important locations in Semarang could be inundated. It needs a strategy of adaptation to include the manufacture of DA, the concept of the waterfront city to Semarang's harbor, cooperation with insurance companies, and society. Integration between the community, the government, and private adaptation is needed in addressing the rise in sea level

BACKGROUND

Climate change is presented as a causal chain of consequences starting from greenhouse gas emissions that alter the atmosphere's radiative balance, changing climate and leading to impacts that range from the biophysical through to the socio-economic (Jones et al, 2007).

One of the climate change impacts is the melting of polar ice that will cause the sea level to rise. The most vulnerable area affected by the sea level rise is the coastal area.

The big cities in Indonesia, mostly located along the coast are Jakarta, Semarang, Surabaya, Medan, Makasar and so on. Those cities grew around the delta because the merging of the mainland and rivers and the sea form their own ecosystem that is unique and people are interested in living there.

A delta's area may be defined as 1) the seaward prograding and area that has accumulated since 6,000 years, when the global sea level stabilized within a few meters of the present level (Amorosi and Miller 2001 in Syvitski, 2008), 2) the seaward area of a river valley after the main stem of a river splits into distributary channels (Syvitski and Saito 2007 in Syvitski, 2008), 3) the area of a river valley underlain by Holocene marine sediments (Kubo et al. 2006 in Syvitski, 2008), 4) accumulated river sediment that has variably been subjected to fluvial, wave, and tidal influences (Overeem et al. 2005 in Syvitski, 2008), 5) the area drained by river distributary channels that are under the influence of tides (Syvitski, 2008)

Semarang City is one of the worst delta cities in the world. The city of Semarang is the capital city of the Central Java Province, located on the North Road crossing points linking the island of the Java city of Surabaya and Jakarta. Geographically, located between 1090 35 '- 1100 50' east longitude and 6O 50'- 70 10' south latitude. With 373.70 km2 area, the city of Semarang has limited its administrative regions as follows: in the north the Java Sea, in the south the Semarang District, in the east the Demak District and the Grobogan District, and in the west the Kendal District.

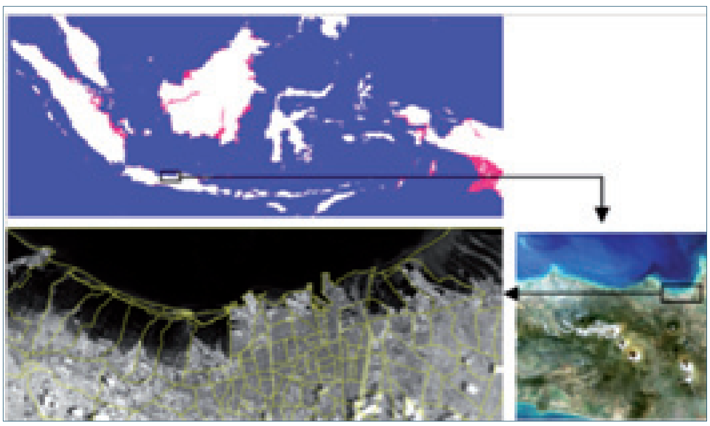

Figure 1 Semarang coastal area

SOCIO-ECONOMIC DEVELOPMENT

Now, more than 50% of the entire world population lives in cities.

The priority development area of Semarang city is divided into four regions and the development of each region is divided in several parts of the city, and each section has a scale with urban development priorities. Development priorities include: trade, offices, services, education, sports, transportation, industrial, residential, agricultural, and the development of the New Town in the sub-district of Mijen.

Semarang city is becoming increasingly crowded and the support capacity of diminishing land should have not happened by setting up additional development centers of industry, trade settlement and so on. The physical condition of the land has exceeded the threshold of its capability, so many problems and disasters often occur in the city of Semarang.

The government should focus more on regional arrangements and perform controls so that the physical condition of the land and industry and the impact of human activity on the environment can be minimized.

It is ironic indeed when the government had to choose between the economy and the environment. Developing countries cannot synchronize between the high economic income with environmental sustainability. Something must be sacrificed. When the government of Semarang intends to develop areas of industry for economic purposes and increase revenue, then what happens is damage to land and the impact of the deteriorating environment. There must be a consequence of the various stakeholders to solve the environmental impacts due to prolific industry in Semarang City.

MULTI-HAZARD ASSESSMENT

A delta's low gradient is both attractive and dangerous for human use. A large flat delta is attractive because it has the potential for easy agricultural development, made further attractive by its rich organic soil. Deltaic sediments are at the finer-grained end of a river's flood plain and are generally rich in important organic carbon; population centers are often located on deltas. It is predicted that they will increase rapidly.

According to the United Nations, more than two-thirds of the world's large cities are vulnerable to rising sea levels, exposing millions of people to the risk of extreme floods and storms. Within the next 30 years, the United Nations predicts that the number of people living in cities will increase to 60% of the world's population (Aerts et al, 2009) Coastal regions have a complex geomorphologic process and a physical process. The physical processes are waves, tidal inundations, erosion, sedimentation, sea level rise, etc. In the case of Semarang, coastal floods driven by high tidal floods, low lying areas, flash floods, and land subsidence occur at many sites.

Subsidence

Semarang is a capital city in Central Java Province. The city is a center of economic activities, housing, industry, etc. Extensive land use change and industrialization increase the groundwater extraction leading to land subsidence. Whereas subsidence increases a delta's vulnerability, the impact is made much worse by anthropogenic control on the supply and routing of sediment to and across a delta. The land subsidence caused by withdrawal of groundwater for industry and household.

The rate of the subsidence can be generated by benchmarking. From the benchmark data, it can be seen that the rate of subsidence in Semarang varies from 2 to 10 cm/year and the maximum rate is about 16 cm/year (Marfai and King, 2007).

People living in the coastal area of Semarang have been experiencing the threat of coastal inundation almost constantly. Assuming a zero-growth rate of the population in future years, it is estimated that <148,000 people would be suffering from inundation (Marfai and King, 2007a).

These areas have a high-population density and are a center of industrial development and therefore, the vulnerability is very high. With the assumption that in the future years the land use pattern remains the same as the current situation, the total potential economic loss due to the coastal inundation under enhanced sea level rise in the capital city of Central Java Province is expected to be about €1,812.8 million for 120 cm of inundation and €2,330.8 million for 180 cm of inundation (Marfai and King 2007b)

Table 1 The prediction of future land subsidence in Semarang (in ha)

Year	Elevation below sea level (cm)				Total
	0-50	50-100	100-150	150-200	
2010	328.5	31.5	2.0	-	362.0
2015	1162.0	187.0	25.0	3.5	1377.5
2020	1464.5	607.0	128.0	27.5	2227.0

Source: Marfai and King (2007)

Flood

In the Semarang region, land subsidence plays an important role for the extended inundation in the coastal area. The other sources of inundation are flash floods and rob. Semarang consists of a hilly area in the southern part and low land area in the northern part. So rain water will quickly come towards the sea. Land use cover change is very intensive, from vegetation to settlement area also cause floods every year which happens to be getting worse.

Furthermore, under the scenario of sea level rise and land subsidence, coastal inundation would be even worse.

Shoreline Change

Sea level rise is one of the results of global warming. It has a direct impact on the increasing inundation in the coastal area. Semarang is clearly a city that annually suffered from flash floods and tidal floods. It will get worse if the sea level risess.

Figure 2 The Semarang Topographic. vulnerable city from flash flood and tidal flood/Rob (Marfai and King, 2007c). Inundated area in red rectangle will be simulated in the iteration model

The most serious physical impacts of sea level rise are (1) coastal erosion, (2) inundation and displacement of wetlands and lowlands, (3) increased coastal storm flooding and damage, and (4) increased salinity of estuaries and aquifers (Barth and Titus 1984 in Marfai and King 2007b).

Semarang annually suffers from flash floods and tidal floods. This is causing large scale inundation in many important sites like roads, residential buildings, public facilities including the airport in 2007. The flood caused by the capacity of the river, canal, or drainage

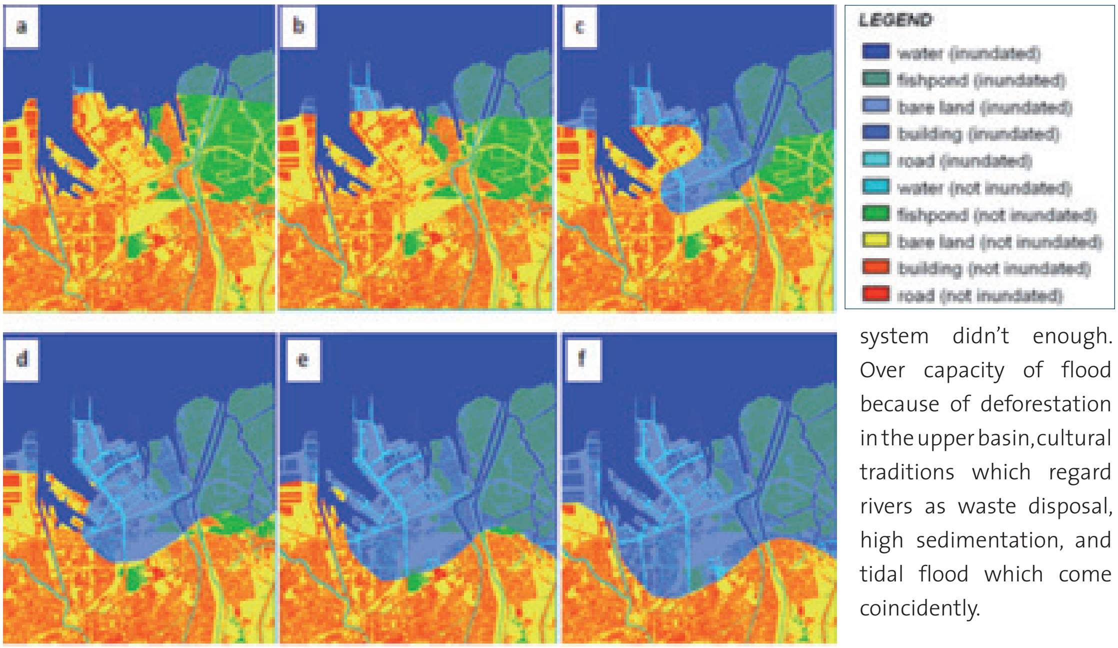

Figure 3 Inundation map of Semarang using different scenarios. (a) 0.25 meter scenario, (b) 0.50 meter scenario, (c) 0.75 meter scenario, (d) 1.00 meter scenario, (e) 1.25 meter scenario, (f) 1.50 meter scenario. Source: Data Processing 2010

system didn't enough. Over capacity of flood because of deforestation in the upper basin, cultural traditions which regard rivers as waste disposal, high sedimentation, and tidal flood which come coincidently.

The warm case related to sea level rise issue is land subsidence. Land subsidence together with the sea level rise cause the city to sink at a rate of t 3.8 /year (Aerts et al, 2009) mainly due to groundwater extraction.

Shoreline position would change the different rate of sediment supply, accretion or erosion process. River deltas are coastal features developed from the accumulation of sediment near the mouths of rivers (Syvitski, 2008). But in Semarang, the delta can't be seen clearly. The main factor is because the dominant process in coastal dynamic is shoreline retreat.

Figure 4 and Figure 5 show that the shoreline change in Semarang is happening very intensively. The temporary Landsat images are used for extracting the shoreline at the same date in different years. The data sources are shoreline in 1972, shoreline in 1982, shoreline in 1992, and shoreline in 2002. The next step is to calculate the shoreline change by using DSAS extension software in ArcView. If the JKR have a negative value, this means that the shoreline has been retreating. But if the JKR have a positive value, the sedimentation was dominant in this shore.

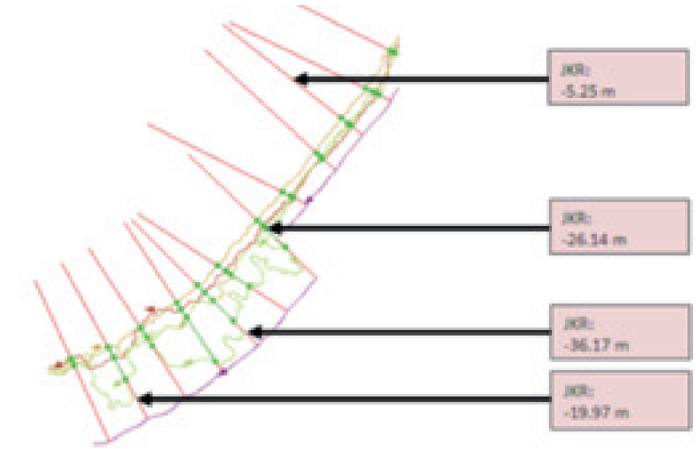

Figure 4 Shoreline change in Semarang at different times. JKR means shoreline change. Sources: Data Processing 2010

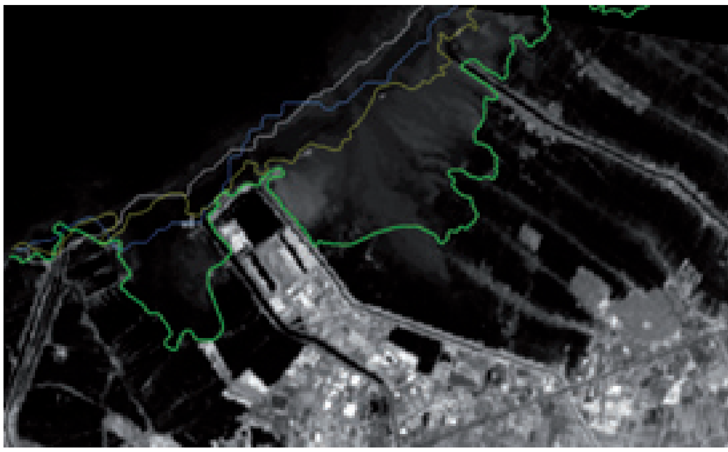

Figure 5 Shoreline retreat in Semarang at different times. Sources: Data Processing 2010

ADAPTATION

Climate change is directly affecting the living conditions of most of the people in developing countries, through increasing variability and uncertainty of the conditions in which people try to pursue their livelihoods (Cannon and Müller, 2010).

Adaptation is the adjustment in natural or human systems in response to the actual or expected climatic stimuli or their effects, which causes harm or exploits beneficial opportunities (Cannon and Müller-Mahn, 2010). Adaptation is defined as adjustments in practices, processes, or structures in response to projected or actual changes in climate (Dixon et al, 2003). Adaptation also influences different parts of the projected range of mean global warming at any given time in the future (Jones et al, 2007).

A global estimation of the cost adaptation to climate change is likely to be below 0.1% of the Gross Domestic Product (The Stern Review in Aerts et al, 2009).

Adaptation to climate change is not simply a response to meteorological parameters, but it is primarily driven by discourses about these phenomena in a society (Cannon and Müller, 2010).

Investing in adaptation would save money in the future (Aerts et al, 2009). The sea level rise will influence the vulnerability in the future. The government, scientists, and society have an important role to prepare the adaptation and assess the risk.

Society, scientists, and policy makers have to consider the climate change issue of adaptation and embed long-term scenario in planning.

Some adaptations can reduce negative impacts or take advantage of new opportunities presented by changing climate conditions (Dixon et al, 2003) adaptation also increases the ability to cope incrementally or produce one or more step changes (Jones et al, 2007). The adaptation strategy must consider the local characteristic of the area including the hazard, resources, institution, etc. This is some of the adaptation that can be implemented in Semarang city based on their characteristic.

Mega DAM construction

Infrastructures have been prepared for global warming threatening. Protection strategy can be implemented by constructing hard structures, e.g., seawalls, dykes and breakwaters as well as using by soft measures, e.g., beach nourishment (Marfai and King 2007c)

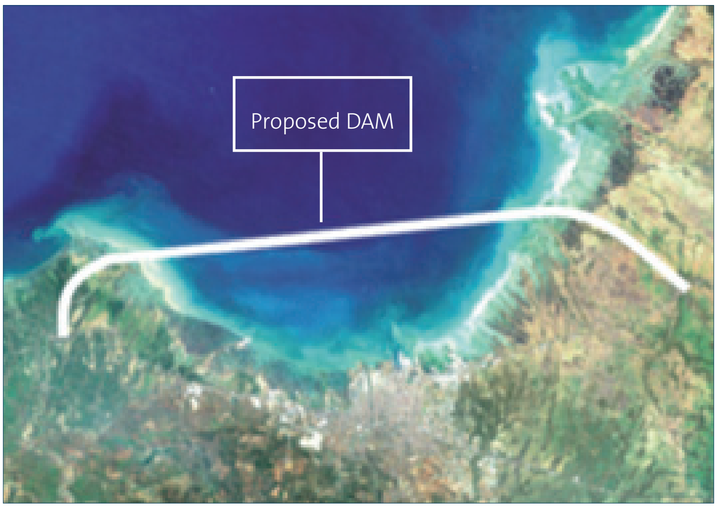

Figure 6 The DAM connected A-B. A-B is the most important road in Indonesia

As mentioned above, Semarang is annually threatened by tidal floods. It will get worse in the rainy season when flash floods and tidal floods come at the same time. So, one of the solutions that can be implemented is the Mega DAM construction to protect Semarang city. Figure 7 shows the vertical section of the concept.

The advantages of the construction are 1) the city is out of danger from the flash flood because the water coming from the hilly area will be pumped out to the deep sea, 2) the city is safe from

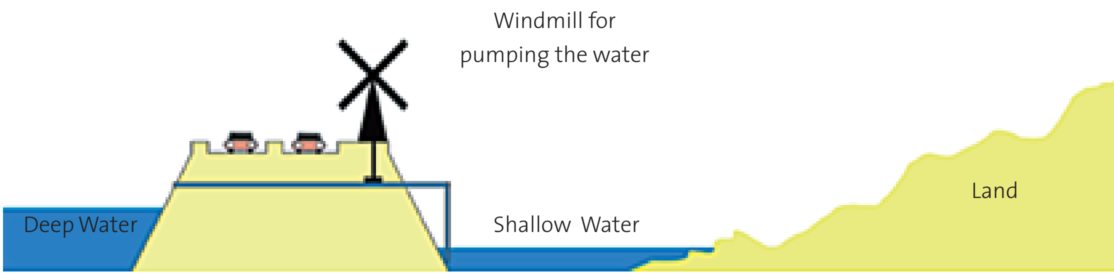

Figure 7 *The upper part of DAM can be used as a national road for connecting the two cities*

the tidal flood, 3) the upper part of the DAM can be a national road that can connect Kendal and Demak, 4) soil conservation because the shoreline retreat intensively happens in Semarang.

Water front cities concept

Semarang has the largest harbor in Indonesia, Tanjung Mas. Because of the DAM construction, the harbor site must be rearranged and the city must be constructed more sustainably. This requires a high level of technology and the science of developing a city without causing damage.

In Semarang, the future population is predicted to increase; one of the factors is industrialization which caused urbanization. Finding properties for living and far from a vulnerable area is very difficult. One of the solutions is integrated between adaptation for sea level rise and comfortable quality for living, i.e. waterfront cities.

There are many cities in the world that have been applying the waterfront city concept for example in Dubai and the Netherlands. This concept can be implemented in Indonesia as an archipelagic island.
Insurance sector.

Climate change is not only a threat for insurers but also provides new business opportunities. The experience of the insurance sector with assessing, managing, and spreading risk may be useful in fostering adaptation of societies to climate change (Aert et al, 2009).

Insurance can take a part in assessing the vulnerability and risk. This product is very useful for the government especially for spatial planning. Another advantage from the insurance sector is that the government prepares for the risk or provides financial compensation if the disaster happens.

Indigenous adaptation

Adaptation works best on the local scale because the biophysical and social characteristics of each location (Jones et al, 2007).

Indigenous knowledge into climate change policies can lead to the development of effective mitigation and adaptation strategies that are cost-effective, participatory, and sustainable (Nyong et al, 2007).

Indigenous knowledge has been defined as institutionalized local knowledge that has been built upon and passed on from one generation to the other by word of mouth (Nyong et al, 2007).

Indigenous knowledge into climate change concerns should not be done at the expense of modern/western scientific knowledge. Indigenous knowledge should complement, rather than compete with global knowledge systems (Nyong et al, 2007).

Figure 8 *House and raised floor reconstruction (Marfai and King 2007b). The adjustments can be made by elevating the buildings on piles*

The poor are considered to be the most vulnerable to impacts of climate change (Nyong et al, 2007). The risks and vulnerabilities of the poor who live in insecure places and need to build their resilience to copewith climatic fluctuations are among the more important challenges in adapting to increasing climate variability and climate change.

FAO has developed and tested a livelihood-based approach to promote climate change adaptation processes at the grass roots level, building on the assumption that most rural communities (as well as in other developing countries) work on the basis of day-to-day priorities rather than for the longer-term. The basic processes are associated with the approach to working with farmers, fishermen and livestock keepers (FAO, 2007)

The day-by-day priorities are:

1. they didn't want to be relocated because of many factors including poverty and social relationship,
2. they have a unique way. For example, building their house over two or more floors. The purpose of this is that if the flood is coming, they have a safe place to relocate their utilities and equipment.
3. they just have short-term priorities and ignore the long-termpriorities.

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BALTIMORE WATER WORKS

Hydrology as Adaptive Infrastructure in the Jones Falls Corridor

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Project Statement

Baltimore Water Works creates a generative landscape infrastructure to re-establish a functional and ecological identity for the Jones Falls River corridor. The new stormwater armature creates a cross grain that reconnects neighborhoods once divided by the JFX highway, while establishing an ecological framework that will regenerate abandoned areas adjacent to the corridor.

The city of Baltimore has a rich industrial history that is rooted in its position as a city founded on a river delta. Jones Falls is one of three rivers within the city and cuts through the heart of Baltimore's residential and industrial neighborhoods. Once a generative asset, Jones Falls is now suppressed. The river has been culverted, contributing to urgent concerns about sedimentation and pollution in Baltimore Bay and the regional Chesapeake watershed. The Jones Falls Expressway, a highway constructed against the city resident's wishes, now occupies the river valley. The highway increases perceptions of the corridor as a division, and acts as a visual and sometimes, physical barrier between neighborhoods.

As both the highway and the culvert approach the end of their life expectancies, there is an opportunity to address the corridor with a new approach to infrastructure. This project establishes an adaptive, landscape framework to address the pressing stormwater concerns of the Jones Falls watershed, while creating new spaces of public occupation and pedestrian traffic, and establishing a specific series of regional identities based in topography and hydrology. The specific position of Baltimore within the northern Chesapeake Bay watershed places it within an oligohaline (low salinity) estuary. Tidal waters push into the Jones Falls river corridor and create zones of fluctuation that can be utilized to support specific, regional ecological communities, and to create a hydrological framework for the corridor. This project allows for the phased removal of the failing JFX highway and creates a dendritic landscape armature that articulates the riverine, tidal and estuarine zones.

Baltimore has been experiencing a prolonged period of depopulation and suburban flight, and as a result large areas of the central city have been abandoned and have fallen into disrepair. A number of these areas are immediately adjacent to the JFX corridor. Additionally, a number of buildings along the corridor are located within the 100-year

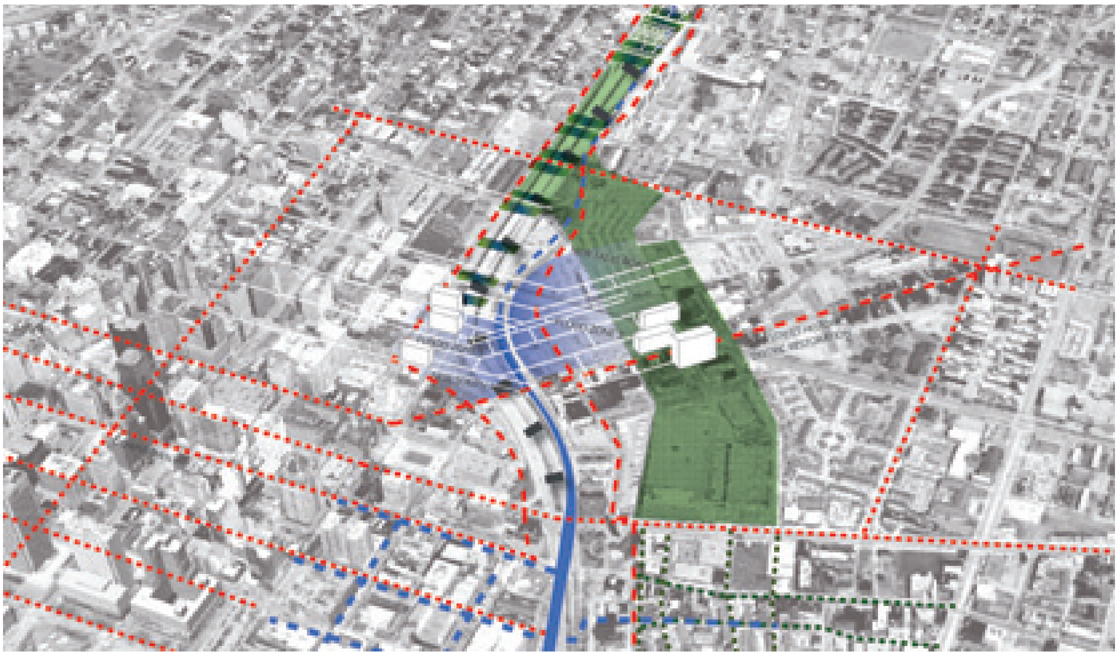

Figure 1 This new infrastructure reconnects neighborhoods through a functional framework for stormwater treatment and pedestrian circulation.

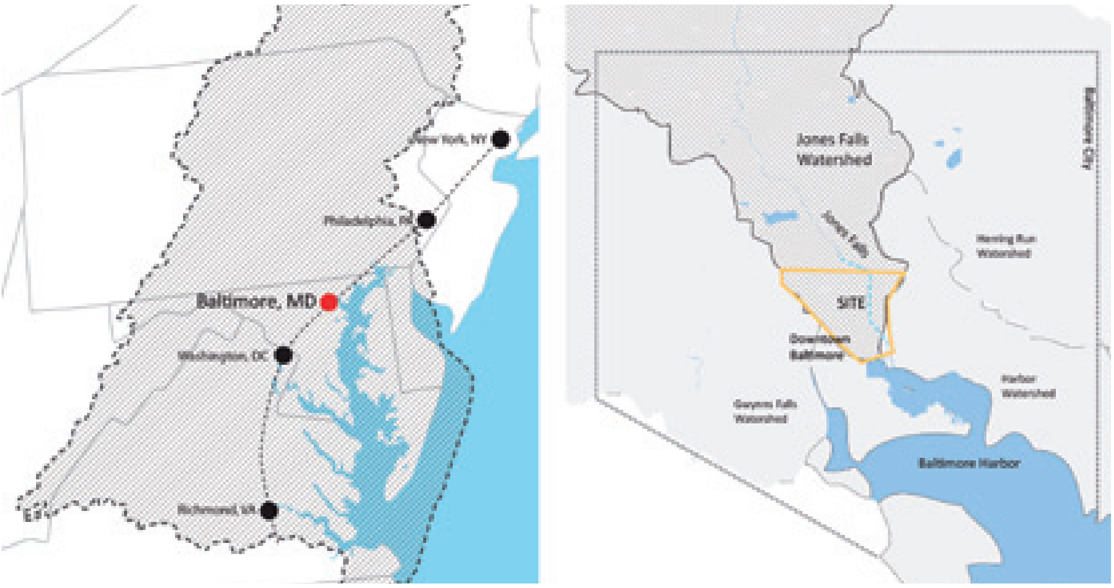

Figure 2 The Jones Falls corridor cuts through the heart of Baltimore city. The river's ecological concerns contribute the larger pollution and sedimentation problems of the Chesapeake Bay watershed.

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flood plain and experience frequent flooding from stormwater surges. This project creates a generative landscape infrastructure that stretches across the corridor through a series of shifting wetland terraces. These terraces create an armature that extends from the river corridor into neighboring areas, providing a new logic for stormwater management, and a regenerative network for neglected areas of the city.

As this infrastructure grows, it extends into surrounding neighborhoods, and ecological parcels are established in abandoned lots. These parcels, along with a pedestrian stormwater network, connect underutilized areas to the river corridor, re-establish value and interest, and allow for strategic redevelopment over time. This model for an

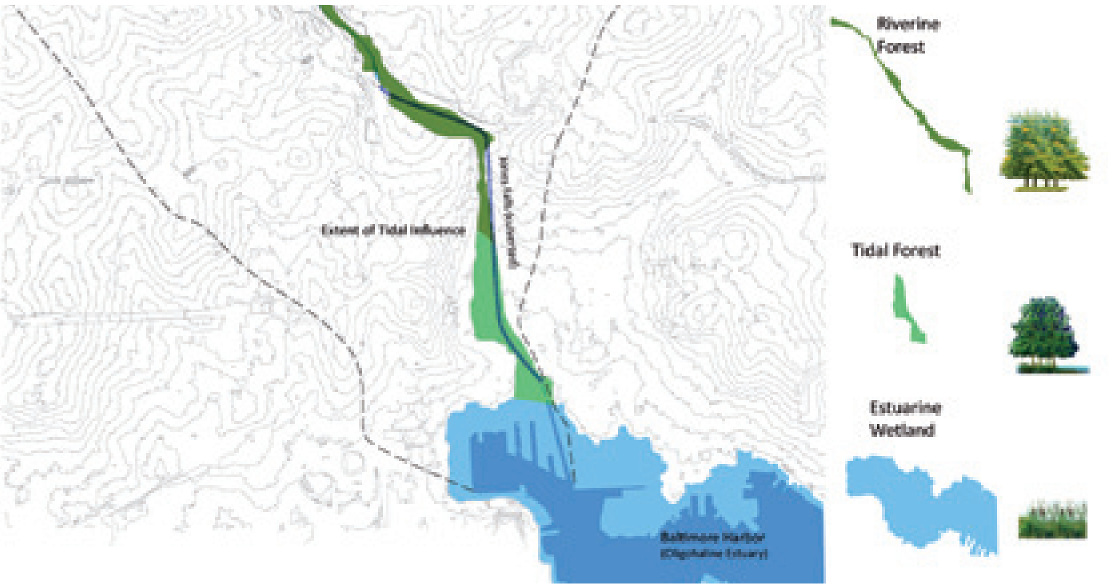


Figure 3 The city's physiographic armature suggests three specific ecological zones along the JFX corridor: the riverine forest, the tidal forest, and the estuarine wetland. Fluctuating water levels are characteristic of the dynamics of these communities. The culvert currently suppresses this fluctuation, thereby suppressing the specific qualities of the city's regional setting..

Figure 4 *Each zone is associated with a specific community of regional plants, tolerant of a fluctuating hydrology and salinity. These ecosystems provide key functions of filtration and erosion control, to contribute to improved water quality downstream. The adaptive qualities of the plants contribute to the adaptive quality of the overall hydrological network.*

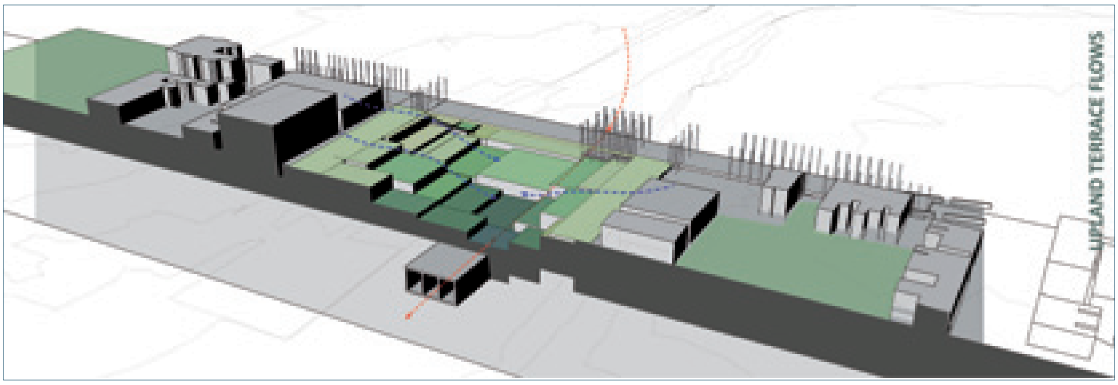


Figure 5 *The wetland terraces collect and filter stormwater from adjacent neighborhoods, decreasing demand on the piped stormwater system, and contributing to improved water quality. The culvert is left in place as a redundant mechanism for large storm events.*

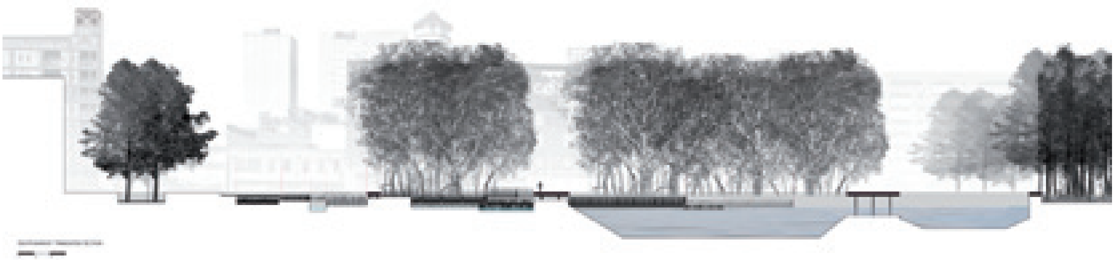


Figure 6 *The unique joint between tidal estuary and freshwater river is exposed as a bioretention plaza. This is the largest space of public gathering along network. .*

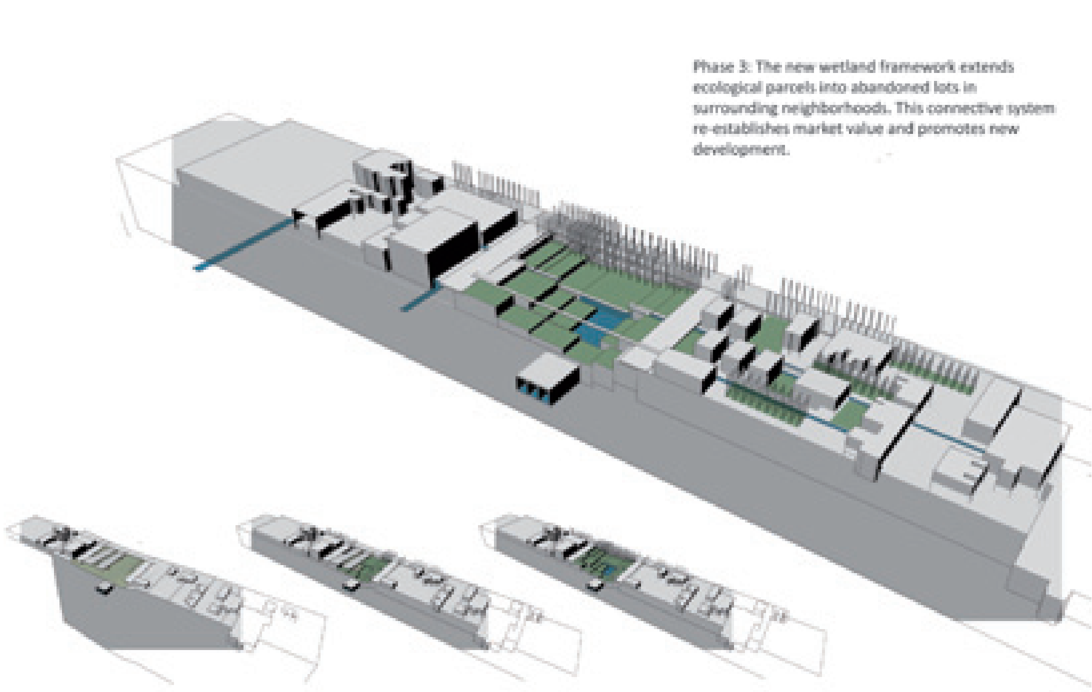


Figure 7 This adaptive and generative framework grows with the city, providing new lots for development and extending stormwater treatment to neighborhood streets.

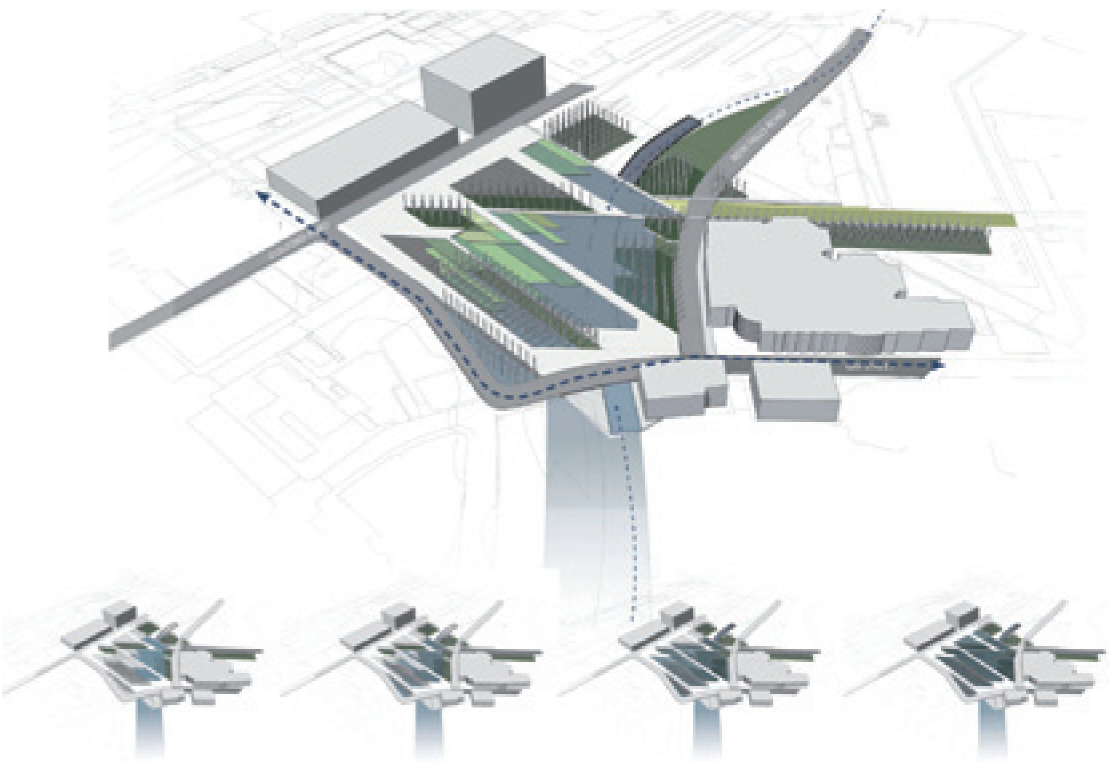
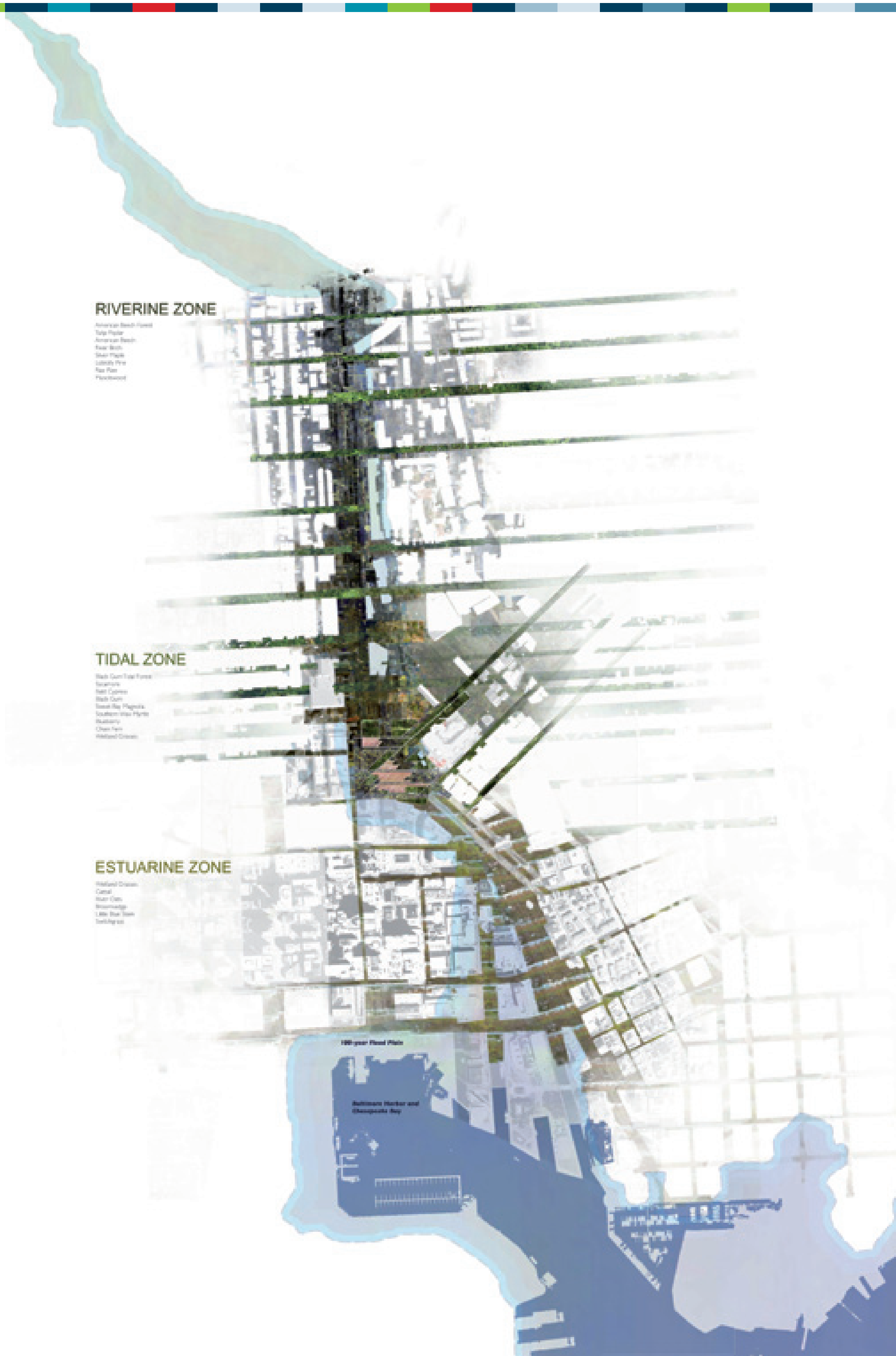
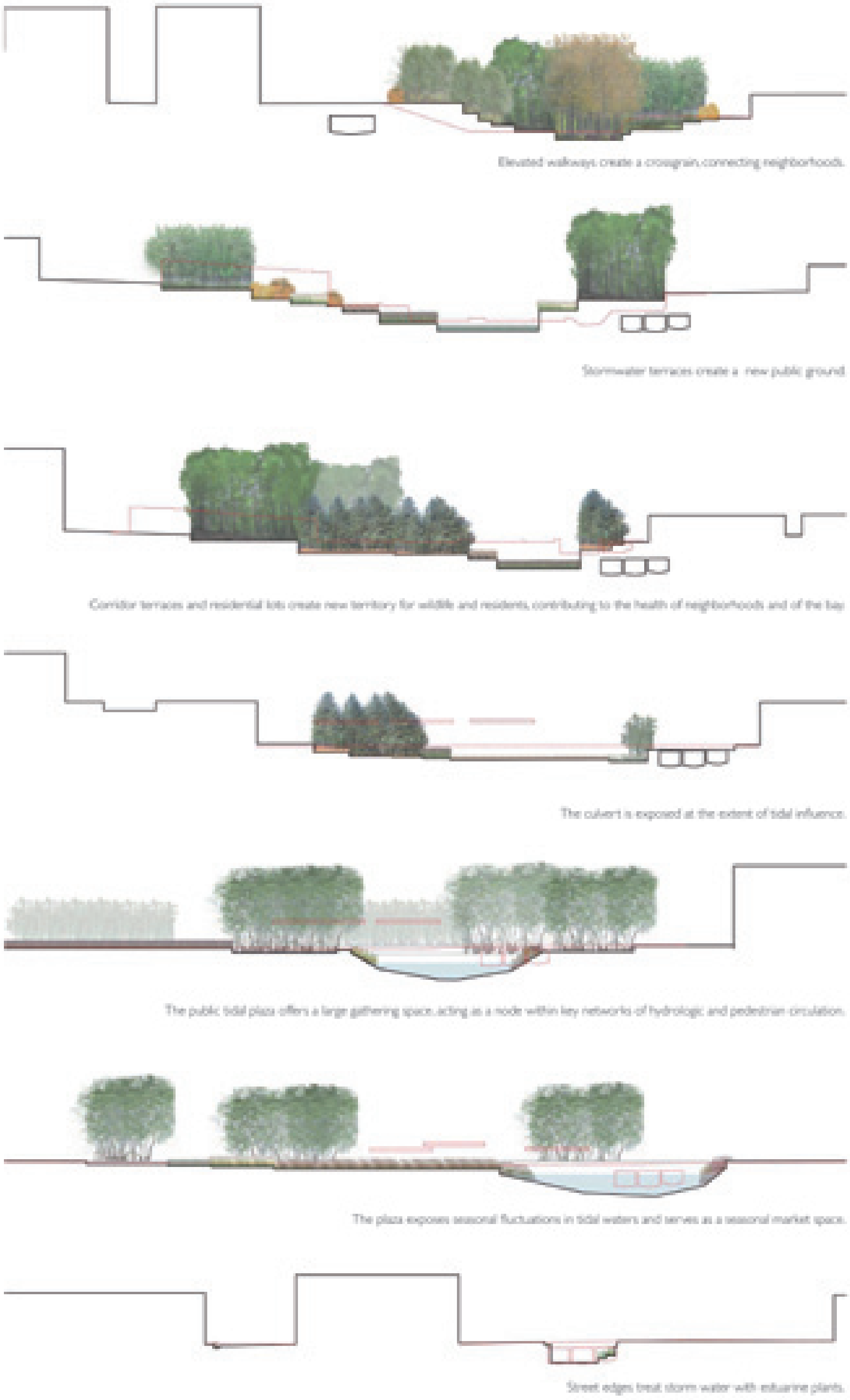


Figure 8 The plaza acts as a joint between Baltimore's Inner Harbor and residential neighborhoods, as well as between the waters of the bay and the river. The seasonal dynamics of these systems animate the public space, linking residents to their city's ecology.


RIVERINE ZONE
TIDAL ZONE
ESTUARINE ZONE



Figures 9 River Matrix: delta ecology as adaptive network.

Figure 10 *View of new ecological parcels and residential fabric*

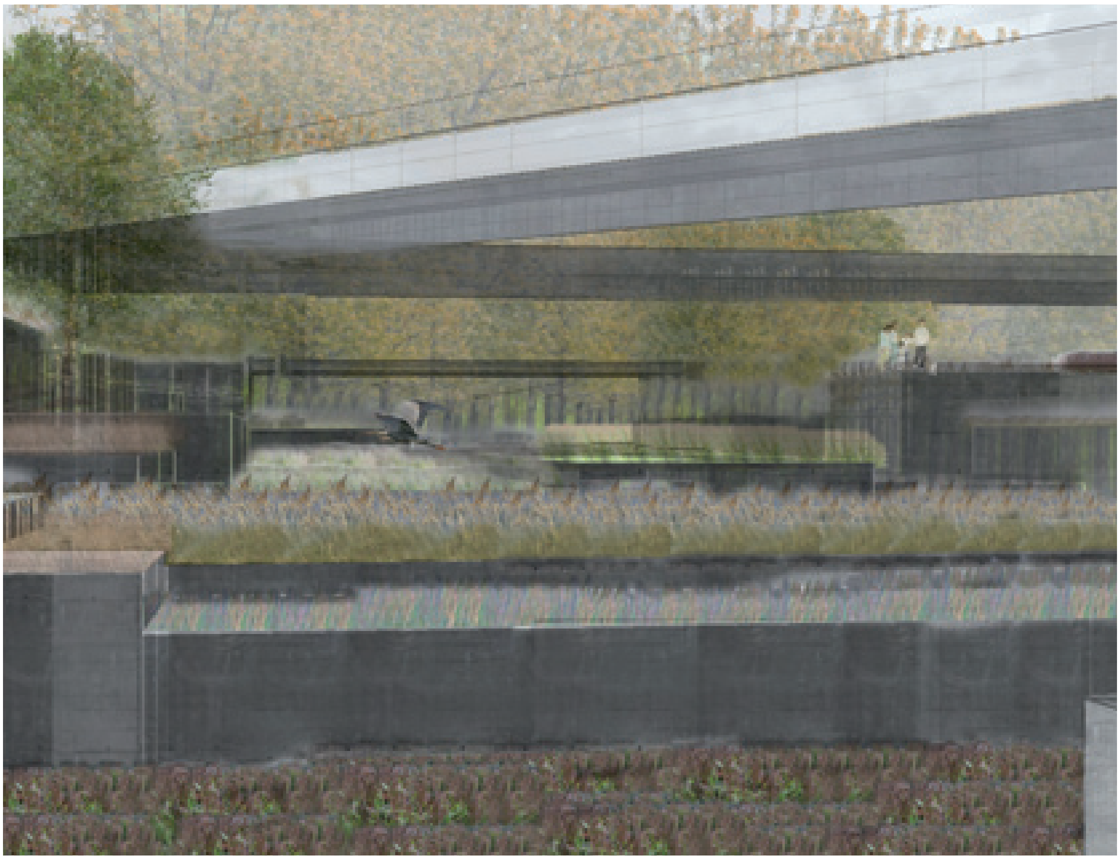


Figure 11 *View of wetland terraces bridging the river corridor*

Figure 12 *View of Tidal Marketplace*

ecological and urban mosaic questions traditional models for urban renewal that prioritize density, and instead proposes a successional model that allows Baltimore to thrive in a state of stabilized ecological and urban flux.

The culvert, which predates the JFX by seventy years, has long subverted the river ecology and fails to accommodate large storm surges. It acts as a conduit for polluted waters coming from agricultural and suburban areas in the upper watershed directly into the Chesapeake Bay. The new armature of wetland terraces within the Jones Falls Corridor will recapture base flows from the culvert and begin to filter harmful pollutants from the water before it reaches the bay. The culvert will remain in place as a redundant system for large storm events. As the culvert reaches the bay, it will be opened into a bioretention plaza. This wetland plaza will act as a joint between overflows from the stormwater corridor and fluctuations from the tide, creating a place within the public realm where the temporal flux of the bay is visible, and creates a thriving wetland ecology. This site also acts as a node between Baltimore's downtown and harbor districts, and its historic oldtown district and downtown mall. Like much of Baltimore, the historic mall has been undervalued and abandoned. The new tidal plaza will support community activities such as a seasonal farmer's market (that currently operates on this site underneath the elevated highway) and act as a regenerative node for the oldtown district.

INSTITUTIONAL DESIGN PRINCIPLES FOR CLIMATE CHANGE ADAPTION

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Summary

This paper provides an evidence-based and policy-relevant contribution to understanding the processes of climate change adaptation in the Netherlands, Australia and South Africa. It builds upon the work of Elinor Ostrom on institutional design principles for local common pool resource systems. We argue that for dealing with uncertainties like climate change impacts (e.g. floods or droughts) additional or adjusted institutional design principles are necessary that facilitate learning processes. Especially since these governance systems are usually dealing with complex, open access and cross-boundary resource systems, such as river basins and delta areas in the Netherlands and South Africa or groundwater systems in Western Australia. In our case studies, the jurisdictional and geographical scale but also the complexity and uncertainty relating to the policy problem are larger. In this paper, we proposed and found some empirical support for a set of nine institutional design principles for climate change adaptation in complex governance systems. These principles support a "management as learning" approach to dealing with complexity and uncertainty. They do not specify blueprints, but encourage adaptation tuned to the specific features of local geography, ecology, economies and cultures.
Key words: climate change adaptation, institutional design principles, adaptive governance, floods, droughts, Netherlands, South Africa, Australia.

INTRODUCTION

Whilst considerable attention has been paid to the mitigation agenda in recent years, it is increasingly recognized that we also need to be planning to adapt to the challenges and opportunities that a changing climate will bring. Managers and policy-makers responsible for water and environment-related issues are under pressure to respond to the unprecedented impacts of climate change such as larger floods, more severe droughts, sea level rise, coastal erosion, ecosystem degradation and reduction of ecosystem services, water supply shortages, increase and new forms of pollution and water related diseases. Current institutional arrangements are often insufficient to manage these new challenges adequately and innovative and adaptive ways of governing water are required.

Adaptation to climate change is defined by Adger et al. (2005, p.78) as: "An adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities. Adaptation can involve both building adaptive capacity thereby increasing the ability of individuals, groups, or organizations to adapt to changes, and implementing adaptation decisions, i.e. transforming that capacity into action. Both dimensions of adaptation can be implemented in preparation for or in response to impacts generated by a changing climate."

We know, as yet, little about the 'politics' of how adaptation processes actually work, e.g. in regard to trust building, conflict resolution and the way in which different interests are weighed against each other. This paper builds on earlier empirical work as well on theoretical notions from the literature in order to develop a framework, which relates the notion of adaptation to institutional design principles. It then develops these notions through drawing on experience from water users and managers in three very different case- studies in the Netherlands, Australia and South Africa. Climate change will test not only the resiliency of ecosystems but also the adaptability of individual cities, villages and societies. This is the reality in the Netherlands, Australia and South Africa, which are all confronted by changing flood and drought regimes (Schulze, 2005; KNMI, 2006; Berti et al., 2004).

This paper will focus on policy changes at the national and/or sub-national level, more specifically, on the initiation and development of climate change adaptation strategies for dealing with floods and droughts in the Netherlands, Australia, and South Africa. The overall objective of this paper is to identify institutional design principles for climate change adaptation based on comparative analysis of strategy development. By doing so, this paper intends to contribute to evaluating strategies and conditions for responding more directly to adaptation challenges.

INSTITUTIONAL DESIGN PRINCIPLES

Research on institutions has not produced many concrete answers to one crucial challenge: how to facilitate institutional change despite massive inertia and opposition without imposing external blueprints and thereby ignoring the intricacies of local conditions (Evans, 2004). The issue is not whether the blueprint is domestic or foreign but the fact that a blueprint approach is pursued.

Adaptation to climate change represents specific challenges for institutional dynamics – uncertainties, conditions beyond the envelope of historical experience and heterogeneous local impacts and capacities to respond. Instead of trying to search for the single, optimal set of rules we agree with Ostrom on the importance of studying the underlying designs of those real-world experiments that have proved to be robust over time (Ostrom, 1990; Ostrom et al., 2007). Ostrom received the 2009 Nobel Prize in Economics for this work.

Ostrom's approach was to derive design principles from analyzing the management of local, common-pool resources (CPR) like irrigation water. When one member of a group uses a common pool resource it is not available for others in that group and it is possible for members of the group to stop others getting access to it (Ostrom, 1990). She came up with eight design principles: 1) Clearly defined boundaries; 2) Proportional equivalence between benefits and costs; 3) Collective choice arrangements; 4) Monitoring; 5) Graduated sanctions; 6) Conflict-resolution mechanisms; 7) Minimal recognition of rights to organize; and 8) Nested enterprises.

However, the design principles for sustaining long-enduring, common pool resource systems on a local scale and those for establishing or sustaining a governance system to deal with the impacts of climate change in a complex, open access, cross-boundary resource system may be expected to be distinct for several reasons (e.g. Healey, 2003; Rotmans, 2005; Grin, 2006). First, complexity is substantially increased since water resources usually must be managed across different time-frames and at different scales (local, regional, national, international). Second, and in contrast to traditional planning for infrastructure, governments and stakeholders at all levels need to be flexible under changing conditions when determining adaptation policies and measures, especially since climate change and its impacts are uncertain.

RESEARCH METHODS

The primary data sources were documents about the process events, water policies and other project plans, and interviews with participants or conveners involved in their preparation, implementation and follow-up. In all three cases the authors were in some way involved in the adaptation process. For each case study we undertook 10 extensive interviews with stakeholders representing ministries, water authorities, planners, academic institutions and civil society. The interviewees in each case study were selected because they had been closely involved in the process of developing the selected strategy. An effort was made to select a mixture of experts to provide a fair representation of the key interests involved in the processes being analyzed. During the interviews we discussed for each design principle the extent to which that specific aspect was similar or different when talking about (the processes of) climate change adaptation in the countries under consideration. The results of our interviews were evaluated against relevant literature in the fields of environmental economics, public administration, political science, spatial planning, environmental studies and climate change adaptation. The complexity of adaptation to climate change problems demands such an interdisciplinary approach (Conklin, 2005).

Table 1 provides an overview of the key institutional features of the adaptation strategies being analyzed in the Netherlands, Western Australia and South Africa. More details on the strategies presented here can be found in Huntjens et al. (in press).

Table 1 - Key institutional features of the adaptation strategies being analyzed in the Netherlands, Western Australia and South Africa

Key features	Netherlands (NL)	Western Australia (WA)	South Africa (SA)
Key drivers	• 1993 and 1995: Extreme peak discharges in Rhine and Meuse rivers > Although no dyke breaches have occurred there was a preventive evacuation of 150.000 people • Climate change scenarios predict more extreme peak discharges (WB21 scenarios, KNMI, 2000; KNMI, 2006) • EU policy, in particular the Water Framework Directive (2002)	• Perth's Water Future (1995) mentions that WA could move into drier climate • 1997: Water Corporation decides to use short term instead of long term historical records for planning purposes • Severe droughts in 1998 and winters of 2001-2002	• Climate stress, effects of climate change are increasingly noticeable in terms of increasing scarcity and extreme events • International discourse on climate change adaptation • Implementation and capacity are both a problem which is a motivation • Food security is at stake
Focal policy	Room for Rivers policy initiated in 2000, leading towards Spatial Planning Key Decision (PKB) in 2006	Three successive strategies: • State Water Strategy (2003) • Security through Diversity Strategy (2005) • State Water Plan (2007)	SA National Climate Change Response Strategy (2004), including Water Sector Climate Change Strategy (DWA), and National Climate Change R&D Strategy (DST)
Time period	2000-2009	2000-2009	2000-2009
Key objectives	1) In 2015 the Rhine branches will safely cope with an outlet capacity of 16,000 cubic metres of water per second 2) The measures implemented to achieve the above will also improve the quality of the environment of the river basin 3) The extra space the rivers will need throughout the coming decades subsequent to expected climate changes, will remain available	Objective of the State Water Strategy was to ensure a sustainable water future for all Western Australians by: 1) Improving water use efficiency in all sectors 2) Achieving significant advances in water re-use 3) Fostering innovation and research 4) Planning and developing new sources of water in a timely manner; and 5) Protecting the value of water resources	1) Strategic resource management 2) Flexibility in water use allocations 3) Water demand and conservation mechanisms 4) Contingency planning for extreme events such as floods and droughts 5) Communication 6) Optimizing the operation of existing infrastructure 7) Constructing new infrastructure
Related policies	• Nationaal Bestuursakkoord Water (2003) • Vierde Nota Ruimtelijke Ordening Extra (VROM, 1992) • National Spatial Strategy ('Nota Ruimte', VROM, 2004) • EU Directives (e.g. Water Framework Directive; Habitat Directive; Common Agricultural Policy; Flood Directive)	• National Water Initiative (2005) • WA Rights in Water and Irrigation Act 1914 • WA Planning and Development Act (2005) • Environmental Protection Act (1986)	• National Water Act (1998) • National Water Resources Strategy version 1 (NWRS1) in 2005, and version 2 (NWRS2) in 2009 • National Environmental Management Act (1998)

Key features	Netherlands (NL)	Western Australia (WA)	South Africa (SA)
Key responsible authorities	• Room for Rivers policy has been initiated by the Ministry of Transport, Public Works and Water Management • Coordinating responsibilities were assigned to provincial level instead of national level	• Premier's Office • Department of Water (est. in 2006), formerly known as State Water Department • Water Corporation	• Department of Water Affairs and Forestry (DWAF), which is now Department of Water (DWA) • Department of Science and Technology (DST)

RESULTS AND DISCUSSION

Based on our comparative analyses below and the original design principles identified by Ostrom and discussed above we propose a set of nine institutional design principles for climate change adaptation in complex governance systems

Table 2 - Institutional design principles for climate change adaptation in complex governance systems

Design Principle	Explanation
Robust and flexible process	Based on transparency, transdisciplinarity, and flexibility (e.g. organizational redundancy)
Equal and fair (re-)distribution of risks, benefits and costs	Requiring engagement with, and strong representation of, groups likely to be highly affected or especially vulnerable
Collective choice arrangements	To enhance the participation of those involved in making key decisions about the system, in particular on how to adapt
Policy experimentation	A purposeful and coordinated activity (e.g. pilot projects) geared to producing novel policy options
Conflict prevention & resolution mechanisms	Including timing and careful sequencing, transparency, trust-building, and sharing of (or clarifying) responsibilities
Monitoring and evaluation of the process	Providing a basis for reflexive social learning and supporting accountability
Nested enterprises / polycentric governance	(In a multi-level context), as functional units to overcome the weakness of relying on either just large-scale or only small-scale units to govern complex resources systems
An integrated approach/strategy tailor-made to local circumstances	Taking into account multi-levels, cultural/historical circumstances, multi-issues, multi-perspectives and multi-resources
Policy learning	Through exploring uncertainties, deliberating alternatives and reframing problems and solutions

In the following paragraphs we will provide the key observations in each case study, while a more detailed description of individual design principles in each case study has been provided in Huntjens et al (in press).
Table 3 shows an overview of the key characteristics and examples related to the institutional design principles for climate change adaptation in the Netherlands, Western Australia and South Africa.

Table 3 – Overview of key characteristics and examples related to the institutional design principles for climate change adaptation in the Netherlands, Western Australia and South Africa.

Principle	Netherlands	Western Australia	South Africa
Robust and flexible process	• Organizational redundancy > no fixed allocation of tasks and responsibilities in beginning of the process > facilitating bottom up initiatives and flexibility • Programmatic approach, including pilot projects and so-called 'decisions for exchange' • Integration of national, regional and local interests, being supervised by provincial authorities • Transdisciplinarity (involving non-academic participants) as a science-policy approach	• Water reform agenda since 1994 • Water resource management was separated from water supply functions in 1996 • National Water Act 2007 clarified roles in water management • Transdisciplinarity (involving non-academic participants) as a science-policy approach	• Drafting of strategy started within very clearly defined boundaries (by DWAF), but no input from other governmental stakeholders and water sector as a whole • Opening up of process was crucial for dealing with complexity • Interdisciplinarity (non-academic participants were not involved so far)
Equal and fair (re-)distribution of risks, benefits and costs	• Stakeholders at risk were given opportunities to participate in reshaping and reducing the risks to which they are projected to be exposed, e.g. in the Noordwaard (in September 2003) and IJsseldelta (in April 2005) • Scenario-based approaches proved to be helpful, amongst others, in handling risks & uncertainties, e.g. Environmental Impact Assessments and Cost-Benefit Analyses (MKBAs) as important decision support tools • First steps in transboundary cooperation as regards sharing of upstream-downstream costs and benefits, e.g. in Rhine High Water Action Plan	• Stakeholder workshops, e.g. the local water forums in 2002, where those at risk were given the opportunities to participate in reshaping and reducing the risks to which they are projected to be exposed • Extensive groundwater and environmental studies undertaken over several years, e.g. to identify the likely impacts of utilizing the Gnangara Groundwater System or South West Yarragadee aquifer > finally decided for climate independent option (= desalinization plant)	• In South Africa equal and fair (re-) distribution of risks, benefits and costs is seen as very much a "first world concept " to be answered in a developing country context, e.g. in a dual economy such as South Africa's, there will always be cross-subsidization from the "haves" to the "have nots" • Strong moral component in the National Water Act (NWA) of 1998 in regard to redressing past (historical) inequities for the previously disadvantaged groups to be mainstreamed into the system of water allocation • Concept of total cost recovery in the water sector in a relatively poor country like SA, with its highly variable climatic regime, in reality remains a first world dream
Collective choice arrangements	• Multi-stakeholder dialogues, e.g. stakeholder design sessions in IJsseldelta (in April 2005) • Organizational set-up which integrated national, regional and local interests, with this being supervised by provincial authorities • Formal management track was supported by consultative groups (klankbordgroepen), which included a variety of stakeholders • Strong influence of civil society reflected in the key spatial planning decision (PKB, 2006)	• Multi-stakeholder dialogues, e.g. 17 public water forums in the Perth metropolitan area and southwest regional areas • Above forums informed the preparation of the State Water Strategy, published by the Government in February 2003 • Also the State Water Plan (2007) involved consultation at all levels in the community	• Process of stakeholder participation is strongly embedded in the National Water Act, as it is within the Catchment Management Agencies (CMAs). However, the CMAs have been slow to evolve and it remains to be seen at what level genuine stakeholder participation will be • There is an emergent influence of shadow networks on the subject of climate change and its implications for the SA water sector, especially among the SA research community which is internationally well connected

Principle	Netherlands	Western Australia	South Africa
Monitoring and evaluation of the process	• External evaluation of the Room for Rivers process in 2007 (Berenschot and Technical University of Delft, 2007) • Ministerial statement ensuring that lessons and experiences from evaluation are used for further steps in policy-making and implementation (Ministry of Water management, 2007)	• Monitoring and evaluation processes are embedded in various types of water management plans • NWI Implementation Plan is monitored and evaluated by the National Water Commission • Irrigation Review informed the governance review, as well as later commitments from the Government, e.g. to sign the NWI	• Monitoring and evaluation is more problematic owing to capacity problems and information gaps • Some pilots on active involvement of citizens in the local monitoring of water and sanitation services (e.g. in four townships of Cape Town and in the eThekwini Metropolitan Municipality (Durban, KwaZulu-Natal)
Conflict prevention & resolution mechanisms	• Programmatic approach, including 'decisions for exchange', was important tool for time sequencing by including proxies for longer-term objectives whose achievements are contingent on more immediate objectives being met • Early and transparent information sharing and communication of uncertainties • Sharing of responsibilities, e.g. masterplan for IJsseldelta Zuid initially caused a lot of resistance, but when provincial deputy asked the public to help him in finding alternatives and solutions the majority decided to co-operate instead of protest	• 2002 water forums and Premier's Water Symposium supported community awareness raising and knowledge transfer > These forums built considerable trust on which to first develop and then implement the State Water Strategy actions • Centralization of responsibilities by Premier's Office (in 2004) after policy conflicts between Water Corporation and Department of Water • In a later stage, these responsibilities were shared again (but without overlap!), e.g. by National Water Act 2007 which clarified roles in water management • Climate-independent option to deal with droughts (i.e. desalinization) removed part of the conflict	• Water Tribunal is in place for water conflicts at all levels that cannot otherwise be resolved. Its use in conflict resolution at this juncture is, however, relatively limited • Water sharing agreements between SA, Lesotho, Zimbabwe, Swaziland, Mozambique, Botswana and Namibia, but these may need to be revisited in light of projected changes in flow regimes • Necessity for 'out of the box'- thinking as regards upstream-downstream conflicts, e.g. hydropower in Lesotho might provide more water to downstream areas in return for food or other services
Nested enterprises / polycentric governance	• Polycentric governance system was deliberately introduced by means of the National Spatial Strategy ('Nota Ruimte', VROM, 2004) > shift from a centralised towards a decentralised mode of governance • Water boards (task-specific jurisdictions) are embedded in general purpose jurisdictions at multiple levels	• General purpose jurisdictions at multiple levels with specific departments focusing on water and climate • All seven water regions of WA have developed their own regional water plans	• Catchment Management Agencies (CMAs) are embedded in general purpose jurisdictions at multiple levels • Governance capacity by CMAs is relatively limited compared to Netherlands and WA due to capacity problems

Principle	Netherlands	Western Australia	South Africa
Policy experimentation	• Netherlands is the only case study with policy experimentation on climate change adaptation • Near Avelingen a management experiment has been initiated to test how decision-making (on flood management plans) might be accelerated by means of timely involvement of stakeholders • IJsseldelta Zuid, as a national pilot project for spatial planning; testing new methods and processes (e.g. design sessions by stakeholders and citizens) to find imaginative solutions to predefined tasks of the Room for Rivers policy • Overdiepsche Polder was a policy experiment in shifting the responsibility for planning from the national to provincial government in combination with extensive stakeholder participation	• In WA three parallel planning processes are ongoing which deal with climate change (but each with different foci), viz. the Gnangara Sustainability Strategy, Water Forever, and the Perth Peel State Water plan. Each of these plans has a committee which tries to line up different planning processes • Not directly related to CC adaptation but in WA there has been a major policy experiment on the development and application of sustainable development principles at the neighborhood level • Policy experimentation is not something new in Australia's water sector, e.g. alternative market based policies (MBI) in northern Victoria, the Pilot Interstate Water Trading Project, and others	• Relatively new concept in SA, but there are pilot projects on bottom-up approaches to water services regulation ("Citizens' Voice"), and because of its success being up-scaled to other regions in SA
An integrated approach/ strategy tailor-made to local circumstances	• Multi-level, multi-sectoral and multi-perspective governance approach, e.g. for developing tailormade masterplans for the IJsseldelta, Noordwaard, Overdiepsche Polder, Hoeksche Waard, Waalweelde, etcetera	• Multi-level approach for developing a tailor-made strategy for the Gnangara groundwater system (Gnangara Sustainability Strategy) and for the Perth-Peel region (Perth-Peel regional water plan) • All seven water regions of WA have developed their own regional water plans, including a multitude of tailor-made management strategies based on a catchment management approach	• Development of (tailormade) adaptation strategies at regional level has just started, e.g. climate change strategy and action plan for the Western Cape (DEADP, 2008) • Capacity for developing tailor made adaptation strategies at the local and regional level in South Africa is relatively limited compared to the Netherlands and WA, due mainly to a lack of capacity in both the Catchment Management Agencies (CMAs) and the more user-specific Water User Associations (WUAs)
Policy learning	• Double loop learning, with elements of triple loop learning, e.g. change in regulatory framework + paradigm shift from 'fight against water' to 'living with water' • For more details see Huntjens et al. (2010)	• Dominated by double loop learning, with elements of triple loop learning • For more details see Huntjens et al. (2010)	• Dominated by double loop learning, with elements of single loop learning (ad-hoc problem solving) • For more details see Huntjens et al. (2010)

Design principle 1 - A robust and flexible process, based on transparency, flexibility and transdisciplinarity

Starting with Ostrom's first design principle of 'clearly defined boundaries' (1990: 259) one of the key observations is that during adaptation processes in the Netherlands and Australia certain responsibilities and relationships were deliberately left open, resulting in a robust and flexible process. This organizational redundancy provided stakeholders more room to find their appropriate position and role during the process, and at the same time allowed for these positions and roles to change when necessary.

The adaptation processes in our case studies were characterized by a two-fold ambition of developing practically relevant and scientifically sound knowledge, and thus stimulating a mutual relation between science and policy. The concepts of public participation and the science-policy interface were strongly embedded in the adaptation processes of the Netherlands and WA (see also design principle 3 – collective choice arrangements). Transdisciplinarity (involving non-academic participants) as a science-policy approach was an important contributor to the robustness of the adaptation processes in the Netherlands and WA, as it was to a lesser extent in South Africa by means of interdisciplinarity (only involving academic participants). In the Netherlands, it was in particular the programmatic approach, including pilot projects and the exchange procedure[1], some organizational redundancy in the beginning of the process, and the integration of national, regional and local interests (being supervised by provincial authorities), which proved to be very successful elements for the process of climate change adaptation.

Design principle 2 - Equal and fair (re-) distribution of risks, benefits and costs

The redistribution of risks among rural and urban areas, as well as among poor and wealthy people in urban areas, is a central theme of flood politics in many regions. We also know that much of what passes for institutional reform at the basin or State level to reduce risks of disaster might really be about redistributing risk away from central business districts and valuable property, rather than reducing risks to livelihoods of the poorest or most vulnerable (Manuta et al., 2006). This is tantamount to mal-adaptation.

As stated by Edward Carr (2008:690): "no adaptation will result in equal outcomes for all", and "the benefits and costs of any particular "adaptation" effort will not be distributed evenly through a social group." However, this does not mean that institutional designs should not strive to achieve a fair and equitable (re-) distribution of risks, benefits and costs. It could prove to be one of the biggest challenges during processes of climate change adaptation. Both in the Netherlands and WA we have seen examples where stakeholders at risk were given opportunities to participate in reshaping and reducing the risks to which they are projected to be exposed, e.g. in the Noordwaard (in September 2003) and IJsseldelta (in April 2005) in the Netherlands and the local water forums in 2002 in WA. Important decision support tools in the Netherlands and WA where scenario- based approaches, including environmental impact, risk or vulnerability assessments and cost-benefit analyses, which proved to be helpful, amongst others, in handling risks, vulnerabilities and uncertainties. In South Africa, equal and fair (re-)distribution of risks, benefits and costs is seen as very much a "first world concept" to be answered in a developing country context, e.g. in a dual economy such as South Africa's, there will always be cross-subsidization from the "haves" to the "have nots". In any case, based on our observations in the Netherlands, Australia and South Africa we argue that reducing the risks of exposure requires engagement with, and strong representation of, groups likely to be highly affected or especially vulnerable. This relates directly to the next paragraphs on collective choice arrangements.

As a refinement of this design principle, especially relevant for river basin management and deltaic regions, it is important to consider the sharing of upstream-downstream costs and benefits. Downstream areas in a river basin are being influenced by physical interventions in the upstream areas of the same basin, which may shift the distribution of benefits or involuntary risks from one group to another. Adaptation may even exacerbate injustice,

1 The exchange procedure means that specific projects might be adjusted or replaced by better alternatives in a later stage of the process. In other words, the Room for River process offers the flexibility to include new initiatives when they apply to the boundary conditions. This approach provided more leverage for decision-making (Berenschot, 2007), and was a crucial instrument for avoiding delays in the decision- making process.

such as when actions in the logic of protecting national assets and interests render some disadvantaged groups even more vulnerable than they were previously (Lebel et al., 2009a). In the Netherlands, Germany and Switzerland the principle of sharing upstream-downstream costs and benefits is taking shape under the umbrella of the Rhine High Water Action Plan, in which countries in the discharge basin are implementing appropriate measures, including those described in the SPKD Room for the River. It might also prove to be an important, but challenging, principle in the case of South Africa, where hydropower schemes in the highlands of Lesotho (upstream) might be adjusted in order to provide more water to downstream areas (mainly in South Africa) in return for food or other goods.

Design principle 3 - Collective choice arrangements

Ostrom (1990) convincingly shows that user communities of a common pool resource have the capacity for self-organization and self-governance and that there are many different viable combinations between the public and private sectors. Involving actors in the design of formal institutions is expected to increase compliance and effectiveness, but this may come at the expense of decreased efficiency since participatory processes are resource consuming (Pahl-Wostl, 2009). Nevertheless, while something is inefficient in the short term, the reasons for that inefficiency (e.g. capacity building) may create a more efficient system in the longer term. Social learning processes often take considerable time and money of both water managers and the other stakeholders. Hence, social learning processes should only be embarked upon for issues that are important for the stakeholders, and not for relatively minor issues. Hence, it is important to find an appropriate balance.

In SA, the process of stakeholder participation is strongly imbedded in the National Water Act, as it is within the Catchment Management Agencies (CMAs), but collective choice arrangements are just recently being introduced in the process of climate change adaptation at multiple levels. In the Netherlands and WA, collective choice arrangements, in particular multi-stakeholder dialogues have been at the center for developing climate change adaptation strategies. Multi-stakeholder dialogues, including social learning processes, negotiation and co-production of knowledge are crucial for adaptation processes and are cross¬cutting many of the design principles discussed in this article. In Lebel et al. (2009b), multi-stakeholder dialogues are defined as “events at which different stakeholders openly engage in facilitated, informed deliberations”. The dialogues in the local adaptation programmes such as IJsseldelta Zuid (The Netherlands) and the 2002 Water Forums (WA) are typical examples of such multi-stakeholder dialogues [2].The purposes (and values) of these dialogues were: 1) To reduce conflicts and explore synergies; 2) Explore alternatives, and; 3) Shape and inform negotiations and decisions. As was discussed in design principle 1, the science-policy interface is an important element of a robust and flexible process, and multi- stakeholder dialogues provide an important tool for facilitating this. During these dialogues, it is important to produce outcomes that are directly relevant for planning and decision-making in the complex politics in which climate change adaptation takes place. Stakeholders should therefore be involved in all steps of analyzing and synthesizing project and process outcomes as well as identifying best practices for governance and implementation.

Design principle 4 - Policy experimentation in a polycentric system

Policy experimentation in our case studies played a supportive role in expanding horizons to find solutions and for adapting to new circumstances. In most cases, it was a coordinated activity, involving experts, stakeholders, ordinary citizens and policy-makers in a process of collective discovery (see also Guba & Lincoln, 1989; Fischer, 1995; Pielke, 2007). According to Heilman (2008), policy experimentation is not equivalent to freewheeling trial and error or spontaneous policy diffusion. It is a purposeful and coordinated activity geared to producing novel policy options that are injected into official policymaking and then replicated on a larger scale, or even formally incorporated into national law. However, policy experiments can be difficult to initiate since the results of experiments do not always lend themselves to clear-cut policy choices, and results may appear when the policy-makers who initially asked for them have disappeared from the political scene (Sanderson, 2002). However they can be an effective way of loosening up policy systems, thereby creating space for innovations (Huitema & Meijerink, 2009). Policy

2 For a more detailed analysis of the multi-stakeholder dialogues in IJsseldelta Zuid (Netherlands) and the 2002 Water Forums in Western Australia see Lebel et al. (2009).

experimentation is a relatively new concept in all case studies and only in the Netherlands has it been used specifically for management experiments in climate change adaptation (for example, see table 3), whereas in South Africa so far only within the context of water services regulation and in Western Australia for sustainable urban development. Nevertheless, these examples show that the potential of policy experimentation is a key institutional practice in adaptive governance to provide the basis for reflexive social learning (Sanderson, 2002).

Design principle 5 - Conflict prevention & resolution mechanisms

In our case studies, it was difficult to identify concrete conflict resolution mechanisms, a design principle mentioned by Ostrom (2005), especially because serious conflicts were prevented by means of effective conflict prevention mechanisms. Based on our observations, we can state that conflict prevention and resolution mechanisms can take many forms, often more implicitly than explicitly. In some cases, a reframing of (initially conflicting) interests was often necessary to identify solutions, such as the climate- independent option of desalinization in WA. It is also interesting to note that investing in conflict prevention during policy development (e.g. by means of time-sequencing3, transparency and trust-building in the Netherlands) might be more cost- and time-efficient than investing in conflict resolution mechanisms. The latter might be especially expensive when it comes to litigation or lawsuits (often resulting in costly delays) during policy implementation.

Design principle 6 - Monitoring and evaluation of the process, thereby supporting accountability

Our case studies in the Netherlands and Australia highlight the importance of monitoring and evaluation as a key institutional practice in interactive governance to provide the basis for reflexive social learning (see also Sanderson, 2002). In the Netherlands (e.g. by means of the Berenschot evaluation in 2007) and WA (e.g. irrigation review, governance review), it has clearly contributed to an improved understanding and in some instances to an adjustment of the course of action, for example in the water reform process in WA. Monitoring and evaluation in South Africa is more problematic owing to capacity problems and information gaps.

The process of evaluation and monitoring serves to adjust the course of action and motivate those driving the processes. During the process of climate change adaptation, actions and objectives can then be adjusted based on reliable feedback from the monitoring programs and improved understanding (Nyberg, 1999).

Design principle 7 - Nested enterprises

Based on our empirical analyses, we can conclude that water governance in our case studies involved polycentric institutional arrangements (see table 3 for examples). In the Netherlands and South Africa there are nested quasi-autonomous decision-making units (water boards and CMA respectively) operating at multiple scales, while WA shows general purpose jurisdictions at multiple levels with specific departments focusing on water and climate. To what extent these polycentric institutional arrangements contribute to climate change adaptation is not clear yet, since the outcomes of its adaptation strategies are largely unknown at present. Most of these strategies have only recently been introduced and there has not been enough time to test their long-term appropriateness and effectiveness in relation to their institutional arrangements. Nevertheless, we have seen that in the process of developing adaptation strategies the responsible decision-making units in all case studies involve local, as well as higher, organizational levels and aim at finding a balance between decentralized and centralized control (Imperial, 1999; Huntjens et al. 2010). Hence, multi-level systems, cross-scale interactions and networks that connect individuals, organizations, agencies, and institutions at multiple organizational levels seem to be of paramount importance (see also Adger et al., 2005; Olsson et al., 2006; Kok & De Coninck, 2007).

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3 The programmatic approach in the Netherlands provided an important tool for time sequencing (see also Wilson et al 2007 & Haug et al 2009) involving near-term objectives for adaptation alongside objectives which characterize an improved capacity or ability to address adaptation in the long-term (see also Keeney and McDaniels, 2001). This avoided biasing the selection of alternatives towards those that provide immediate gains. Indeed, an important lesson of successful and adaptive management strategies is the importance of avoiding low- probability but high-consequence outcomes in the long term, even though immediate outcomes may be suboptimal (Gunderson and Holling, 2002).

Design principle 8 - An integrated approach/strategy tailor-made to local circumstances

An integrated strategy for climate change adaptation might be considered as an outcome of the functioning of the design principles mentioned previously, and it is as a minimum considered to be an important milestone during a robust and adaptive process (see design principle 1). Since the projected impacts from climate change can differ significantly within small geographic areas, adaptation is challenging and requires predominantly site-specific, local efforts, related to geographic and water-related circumstances, the socio¬economic circumstances, the political system and the specific institutional arrangements, which include the availability of relevant capacity and skills at the local level.

At the same time, we have seen that local adaptation programmes require tailor-made arrangements which, inter alia, take into account situational conditions regarding the content of the issues, relationships with other sectors, and commitments. Climate change adaptation requires management of water resources across different time-frames and at different spatial scales (local, regional, national, international). In contrast to traditional planning for infrastructure, governments and stakeholders at all levels need to be flexible under changing conditions when determining adaptation policies and measures, especially since climate change has an unpredictable future.

Design principle 9 - Policy learning through exploring uncertainties, deliberating alternatives and reframing problems and solutions

In addition to the working hypotheses of Ostrom, we have assessed the level of policy learning in the case studies. It is important to take into account that learning may have different levels of intensity (Pahl-Wostl, 2009). These levels are addressed in the concept of double loop learning (Argyris, 1999) or even triple loop learning (Hargrove, 2002), an extension of the double loop concept represented below (figure 1).

Based on a detailed assessment in Huntjens et al (in press) we can state that the adaptation processes in the Netherlands and WA are predominantly characterized by double loop learning, although elements of triple loop learning have been observed as well. Climate change adaptation in South Africa is characterized by a combination of single loop and double loop learning (Huntjens et al., 2008, 2010). In general, we can state that during processes of climate change adaptation policy, learning is achieved by exploring uncertainties, deliberating alternatives and reframing problems and solutions.

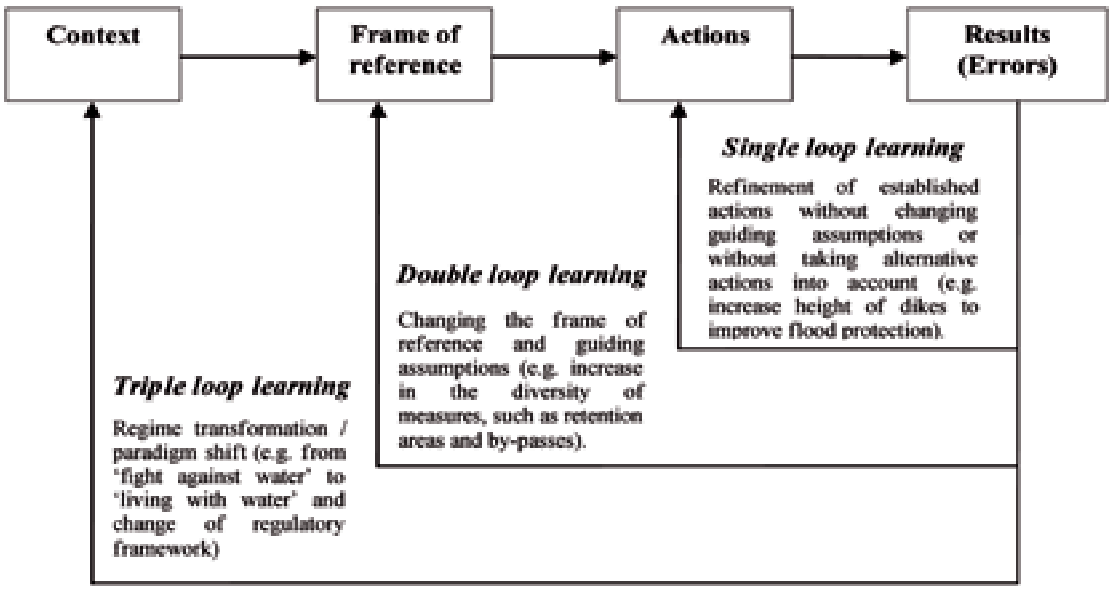

Figure 1 Different levels of policy learning (Adjusted version from Huntjens et al. (2008), based on Hargrove (2002))

DISCUSSION & CONCLUSION

In this paper, we proposed and found some empirical support for a set of nine institutional design principles for climate change adaptation in complex governance systems (see Table 2). These institutional design principles provide useful support for a "management as learning" approach when dealing with complexities and uncertainties. This approach does not foster a narrow blueprint style but rather the opposite locally- appropriate institutions treated as experiments.

The design principles have several potential uses in practice. First, by taking into account the issues they highlight, decision-exploring, making and evaluating steps at different levels of governance can be made more adaptive. In this type of application, the design principles can be seen as diagnostic tools rather than blueprints for institutional reform. The specific solutions are almost always very highly context dependent.

Second, the principles should be useful for exploring new, and refining existing adaptation strategies, by focusing more attention on their governance – in particular how decisions about particular strategies are reached and not just their technical content. This can help overcome the frequent neglect of power relations and interests in the making of "adaptation" policy.

Third, the principles may be useful not just to planning agencies and processes of governments but also to community-based organizations and the private sector interested in working with other stakeholders in pro¬active approaches to adaptation. Several of the roles implied by the design principles may be taken up effectively in some situations by non-state actors and multi-stakeholder bodies.

The initial set of design principles suggested need further testing and elaboration. In particular issues of generalizability and trust building deserve further exploration. The design principles proposed here arose from explicit consideration of water management challenges in the context of a changing climate. It is not yet clear to what extent these findings are generalizable to adaptation in the water sector in less developed country contexts or to other sectors. Trust building is clearly important to collective action and thus an important component of several design principles. More work is needed on how trust is built starting with areas that this paper suggests, such as: early communication of uncertainties, joint/participative knowledge production, open access to, and shared information sources, transparency about the decision-making process, and sharing of responsibilities.
Successful governance of adaptation to climate change depends on enabling and supporting adaptive institutions that are able to cope with complexity and uncertainty in the face of new challenges and possible surprises (Pahl-Wostl, 2002; Huntjens et al., 2008; Pahl-Wostl, 2009). In order to adapt to new situations, institutional arrangements that are flexible and encourage reflection, learning and innovative responses to often very specific local capabilities and needs are required. A certain degree of redundancy and experimentation also appears to be important. Social learning processes and trust building are critical to exploring uncertainties, deliberating alternatives and reframing problems and solutions. If one was to identify an overarching frame for institutional design principles for climate change adaptation it might be called 'mechanisms for facilitating social learning and policy learning' (Huntjens et al., 2008).

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