DeltAAlliance

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Knowledge for Climate

Delta Alliance Young Professionals Award

Innovative solutions for delta challenges worldwide

A contribution to the Rio+20 theme
'Green economy in the context of sustainable development and poverty eradication'

Ministry of Infrastructure and the Environment
University of Twente. ITC Faculty of Geo-Information Science and Earth Observation
Both ENDS
Deltares Enabling Delta Life
Alterra Wageningen UR
ARCADIS Infrastructure · Water · Environment · Buildings
WWF
jwh initiative supporting young environmental leaders
Grontmij

Supported by the Dutch Ministry
of Infrastructure and Environment

Ministry of Infrastructure
Environment

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Partners:

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Foreword

Delta Alliance Young Professional Award

Innovative solutions for delta challenges worldwide

Deltas are fragile, dynamic landforms at the boundary of land and ocean. They belong to the most valuable, but at the same time also to the most vulnerable areas in the world. With increasing pressure from population growth, industrialization and changing climate, it is more important than ever that these locations increase their resilience to changing conditions.

The mission of Delta Alliance International is to improve the resilience of deltas. It is a knowledge driven global network that connects people and organisations dealing with the challenges that deltas are facing worldwide.

The Dutch Ministry of Infrastructure and Environment has offered Delta Alliance International the opportunity to present itself during the Rio+20 Conference on Sustainable Development as a successful partnership. As a partnership that strengthens the resilience of deltas worldwide through fostering the exchange of knowledge, expertise and practice experiences on common delta topics such as spatial planning, integrated water resources management, food security, nature conservation, disaster risk management, water governance and climate adaptation.

Deltas are facing many challenges today but even more so in the future. This is the reason why we used this opportunity to actively involve the young generation by organising the Delta Alliance Young Professional Award. In line with the central themes of the Rio+20 Summit *Green Economy in the context of Sustainable Development and Poverty Eradication*, young professionals have been challenged to find innovative solutions for future sustainability of deltas.

We were very pleased with the active, international participation in this award, since the call for solutions published in January 2012 drew an impressive number of 53 contributions, originating from 29 countries.

An international jury had the difficult task to select the three Award winners:

Thriving Deltas proposes the transformation of a location at risk in the Sacramento – San Joachim Delta in California into a pilot ground for new promising developments.

Re-generating Delta proposes a strategy for large scale micro-algae harvesting, converting the farmland along the coastline of the Pearl River Delta into large scale open algae harvesting ponds.

Balance Island aims at reducing salt intrusion and restoring natural estuarine dynamics and ecology by creating a semi-enclosed estuary with a series of constructed sandy islands in the South West Rhine-Meuse Delta in the Netherlands.

The three Award winners will receive organizational, financial and scientific support to further develop their proposed solution, in close cooperation with one or more of the supporting partners and preferably in one of the member deltas of Delta Alliance International. The Award ceremony takes place during a special event at the Rio+20 Summit.

I would like to congratulate the Award winners and our Partners (Alterra, Arcadis, Both ENDS, Deltares, Grontmij, ITC-University of Enschede and WWF Netherlands) with the success of this competition. The ten best solutions are presented in this booklet. We hope they will serve as examples and provide inspiration to all of you to assist in improving the resilience of deltas.

Tineke Huizinga

- Delta Alliance International, Chair International Governing Board
- Chair International Jury of the Delta Alliance Young Professional Award

International Jury

The international jury for the Delta Alliance Young Professionals Award is composed of:

Mrs J.C. Huizinga-Heringa
Chair of the Jury. Chair of the International Governing Board of Delta Alliance International, former Minister for Housing, Spatial Planning and the Environment, the Netherlands.

Prof. Charlotte de Fraiture
Professor of Land and Water Development, UNESCO-IHE. Former Head of the West-Africa Office of the International Water Management Institute (IWMI), Accra, Ghana.

Dr. M. Monowar Hossain
Wing coordinator of the Delta Alliance Bangladesh Wing, Executive Director of the Institute of Water Modeling (IWM), Professor at the Bangladesh University of Engineering and Technology, Bangladesh.

Dr. Lifeng Li
Member of the International Governing Board of Delta Alliance International, Director Freshwater, WWF International, Switzerland.

Hans Huis in 't Veld
Chairman Topsector Water, the Netherlands, former director TNO and former director DHV, member of the Supervisory Board of several international companies and organisations.

Report

Report of the International Jury

On Friday, the 1st of June 2012 the Jury of the Delta Alliance Young Professionals Award met at UNESCO-IHE in Delft, the Netherlands, to assess the submissions to the Delta Alliance Young Professional Award. The jury was pleased by the active, international participation in this award, since the call for solutions published in January 2012 drew an impressive number of 53 contributions, originating from 29 countries.

The Jury members appreciated the creativity and originality of the submissions, as well as their scientific quality. Furthermore, the jury was highly impressed by the diversity of the contributions and the broad enthusiasm of young professionals around the world for solving delta issues.

Entries were assessed on the basis of the criteria as published in the announcement of this award:

- Relevance for the acute Delta challenges as referred to in the call
- Scientific quality,
- Creativity & Originality
- Innovativeness of solution
- Degree of integration of approach
- Presentation of solutions

In two selection rounds the jury has decided to grant the Delta Alliance Young Professionals Award to three entries, and to present these, together with the seven entries which qualified as next- best in the present booklet.

The Winners of the 2012 Delta Alliance Young Professionals Award are:

- **Thriving Deltas** by Richard Fisher and Ryan Whipple
- **Re-generation Delta** by Federico Curiel
- **Balance Island** by Sander van Rooij, Emil Kuijs, Bert van Bueren

The following paragraphs give a brief justification for the selection of these three contributions by the Jury.

Thriving Deltas proposes the transformation of a location at risk in the Sacramento – San Joachim Delta in California into a pilot ground for new promising developments.

Jury acknowledges the high relevance of this solution to Deltas around the world. The authors of this proposition followed a comprehensive line of thinking, and designed and presented their idea in a convincing manner. A creative combination of measures is proposed, which is worked and thought through carefully. In the further development of the presented solution, the jury suggests to pay attention to a full integration of the various elements of innovation and alternative land and water use, the impacts on the neighboring areas in the delta and a sound cost-benefit analysis. In this respect potential positive effects on upstream communities could help to increase the feasibility of the solution.

Re-generating Delta proposes a strategy for large scale micro-algae harvesting, converting the farmland along the coastline of the Pearl River Delta into large scale open algae harvesting ponds. The Jury appreciates this solution as it is a creative and very relevant contribution to the ongoing discussions about green economy, also in scope of the Rio+20 Summit on sustainable development. The jury was taken by the simplicity and the high scientific quality of this solution, and sees great chances for implementation. Albeit at a relatively initial stage, the jury is convinced that this innovative idea would profit strongly from further elaboration focusing on an in-depth feasibility study (including a societal cost – benefit analysis) and on the possible repeatability of the idea in other river deltas.

Balance Island aims at reducing salt intrusion and restoring natural estuarine dynamics and ecology by creating a semi enclosed estuary with a series of constructed sandy islands in the South West Rhine-Meuse Delta in the Netherlands. This truly innovative, creative, nicely presented and original contribution has been thoroughly thought through. Not only the physical and ecological but also the socio-economic aspects of the proposed solution are clearly analyzed. By presenting a new measure to mitigate saltwater intrusion, the authors contribute to solving an important and relevant challenge which deltas around the world are facing. The proposed solution responds highly to all the criteria of the call. The jury appreciates the high scientific quality of this paper, and suggests to focus on the further elaboration of this solution on the inherent uncertainty of hydro-morphological predictions in medium and longer term, particularly in the chosen study region, where the Maasvlakte 2 is now under construction with its own morphological effects. Attention should also be paid to the current (environmental) value of the location where the island is projected.


Sacramento
River
San Joaquin
River
San
Francisco
Bay

A

Thriving deltas: An adaptive approach

Sherman Island
Source: Miyamoto (2010)

Richard Fisher[1] | Ryan Whipple[1]

Delta Alliance Young Professionals Award WINNER!

Abstract

Deltas are pinnacles of life: they provide environmental wealth to support biodiversity, human population centers, and industrial and agricultural production. Land use, water diversion, flooding, subsidence, salt water intrusion, and ultimately levee failure threaten these complex ecosystems and it is therefore important that dynamic approaches be taken to avoid disaster, and sustain thriving Deltas. This report focuses on the Sacramento-San Joaquin Delta but the lessons learned can be extended across the globe. The Sacramento-San Joaquin Delta is the primary water resource for California's urban and agricultural development. Sherman Island sits on the western edge of the Delta and is a critical geographic feature in balancing the flux of saltwater in the Delta. However, Sherman Island is at risk of catastrophic failure. Flooding, saltwater intrusion, and ongoing subsidence are current threats that become further exacerbated by global climate change. Through collaboration with industry representatives, inhabitants, academics, and local government officials, the environmental, social, and economic impacts of these issues were holistically addressed. The synthesis of stakeholder input with natural and engineered environments led to the design of an Adaptive Water Management and Agricultural Diversification System (AWMADS) composed of a levee enclosed flood storage and wetland habitat area that can dynamically support hydroponics (soil-less agriculture), aquaculture (concentrated production of aquatic

1 University of California at Berkeley, CA, US

species), and many other optional components over the system's life. Engineering, socio-economic, environmental impact and life cycle analyses, and exploration of mitigation strategies demonstrate the theoretical success of the system to protect against flooding, sequester carbon, restore habitats, and reinvigorate the local economy.

Introduction

Deltas are deteriorating due to land use and water diversion practices, flooding, subsidence, salt water intrusion, and ultimately levee failure. The preservation of these complex ecosystems is paramount, thus dynamic approaches must be taken to avoid disaster. After discussing the issues facing the Sacramento San Joaquin Delta (SSJD), CA, US, this report will describe a design approach and result for an Adaptive Water Management and Agricultural Diversification System at Sherman Island. While this design serves a specific application, the design strategy can act as an archetype for future projects to support thriving deltas globally.

The Sacramento-San Joaquin Delta is located at the confluence of the Sacramento and San Joaquin Rivers in Northern California of the United States, as shown in Figure 1. Sherman Island sits on the western edge of the SSJD and is one of the key geographic features protecting 21,770 hectares of farming, 25,900 hectares of cities and towns, and 30,400 hectares of undeveloped land. The SSJD is home to approximately 515,000 people and 500 unique plant and animal species as well as major transportation and utility infrastructure (Department of Water Resources 2008). Fresh water pumped from the SSJD throughout California supplies more than 22 million people, approximately two-thirds of the California's entire population.

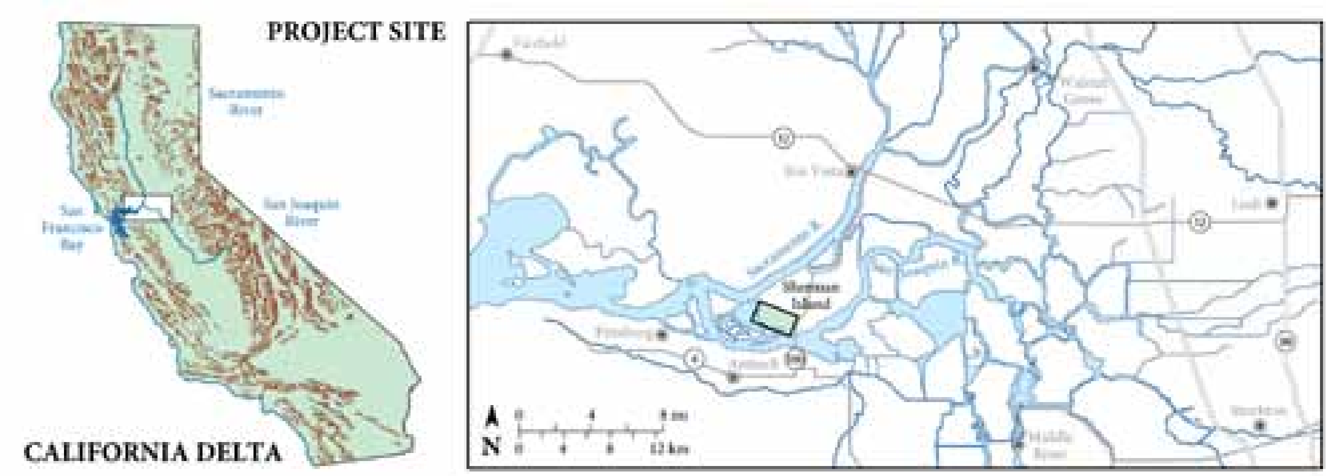


Figure 1: Location of the SSJD and the Sherman Island Project Site
Source: Jacobs (2012)

The SSJD provides a habitat for two-thirds of California's migrating salmon and half of its migrating waterfowl and shorebird populations (Department of Fish and Game, 2008). Forty-six species of fish, including nineteen native, take refuge in these waters. However, this environmental sanctuary is becoming increasingly threatened by human use. Over the last century fertilizer runoffs have promoted algal blooms and eutrophication leading to fish deaths (Terry, 2000). Pesticide use has been detrimental to health of aquatic and bird species, especially as toxins bio-accumulate. Additionally, water treatment sites have harmed fish through the removal of beneficial nutrients (Seed, 2010). Native species populations are in decline such as the Delta smelt, Sacramento chinook salmon, longfin smelt, Sacramento splittail, California red-legged frog, tiger salamander, giant garter snake, and western pond turtle, which are among the listed endangered species in the SSJD.

Millions of hectare-meters of fresh water are diverted from the SSJD to the Central Valley and Southern California. The SSJD struggles to maintain a balance of salt to fresh water as more fresh water is continually diverted. This situation is compounded during years with less precipitation and drier months of each year. Thus, salt-water from the San Francisco Bay intrudes farther into the delta each year (Kisliuk, 1990). Increased salinity has decimated the once great agricultural industry that was present on Sherman Island. Island residents once produced corn, asparagus, beets and grain crops. However, the viability of such crops has been greatly reduced, and only salt resistant crops and livestock can be produced today. Therefore the government has been required to subsidize the dwindling agricultural economy and switch to the production of livestock, which creates an unsustainable economy (Roe, 2010). Figure 2 provides land use area data on the crop transition over time, and emphasizes the crop trend toward less-profitable salt-tolerant crops.

Sherman Island levees were originally built in the late 1800s as small earthen berms to regulate agricultural irrigation and to make nutrient rich peat soil dry enough for farming. Over time, agricultural practices have caused the top layer of peat to oxidize, perpetuating subsidence at a rate of approximately 7.5 cm/year (Seed, 2010). Many portions of the island are now between 3 and 7.5 meters below Mean Sea Level (MSL) as shown in Figure 3. Sherman Island is the most subsided (or sunken) island, by volume, in the SSJD with 108.5 million cubic meters of subsided volume. The pressure differential created by the difference between the river and island levels puts much greater stress on the archaic levee infrastructure than it was built to withstand.

With the growth of industrialized cities, these decaying levees now serve not only to protect crops, but also to protect major transportation and utilities infrastructures, a purpose for which they were never designed. Highway 160 connects Contra Costa and Sacramento counties via two bridges: the Antioch Bridge spanning the Sacramento River, and a lift bridge spanning Three Mile Slough. Three major 500 kV Transmission Lines pass through the island which serve to interconnect the California electricity grid to generation sources located in the Pacific Northwest. Additionally, Sherman Island is home to 60 natural gas and oil wells and 44,383 m of a natural gas pipeline (Hanson, 2009).

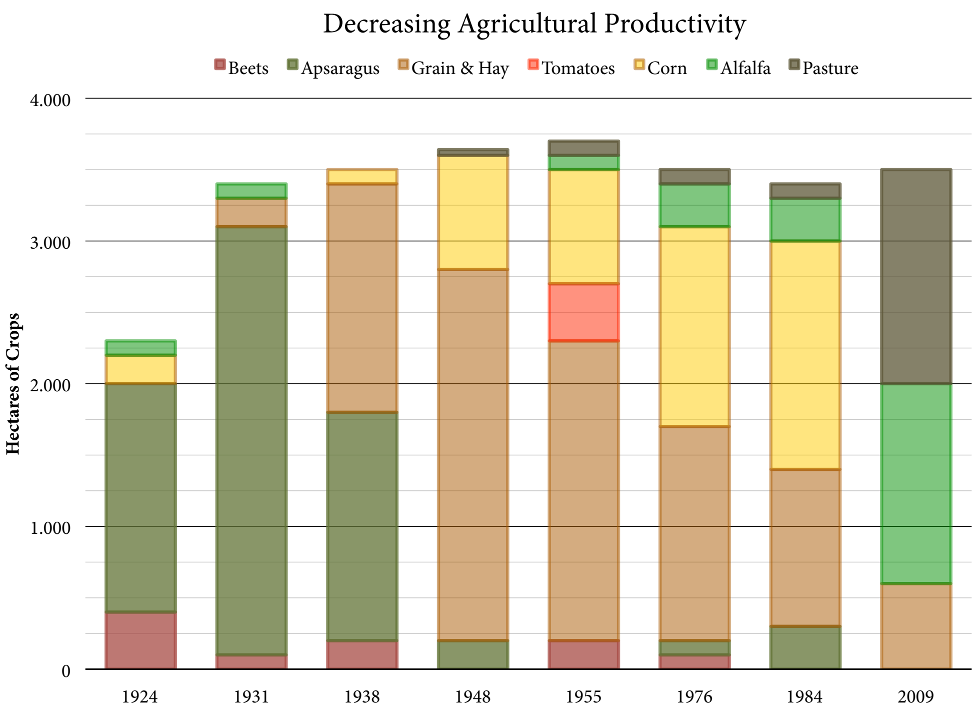


Figure 2: Agricultural Trends on Sherman Island from 1924-2009

Source: Jacobs (2012)

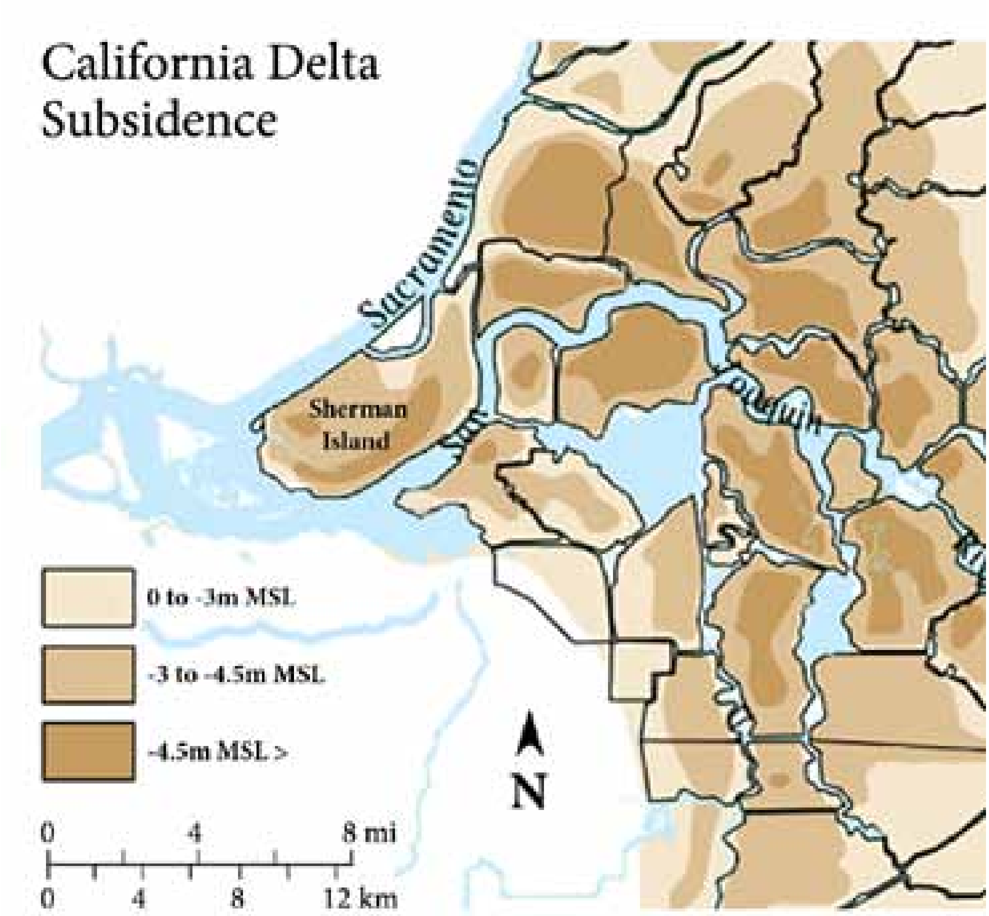


Figure 3: Land Subsidence in the SSJD
Source: Jacobs (2012)

These issues facing the SSJD are further exacerbated by climate changes. Changes in sea level, river flow rates, wind velocities, precipitation, and temperature must be considered when designing resilient systems. The Intergovernmental Panel on Climate Change (IPCC) estimates an increase in global mean sea level (GMSL) of 0.1 m - 0.9 m between the year 1990 and 2100 (DRMS, 2008). Similarly, a more recent study suggests that sea level will rise by as much as 0.5 m - 1.4 m over the course of the next century (DBE, 2009). Changes in sea level increase the stresses already plaguing the SSJD. The crucial balance of salt water to fresh water in the SSJD is very susceptible to changes in salinity due to rising sea level (DRMS, 2008).

Rising sea levels and changing river flows promote salt water intrusion, which presents a great threat to sustaining the SSJD as a water resource for California. As salt levels increase, crop yields in the SSJD will continue to decrease as the plants struggle to maintain homeostasis. While rising sea level causes problems associated with long-term water level variations, changes in river flow have a significant effect on water quality on a seasonal-timescale (DRMS, 2008). Increases in temperature will reduce the snow pack, creating more water runoff during the winter and spring, increasing flood potential during the highest precipitation months. Additionally, the amount of water available for spring flows from snow melt will be reduced (CA CCC, 2009). This reduction of spring and summer flows allows saltwater intrusion further inland into the SSJD making less fresh water available as California approaches warmer temperatures and increased water demand. Increased temperature due to climate change will also significantly affect the temperature gradient between the San Francisco Bay Area and the Central Valley. This gradient increases the intensity of wind velocities (DRMS, 2008) and thus wave action that further weakens the levee system (DRMS, 2008).

Consequences of Levee Failure	Cost (USD)
Flooding of Sherman Island and Associated Destruction	$221 M
Two Month Power Outage of two of the three 500kV lines	$42 M
Water Quality – 5% Compromised	$23 M/month
Water Quality – 100% Compromised	$81.9 B/month
Highway 160 Closure	$70 k/day

***Table 1:** Economic Cost of Levee Failure*

Source: (Hanson, 2009)

If Sherman Island's levees were to fail, water quality for the entire SSJD (as well as the majority of California), would be compromised on a timescale of years to decades. A significant levee breach occurring on Sherman Island has the potential to double salinity levels at key water intake locations in the SSJD, endangering public health, ecosystems and the economic livelihoods of those who utilize this source of freshwater, including California's $18 billion USD agricultural industry (Walkling, 2001). California would experience extreme drinking water shortages as access to virtually two-thirds of its water supply would be gone. The increased salinity in the SSJD would likely be too rapid and drastic for freshwater species to adapt and therefore whole ecosystems would be susceptible to deterioration or collapse. Delta Bearier Engineering estimates the cost to recover lost water supply and to repair levees, infrastructure, and damaged homes in the event of levee failures to be as high as $2.2 trillion USD (DBE, 2009). Flooding of the island could cause interruption of the electrical transmission lines and gas service to the oil wells and natural gas pipeline (Hanson, 2009). The economic cost of Sherman Island levee failures are presented in the Table 1.

Design Process

The goal of this design process is to holistically address the issues facing the SSJD. In order for the design to be successful, it must be adaptable for the dynamic future and sustainable for economic, social and environmental stakeholders. To create a sustainable design result, it was necessary to synthesize stakeholder inputs. While the design is an attempt to meet realistic political, economic and environmental pressures today, it also maintains adaptability to meet the needs of future generations.

Sustainability is directly connected to that which is most valuable to all living things: time on Earth. The value of that time can be quantified by monetary means, social interaction and natural processes amongst other things. Without truly holistic sustainability, however, none of these can exist independently. Therefore to value any one of them is to value them all. This is the ideology by which this design is based.

Technology Delivery System

In order to apply this definition of sustainability, the design process incorporated the Technology Delivery System (TDS) as developed by Dr. Ed Wenk, Jr. (Professor Emeritus, University of Washington) and adapted by Dr. Robert Bea (Professor Emeritus, University of California, Berkeley). There are four components to the TDS: Public, Industry, Environment, and Government. Issues are easy to ignore or become confused when a stakeholder does not understand the risks and benefits or when the designers disregard the concerned parties. Learning from the stakeholders played an important role in understanding the complexity of the issues. Each component and their interfaces are crucial to creating a sustainable solution. Larger scale solutions must consider the smaller components while localized solutions must contribute to greater change. To achieve a truly sustainable design and application, each component must work together. The following is a description of each component and the roles that they play in the design process.

Public
The local and regional public needs must be addressed to create a sustainable approach to the survivability and thrivability of the SSJD. The public of California has the potential to play a crucial role by providing pressure to bring a change to the region. The primary focuses of the residents are safety, a return to high-profit crop agriculture and the departure from the livestock industry (Vallier, 2010). The localized issues as described by the residents offered a more palpable reality than trying to imagine total meltdown of the California Water System. However, the issues facing the greater population of California are extreme and a solution must be based on securing water quality and safety for the entire public.

Industry
Stakeholders in industry value bolstering the local economy while contributing to regional economic security and longevity. The primary players in industry on Sherman Island include agriculture, transportation, electric and gas transmission, and recreation. The concerns of these groups include the protection of the transportation and utility infrastructure, maintaining habitats for fishing, hunting and boating, and bolstering the area's agricultural investments.

Government
The SSJD is a topic of considerable debate given the region's numerous political, economic and environmental stakes. Key issues of governmental concern for Sherman Island are the protection of water resources, the environment, transportation infrastructure, and public safety. Currently, the California financial deficit is adding to the difficulty of meeting SSJD's needs.

Environment
Finally, and most importantly, we must consider the interests of the environment. Defending its interests are numerous environmental groups with the goal of protecting different aspects of the ecosystems. While investigating environmental concerns and potential solutions, reinvestment in habitat to provide for the renewal of the SSJD's biodiversity emerged as a top priority.

Synthesis of Stakeholder Inputs
After identifying the stakeholders and their various individual needs, the design concept took shape based on the following identified shared stakeholder needs: human and infrastructure safety, economic stimulation, and environmental and resource protection. Consequently, the design goal of the proposed system is to reverse subsidence, stabilize the fragile levee systems, increase economic productivity, and protect vital water and environmental resources.

Design Result

To address these goals, the Adaptive Water Management and Agricultural Diversification System (AWMADS) features a restored wetland enclosed in a flood storage that can dynamically support hydroponics (soil-less agriculture), aquaculture (concentrated production of aquatic species), and many other optional components over the system's life. The location of the project site is shown in Figure 1, and the system layout is shown in Figure 4.

Foundation
The foundation for the AWMADS is a 324 hectare Flood Storage Zone. To enclose the Flood Storage Zone, levee construction and upgrades will be needed. Levees currently bound the northern, southern, and western edges of the proposed system and would likely need inspection and potential upgrades. The western and southern edges are bounded by U.S. Army Corps of Engineers' (USACE) levees protecting Sherman Island from the Sacramento

Figure 4: Layout of AWMADS

Source: Angell et al. (2012)

and San Joaquin rivers, respectively. The northern edge is bounded by Mayberry Slough levees which are non-USACE engineered. The largest infrastructural component required is the internal cutoff levee, spanning approximately 1055 m, which will enclose the Flood Storage Zone by bounding the eastern side. Once the area is enclosed it will be flooded with 0.6 to o.9 m of water. During high river events, flood water will be siphoned into the Flood Storage Zone until the river levels have subsided, at which time water will be pumped back to the rivers.

Utility infrastructure is necessary to support siphoning and pumping water out of the Flood Storage Zone. Siphons are currently installed on site for seasonally flooding the agricultural land, but more siphons may need to be installed to increase the flow rate capabilities of siphoning flood water. Mobile Pump Stations will need to be available for pumping water from the Flood Storage Zone to the rivers. Additionally, electricity will be required at the site to support the flood water transport and provide the necessary electrical infrastructure for the optional components. There are several feasible electrical sources. The first available electrical source is the set of backup power transmission lines located directly under the Antioch Bridge which carry 12 kV (Pazooki, 2010). While this may be a convenient initial electricity source, there is an opportunity to produce renewable wind and solar energy at or near the site as a part of the system's optional components.

Road access will be necessary to facilitate construction, operations, and maintenance of the AWMADS site. Currently, Victory Highway and old, unmaintained dirt roads provide access to the site from Hwy 160. According to Mr. Pazooki, a project manager with Caltrans for the Antioch Bridge, several roads are being constructed for the seismic retrofit of the Antioch Bridge near the proposed site. With Caltrans construction of these roads and an additional upgrade of approximately 0.87 km, Victory Highway access to the proposed site would be possible. An alternative route would involve revitalization of a larger portion of Victory Highway stretching roughly 3.5 km to Hwy 160 and is therefore a less desirable option.

Within the Flood Storage Zone will be approximately 283 hectares of multi-use wetlands with approximately 41 hectare set aside for optional components to be developed over time. The wetlands should utilize plant species that are native to the region to help support habitat for native species and the redevelopment of biodiversity. Additionally, these wetland species must be adaptable to flooding conditions within the Flood Storage Zone during times of river flooding. They must be able to survive repetitive flooding for up to several weeks at a time. Therefore, the wetland will be planted with alkali species composed primarily of bulrush and cattails. In order to prevent plant invasion into areas supporting optional components, such as hydroponics, a water depth of 1.5 m or greater with steep slopes should be maintained around the components (Horne, 2010).

Options

The foundation of the AWMADS will provide the necessary infrastructure to support the development of 41 hectares for optional components. The optional components will be interchangeable within the foundation structure and can include the aquaculture, hydroponics, carbon sequestration, an eco-tourism park, residential or recreational houseboats, methane capture, and wind and solar energy production. Two of such options were chosen to demonstrate the ability of the foundation to support multiple stakeholder needs through an adaptive design. Hydroponics and aquaculture are combined into an aquaponics sub-system to produce crops and fish.

Aquaponics is a bio-integrated system in which waste byproducts from aquaculture are used as nutrients for plant growth in the hydroponics components. Each aquaponics system consists of fish rearing tanks, solids settling and removal tanks, a bio-filter, the hydroponics rafts and a sump. Design ratios are based on the reliable and robust University of Virgin Island's 0.05 hectares system which has been in operation since the 1980's and is a model system for commercial aquaponics around the globe. In the first step of the aquaponics cycle the fish eat and excrete ammonia rich effluent. This effluent is sent through the settling tanks to reduce the amount of suspended organic matter. Next, the ammonia is removed and bacteria convert ammonia and nitrites to nitrates in the bio-filter. The nitrate rich water is then pumped to the hydroponics component where plants' roots hang into the pipes and absorb the nutrients from the water. Once water has reached the end of the hydroponics component, it is collected in a sump and then returned back to the rearing tanks (Rakocy, 2006).

A synthesis of Nutrient Film Technique and Deep Water Raft Hydroponics was used to address the needs of the AWMADS. The hydroponics component includes three main subcomponents: Nutrient Film Tubes, Buoyant Rafts and Anchors. Nutrient Film Tubes are hollow core pipes with holes 20.3 cm apart containing net pots with growing media that supports plant roots. With 30.5 m tubes per subsystem, each will support 5,400 planters for an expected annual production of 4990 kg of vegetation. The aquaponics sub-system has been designed with 600 subsystems, so there are 3,240,000 planters in total for an approximate annual yield of 2.72 million kg of produce.

Buoyant rafts allow the nutrient tubes to float on the water in the Flood Storage Zone. Buoyant rafts can be constructed from encapsulated styrofoam, which may be recycled from styrofoam used in packaging or other prior uses. The buoyant force per volume of styrofoam raft is approximately 881 kg/m^3. The buoyancy required to keep each subsystem afloat is approximately 15,900 to 18,200 kg. Therefore, to provide floatation for the hydroponics component approximately 11,300 m^3 of styrofoam rafts to produce approximately 9.5 to 10.8 million kilograms of buoyancy are required. Anchors are based on a pole and slide method designed to prevent lateral movement of the rafts by wind and wave action while allowing for vertical movement of the rafts when there are changes in water height as shown in Figure 5.

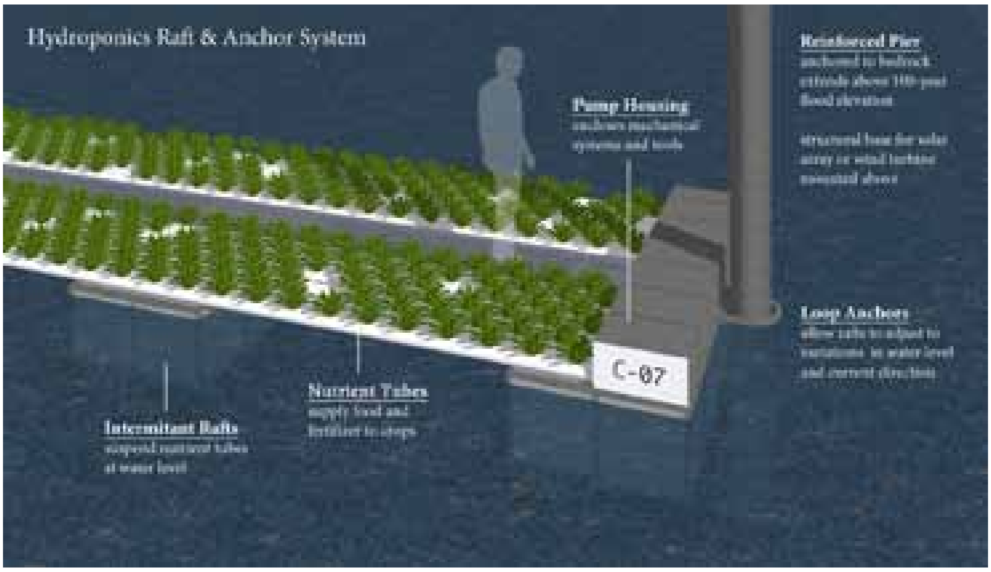


Figure 5: *Hydroponics Raft and Anchor System*
Source: Jacobs (2012)

The equipment and resources required for aquaculture vary based on the fish species, but a general outline can be elucidated. Incubation jars and tanks of varying sizes are needed to raise the fish (Logan, 1995). Stocking density depends on the fish size and stage of life and affects the number of tanks needed. For fish health, filters are needed to regulate particulate concentrations in the fish tanks, but the number of filters can be reduced by using snails in the tanks for cleaning (Lindberg, 2010). Parameters to monitor are water pH, total ammonia nitrogen concentration, salinity, water temperature, and dissolved oxygen concentration. These parameters can be monitored by sensors and controlled by filters, heaters or chillers, and aerators. The water capacity for each of the 600 aquaponics subsystems includes 31,192 liters for rearing tanks, 1,514 liters for filtering and degassing tanks, 7,571 liters for clarifiers, 189 liters for base addition tanks, and 757 liters for sumps (Rakocy, 2006).

Analysis Approach

To determine the potential effectiveness of the design to sustainably meet stakeholder needs, the engineering and safety, economic production, and environmental restoration feasibilities were analyzed. The analysis compares the tradeoffs of the no action alternative in which the issues in the SSJD continue to worsen as stated in the Introduction.

Given the imminent danger in the SSJD, various solutions have been proposed. The Public Policy Institute of California (PPIC) explored a variety of Freshwater Delta Alternatives, Fluctuating Delta Alternatives, and Reduced-Exports Alternatives. These solutions favor protecting the SSJD for farming and urban use and fail to adequately address declining environmental health. Fluctuating Delta Alternatives would utilize peripheral or through-Delta aqueducts for managing the SSJD water system in order to vary water quality standards with relevant respect to environmental habitat needs and urban and agricultural human use. These solutions involve large capital investments in billions of dollars. Reduced-Exports Alternatives would decrease the presence of water extraction and exportation of goods in order to improve the ecological conditions in the SSJD. These solutions limit the SSJD's role as a significant freshwater source and mode of goods transportation for the state year-round. While these large scale solutions were taken into considered it was determined that initiating a localized incremental approach would be the most feasible way to address the issues facing the SSJD in the immediate future. By implementing smaller scale solutions at geographically critical locations, such as Sherman Island, and then multiplying and adapting these solutions to meet the needs of the greater SSJD System, immediate action can be taken to address the current issues while maintaining the ability to adapt the design as conditions change. This is a far more sustainable approach than continuing the standstill over a large scale solution that does not meet the needs of all stakeholders while the risks to California's population continue to escalate.

Engineering Analysis

The basis for the engineering analysis is to determine the efficacy of the system to reduce the risk of levee failure and protect Sherman Island from catastrophic failure. Therefore, the system's potential to protect Sherman Island from flooding is analyzed using USACE safety standards as a minimum requirement. The minimum factor of safety for levee slope stability is 1.3 to 1.4. A factor of safety of 1.0 or less indicates failure.

Existing Levees

The existing levees that surround Sherman Island feature clearly delineated layers of soil similar to that in the internal portion of the island. In addition to the dangers of underseepage and piping, the levees themselves are constructed of sand rather than low hydraulic conductivity clays. This furthers levee instability as water flows through more readily. Furthermore, differential settlement through the years has led to an irregular levee shape and the need for constant repairs. Figure 6 displays the soil and levee profile that will be used for the geotechnical analysis. This levee is extremely susceptible to failure in high flood water events due to the high head differential between the rivers and subsided land inside Sherman Island. Therefore, backflooding the Flood Storage Zone is a favorable approach since it reduces the difference in hydraulic gradient or speed at which water flows through the levee.

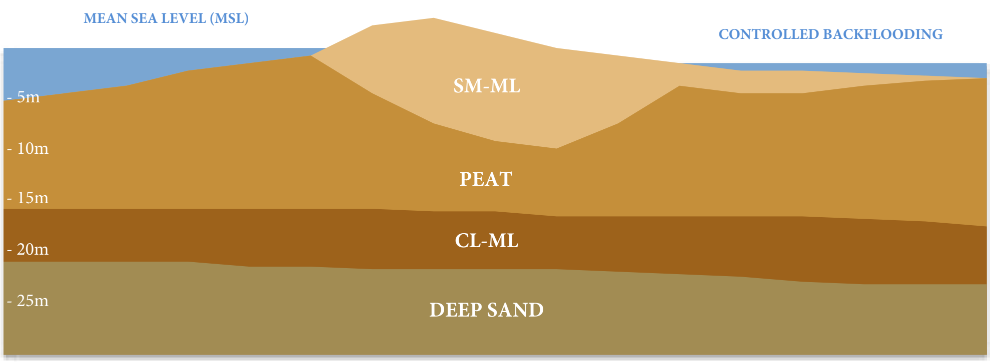


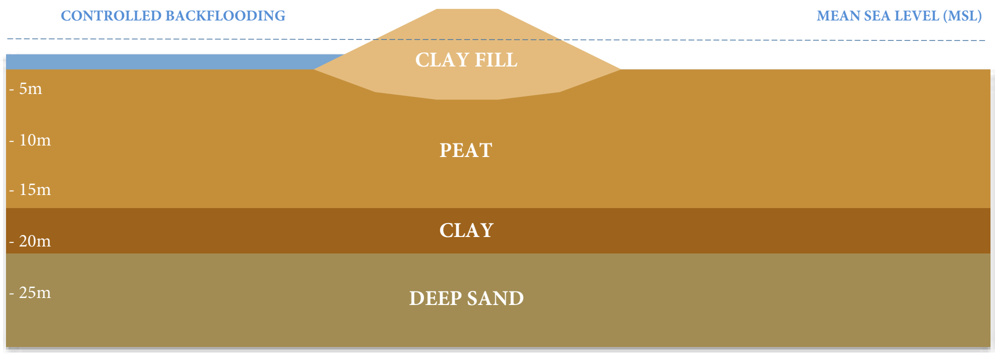
Figure 6: *General Soil Profile for Existing Levees with Proposed Backflooding*
Source: Jacobs (2012)

Proposed Internal Cutoff

Since the internal cutoff levee will act as a secondary level of protection from island flooding caused by levee failure along the Sacramento and San Joaquin Rivers, it must withstand the principal causes of levee failure. The causes of levee failure include overtopping, surface erosion, internal erosion (piping), and slide within the levee embankment or the foundation soil (USACE, 2000). The internal levee must maintain at least a factor of safety of 1.4 even during high water events to protect the systems and Sherman Island. Spanning approximately 1,055 m, this levee will be made of compacted clay fill with a unit weight of 1,760 kg/m³ and cohesion of 4,880 kg/m². The levee will have a slope of approximately 3H to 1V, a crown width of 4.9 m, and a height of 2.75 m above Mean Sea Level (MSL), which is approximately 0.45 m above the 100-year flood freeboard elevation (Hanson, 2009;

Seed, 2010). A generalized subsurface soil profile and proposed internal levee design when back flooded to a level of 0.9 m (-1.5 m MSL) is shown below in Figure 7.

The quality of the foundation soils strongly influences the performance of the levee. The most concerning aspect of the foundation soils is the approximately 12 m peat layer that immediately underlies the levee. Peat is an extremely weak and compressible, variable soil that is vulnerable to underseepage, which can lead to piping and levee failure (Seed, 2010). While the common method to prevent the issues caused by peat is to excavate and replace the layer with a more suitable material, this is not economically feasible because of the large size of the peat layer. To counteract these issues, the internal levee needs to be installed in lifts. The peat layer will initially settle one foot for each foot placed. Therefore, the first layer should be installed and allowed to settle for approximately 18 months, and then the second layer can be installed. The presence of a deep sand layer is an additional concern because it has the potential to liquefy during a seismic event. Unfortunately, in the case of a large seismic event the designed system as well as the entire SSJD is susceptible to soil liquefaction. The extent of this layer as well as the seismic vulnerability of the SSJD as a whole yields this potential hazard beyond the scope and control of the project design. However, if this project were multiplied throughout the SSJD, the catastrophic effects of a seismic event on the California water system could be mitigated by the growth of the peat layer from the decomposition of the wetland over time.



Levee Figure 7: General Soil Profile for Proposed Internal Cutoff Levee with Backflooding
Source: Jacobs (2012)

Geotechnical Modeling

Geostudio modeling of seepage and slope stability were conducted to determine the effects of backflooding for the proposed clay fill levee and the existing Sherman Island levees. The profile for the Sherman Island levee was created for the RESIN (Resilient and Sustainable Infrastructure Networks). Project and is based on borings near a previous levee failure containing a large peat layer. Therefore this profile represents a worst case scenario sample. If the engineered system can protect this failure prone area, then the system is suitable for the protection of levees throughout the island. The profile for the proposed internal levee was generated from soil borings and CPT tests collected by Caltrans near the Antioch Bridge. The model was run using the Spencer (1967) method which is the most accurate for the situation with the assumption of no tension crack (Seed, 2010). The 100 and 50 year flood levels for this region are approximately +2.3 m Mean Sea Level (MSL) and +1.7 m MSL. A water level measurement of +0 m MSL indicates water levels are at sea level. A 100 year flood level means that there is a 1% chance each year of this flood level occurring, while a 50 year flood level indicates that there is a 2% chance each year for this flood level to occur. Using these values provides estimates of the factors of safety for the levee.

The factor of safety data produced from the Geostudio modeling of the internal levee at various heights of backflooding illustrated that a back flood height below +1.8 m MSL maintains a factor of safety greater than 1.4. Therefore the maximum backflooding of the

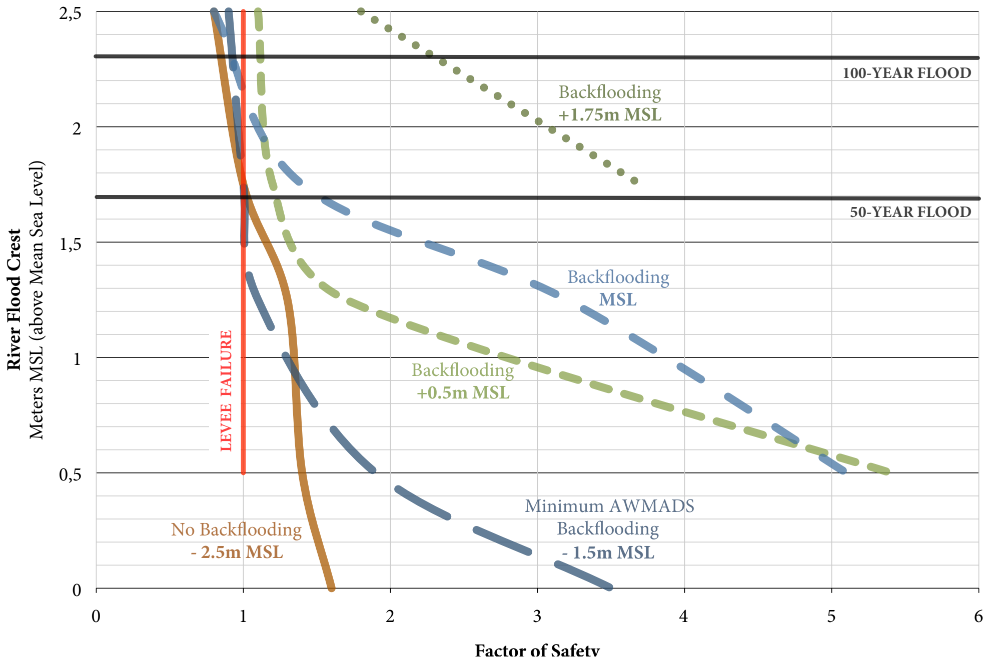


Figure 8: *Levee Factors of Safety for Backflooding vs. River Flood Crest*
Source: Jacobs (2012)

system should be no greater than +1.8 m MSL. Using +1.8 m MSL as a maximum backflooding height, simulations were run for the existing levees to determine the effects that increasing river heights versus increasing backflooding levels has on factors of safety. The data produced is shown in Figure 8.

The results demonstrate that factors of safety increase with increased backflooding and thus significantly higher factors of safety can be achieved by the incorporation of the AWMADS at Sherman Island. In addition, the exit gradient can be decreased and pore pressure equalized to increase overall slope stability. Figure 9 compares the exit gradient for a 100 year level (+2.3 m MSL) under existing conditions to the exit gradient of the minimum AWMADS backflooding level. A reduction of the exit gradient by approximately half is show as a result of backflooding.

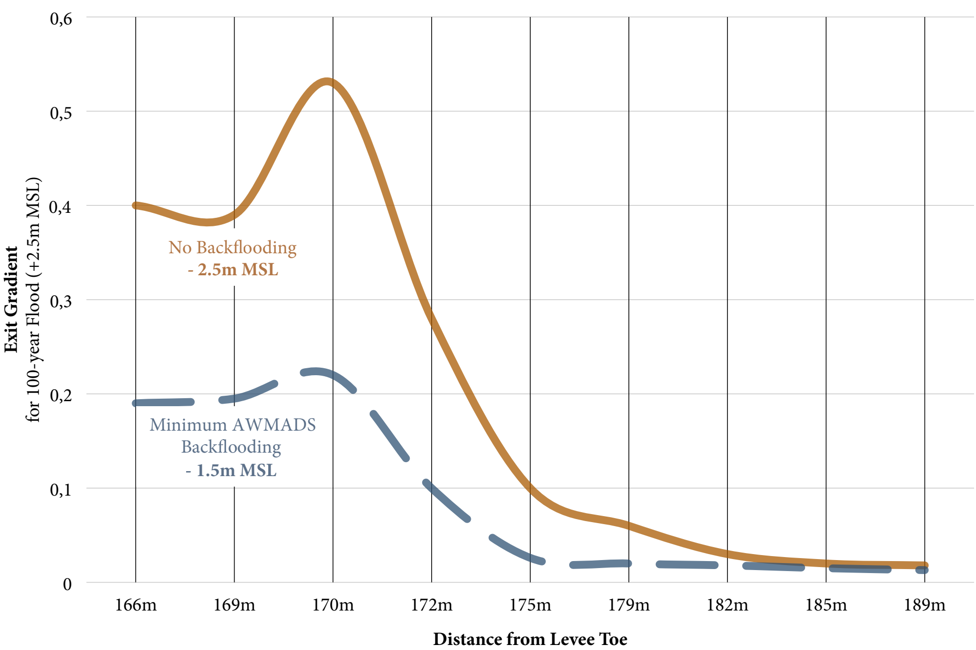


Figure 9: *Exit Gradients for Existing Conditions vs. AWMADS Backflooding*
Source: Jacobs (2012)

This is significant because the driving force for slope failure stems from high exit gradients caused by differential pressures on a levee. These differentials lead to high exit gradients, which result in piping (water flow under the levee). As the pressure builds up on one side of the levee, water is forced towards the backside of the levee, which compounds the already high hydraulic gradient potential of the peat layer. However, the system reduces these concerns by backflooding the levee. As water levels balance on each side, the exit gradient decreases, pore pressures on each side of the levee equalize, and the stability of the levee is increased.

Economic Analysis

While further research and economic analysis are required to estimate the costs of design, construction and operations of the system, the estimates below are given to provide a basis for feasibility and potential economic opportunity of the system. In addition considerations must be made regarding the fiscal impact of not implementing the proposed system and the associated indirect costs and benefits. Therefore, the costs of the no-action alternative are considered as the basis for comparison as summarized in Table 1.

Costs of Proposed System

Foundation

The major costs of site infrastructure are associated with the internal cutoff levee and site access. The cutoff levee will require approximately 336,400 m^3 of fill. At \$19.60/m^3 of fill, the material cost for the levee is approximately \$6.6 millionx (Seed, 2010). For access and egress to the site, revitalization of a section of former Victory Highway is the most affordable option at \$972,000. This estimate is the base cost to construct 0.87 km at \$1.125 million/km (Pazooki, 2010). This value reflects construction equivalent to a one-foot asphalt concrete layer. An alternative route involving revitalization of a larger portion of Victor Highway stretching roughly 3.5 km would cost \$3.9 million.

The cost of wetland development is determined by the scale of the project and quality of the material and labor used. The range for construction is between \$5,000 and \$185,600 per hectare for volunteer or high quality labor respectively (Horne, 2010). A value of \$61,900 per hectare was used to estimate the construction of 283 hectares at approximately \$17-18 million. This estimate was based on the recommendation of Dr. Horne given the scope and quality necessary for such a project.

Aquaponics Option

The material costs for the aquaponics system are based on data from the UVI system and then modified for design-specific needs using cost catalogues from major aquaponics and dock suppliers. The aquaponics subsystems cost between \$30,000 and \$50,000 each, with an average cost of approximately \$38,500. Therefore the total material cost of the 600 aquaponics subsystems is approximately \$23 million. Construction design and labor costs are not included since further design and bidding by licensed aquaponics contractors are needed.

Potential Economic Benefits

Three primary sources of economic revenue are considered to demonstrate the economic feasibility of the AWMADS: the economic value of wetland services, the sale of agricultural goods and fish. The production guidelines and benefits for these sources are discussed below.

Foundation

The Foundation offers the direct and indirect economic benefits associated with the ecosystem services of the constructed wetland within the Flood Storage Zone. Wetlands can provide gas disturbance, water regulation, water supply, waste treatment, habitat, food production, raw materials, recreation, and cultural ecosystem services (Costanza, 1997). An economic evaluation of these services is presented in Figure 10. Therefore the economic benefit associated with the wetland component of the AWMADS could be between $4,300 and $4.42 million per year depending on the extent to which these services are considered.

Aquaponics Option

Income generated by agricultural yields is controlled by the type of crop grown and the frequency of harvesting cycles. The advantage of hydroponics over terrestrial agriculture is that it allows for more diverse crop production. A large variety of vegetables, herbs, and floriculture are proven to be compatible with hydroponic systems (Rakocy, 2006; Hydroponics-at-Home, 2010). Combinations of these candidates could be used to take advantage of seasonal cycles. This system provides a competitive opportunity to produce crops that are unique to the area and specific to a niche market. Demonstrating the feasibility of the hydroponic component of aquaponics, an estimated 5,000 kg of crop per system can be produced each year (Rakocy, 2006). Production values are extrapolated from price indices for crops typically used in hydroponic production. Thus the system can produce a range of income from $1,100 per year growing onions to $88,000 per year growing cilantro. By taking the average across possible crop yield, each year of production will generate roughly $25,000 to $30,000 in revenue per subsystem, resulting in the potential of approximately $17 million gross income over a two-year time period. Further economic analysis will be necessary to determine whether the market can support sales at these production levels.

The Aquaculture component has the potential to produce fish species for several purposes including conservation, fishing or live market sale. In general, systems should utilize local fish species to ensure that an unintentional release into the local environment will not damage the ecosystem. The incorporation of fish rearing for release into the environment is a unique possibility to aid in reviving the floundering populations of fish in the SSJD. While rearing of the endangered species like the delta smelt is a potential, the economic analysis is based on a sellable production of another local species, the sturgeon. Since sturgeon is already present in the SSJD, unintentional release into the San Joaquin River would not jeopardize the SSJD's fragile ecosystems.

The economic yields produced from the aquaculture are based on price indices developed from data on rearing 5, 10, and 15 brood stocks of sturgeon (Logan, 1995). To produce the maximum yields and a more continuous harvesting cycle, production should be staggered. With the 600 subsystems, there is theoretically enough capacity for fifteen brood stocks and their offspring. At about 18 months of age, sturgeon is profitable to sell on the live market. Therefore, the system has an expected yield of approximately 215,000 fish for sale within 18 months of its inception.

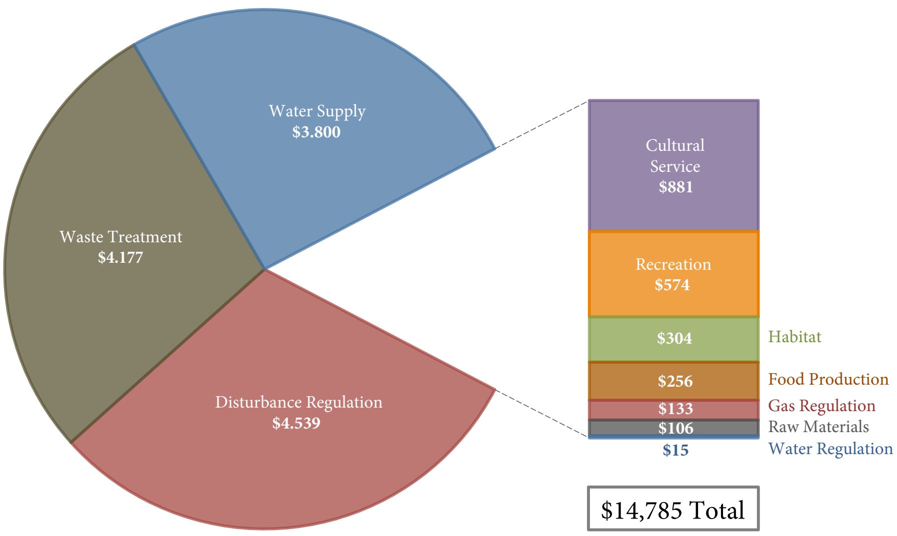


Figure 10: Economic Evaluation of Annual Wetland Ecosystem Services per Hectare
Source: Jacobs (2012)

Sturgeon is approximately $2.05/kg; using this price and an 18 month average harvest maturity, the system could produce approximately $17 million over a two year period.

Additional Optional Economic Sources

Other sources of income include development of an educational and tourist eco-energy park which could include methane capture, wind and solar energy production and the potential for floating structures for recreational or residential use. Further feasibility studies will need to be conducted for these options.

Environmental Analysis

The AWMADS design incorporates many potential environmental benefits; however it is important to look at any proposed solution with the understanding that it will create side effects. This leads to an examination and evaluation of the environmental tradeoffs of the design. The potential benefits, concerns and mitigation strategies are discussed below for the wetlands, hydroponics, aquaculture, and energy requirements.

Wetlands

The potential environmental benefits of the constructed wetlands include carbon sequestration (the capture of atmospheric CO_2 by plants through photosynthesis), subsidence reversal, and renewal of habit. A Bulrush wetland can grow approximately 500 g C/m^2 per year, half of which is preserved. As plants decay, their absorbed CO_2 is incorporated into the soil biomass. A wetland can sequester as much as 62 metric tons of CO_2 per hectare per year. This helps to reduce carbon in the atmosphere while rebuilding the soil biomass (Horne, 2010).

The AWMADS can also actively stop and reverse subsidence. By flooding the land surface inside the system, the peat layer--which would otherwise continue to oxidize and erode away--is preserved because it is wet. As the plant biomass from the wetland decomposes, it increases the peat layer and therefore reverses subsidence. Wetland vegetation and non-sellable crop yields from the hydroponics system can also be used to restore peat. At Twitchell Island Ponds, a project currently on Sherman Island, subsidence of 4.1 cm/year has been prevented and a peat layer of 2.54 cm/year has accumulated. Additionally, sediment can accumulate in the system by transport and settlement during and after flooding events (URS Blue Ribbon Task Force, 2007).

In addition, the wetland restores natural habitats for birds and aquatic species, thus sustaining future bio-diversity of wetland species. Many fish and reptile species would take advantage of this wetland ecosystem, including carp, crappie, striped bass, white catfish, and pond turtles along with hundreds of different bird species including the mallard duck, red-tailed hawk, eagle, Canadian goose, cinnamon teal, ring-necked pheasant, ruddy duck, wood duck and many more.

The proposed wetlands could also pose some potential environmental concerns. While wetlands sequester carbon and hence reduce carbon dioxide, they also release other green house gases (GHGs), primarily methane (CH4) and nitrous oxide (N2O) due to biomass decomposition. These emissions should not be compared to zero emission but rather to the emissions of the livestock production that currently exists on Sherman Island. Approximately 100 to 500 liters of methane is produced per cow per day which is far more than what is produced by plant decomposition in a wetland (Silverman, 2010). Furthermore, the methane and nitrous oxide produced by the decay of plant materials does not create a net increase in GHG emissions as the continued growth of the wetlands will reincorporate such compounds into the plant materials.

Leaching and transport of toxins from the soil into the surrounding environment could also threaten the surrounding environment. The soil at Sherman Island has been exposed to pesticides, fertilizers, and dredged soils containing heavy metals. Partial flooding of the Flood Storage Zone could cause toxins to leach from the soil (Horne, 2010). However, many of the contaminants of potential concern such as the heavy metals including copper, zinc, and nickel can be immobilized in wet peat soils. Organic compounds will bind to wet peat and once the wetlands have been established the plants can remove toxins from the water. Finally, because the Flood Storage Zone will contain a large volume of water, the toxins will be diluted. Test flood plots should be used to gather data for further assessment and monitoring throughout the life of the project.

Hydroponics
Current methods of terrestrial agriculture require large amounts of water, petrochemical fertilizers and pesticides, the majority of which are not absorbed by plants but leave the land via groundwater runoff. Water contamination and waste is reduced by the hydroponics system since nutrients and water are recycled back into the system through closed loop water recirculation. This separation of the system from the surrounding environment reduces water waste due to runoff and agricultural pollution when compared to terrestrial agriculture.

Aquaculture
Aquaculture has the potential to be environmentally detrimental or beneficial depending on the design and management of the system. Aquaculture can potentially reduce the pressure placed on aquatic environments caused by overfishing. Conversely, if aquaculture is managed with disregard to carrying capacities the practice can be quite unsustainable and detrimental to the environment. There are tradeoffs in the design and management practices that need to be considered. Overcrowding reduces fish health and leads to spread of disease. Antibiotics are thus heavily used, which can potentially be passed up the food chain to result in treatment-resistant bacterial infections. To prevent this, fish rearing densities can be reduced to a sustainable level and systems can be placed in parallel to prevent cross contamination. Another potential issue lies in using fish from a lower trophic level to feed the fish that are being reared. This creates no net benefit in reducing pressure on fisheries. In fact, when feeding in this way, each trophic level receives less energy than the level before it and thus requires more fish in the rearing than produced as a result. To mitigate this issue, worms can be sourced onsite by incorporating composting of wastes and then harvesting the worms for fish food.

Energy Requirements
Energy requirements of the system will contribute to carbon emissions if the energy is sourced from now-renewable fossil fuels. Currently, there are wind power turbines in the nearby county of Rio Vista that could provide a source of electricity for the system. Windmills could also be implemented onsite as a localized mechanism for aeration and water transport throughout the system. Windmills connected to water pumps would be an effective way to pump water out of the Flood Storage Zone after high water events instead of using fossil fuel powered pumps. Furthermore, it may be feasible to install floating solar arrays as another renewable power source. These installations could provide electricity to the system and potentially offset non-renewable electricity on the grid.

Decommissioning
The fate of California is dependent on the vast expanse of waterways, agriculture, and habitat that the SSJD provides. Therefore, approaching the SSJD with the goals of sustainability is the key to preserving such a great resource for future generations of Californians. It is crucial to understand that sustainability is not a static condition but rather a dynamic equilibrium that should be allowed to ebb and flow to meet the needs of species today and many generations from today. With this in mind, the long term vision for this project is that it will act as a stepping stone to allow the SSJD to return to a natural estuarine state that can support both the needs of the environment and people.

The foundation of the AWMADS is to rebuild subsided islands, thus serving the long term goals for improving ecological health, water quality, water supply reliability, and levee system integrity (NHI, 2002). The nature of AWMADS on Sherman Island offers great potential for full restoration of marshland when system components reach the end of their usefulness or economic viability. The AWMADS can act as an integral link between the issues faced today and achieving the long-term sustainability of the SSJD. Over the system's useful life, its sustainability will be subjected to market fluctuations, changing environmental conditions, natural disaster and evolving social values. Therefore, the system's ability to adapt is critical. As such, this system has dynamic capabilities built-in such that the foundation of the project may remain relatively unchanged while the system as a whole may adapt and be recycled to meet multiple needs over time.

Further Development and Conclusion

While this study lays the framework for the conceptual design for the AWMADS, substantial work still remains to make this solution a reality. To advance this project, the following aspects of the project must be developed further before installation can occur: business model, feasibility studies for optional components, design documents, legal development, pilot studies, and partnership development. Further economic analysis with a business model will be necessary, including research into the market capabilities of various crops and fish, as well as the fiscal value of wetland swapping, carbon credits, and the quantification of intangible benefits and disaster cost avoidance. Additionally, continued feasibility studies need to be developed for various optional components including floating structures, energy production, aquaponics for conservation, niche agricultural markets. Design documents needed to be developed for the foundation of the project including the design of the internal cutoff levee, Mayberry slough, and the wetland component. Further design and testing of levee stability must be completed, including collection of more substantial data for the levees surrounding Mayberry Slough. Environmental Impact Reports, water and land use agreements, mitigation studies, and Environmental Protection Agency (EPA) submission and review will be required as part of the legal development of this project. Piloting of various components will be necessary to identify the benefits and concerns of the various system components. These pilot studies can be undertaken by initiating joint ventures or partnering with existing pilot research on individual components. The development of project partnerships will be necessary for the procurement of funding and research expertise for the advancement of further feasibility and pilot studies, design and construction documents, protocols and procedures for operations and maintenance, and system implementation.

This paper serves to advance the design and feasibility of a system synthesizing the technologies of aquaponics, wetland restoration, and water management at Sherman Island to provide future resilience and sustainability. The proposed AWMADS provides protection against levee instability, bolsters a sagging agricultural economy, and restores fragile SSJD ecosystems. It is a concept that works to improve all aspects of life on Sherman Island, from economic to environmental, while also taking into account the needs and concerns of the public, government, and industry. By using Sherman Island as an initial demonstration site and adding further innovative design, this solution may be applicable to much of the SSJD and deltas throughout the globe.

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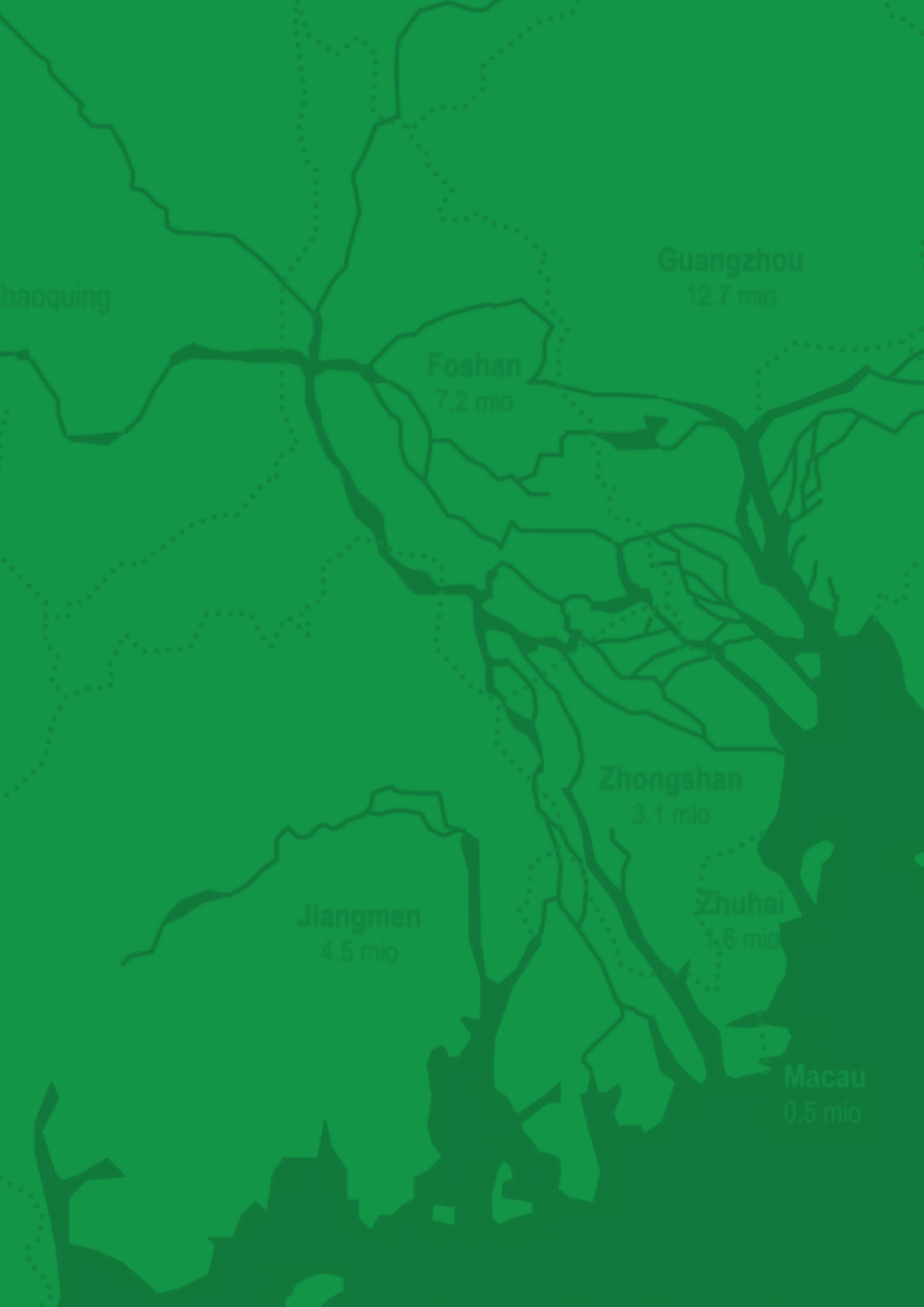

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Macau
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B

(re)Generation Delta

Landscape strategy for a sustainably managed Pearl River Delta

Federico Curiél[1]

Abstract

The project presents a multi-layered strategy for a sustainable management of the Pearl River Delta (PRD). Re-Generation Delta proposes a large scale micro-algae harvesting system, converting the farmland located by the coastline of the PRD into large scale open-air harvesting-ponds. The newly established infrastructure will be realized to function as a physical barrier preventing eventual water flooding.

After analyzing the political conditions, global and local issues, and foreseeing future needs and potentials of the metropolitan area of the PRD, the paper will explain how a single landscape strategy could be a solution to several glocal matters, exploiting the artificiality of the existing rural landscape and the specific conditions and needs of the different metropolitan clusters of the region.

All the energy is produced by micro-algae harvested on a large regional scale, processing into bio-fuel the CO_2 captured and collected from local polluting sources, releasing oxygen to the atmosphere and providing biological resources to different activities and spheres of production.

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This kind of intervention is preserving the pre-existence while generating new landscape scenarios. At the same time the new program and functions will enrich the existing conditions and allow various experiences on site: a productive landscape park, producing benefits on various layers and on different scales.

Artificiality, pre-existence and specific features of the territory determine the creation of a new landscape type, which satisfies both the economical (productivity) and ecological (sustainability) needs of a complex and expanding Delta Region inhabited by more than 60 millions people, while facing an emergency such as sea level rise, preventing the worst consequences.

In this proposed strategy, sustainability is not just a layer added to the design afterwards but the starting point from which the optimal transformation of the landscape is generated.

Geography of the Pearl River Delta regions

The Pearl River Delta region is one of the largest growing and fastest developing delta areas in the world, embracing a population of approximately 60 million inhabitants. With such conditions, an evident high level of urban density and pollution is deeply affecting the metropolitan areas of the whole river delta, its ecology and its natural dynamics.

Not only the intense development is endangering the region, but also the different policies adopted by the different municipalities of the Delta play a key role in different aspects. Above all it should be considered that the Hong Kong and Macau regions are not directly

Figure 1: *Border between Shenzhen and Hong Kong.*
Source: Google Earth, 2011

Figure 2: *Waterscape and different regions in the Guangdong province*
Source: author's elaboration, 2012

following goals by the Chinese government, therefore the priorities of the management of the territory are following goals in different ways, almost at their opposite extremes.

In the overall metropolitan area we can find very different situations, with their own specific features in matter of business development typologies, demographics, flows and urbanization plans. Hong Kong is a metropolitan cluster that can be considered a green buffer thanks to the New Territories and the agricultural and breeding activities still ongoing here, while Shenzhen is the fastest growing urbanised cluster. Guangzhou and Dongguang can be labelled as the major sources of pollution due to the large amount of productive activities settled in the area. Jiangmen is strongly characterised by the presence of heavy industrial settlements, and therefore the main cause of water pollution of the Delta, together with Huizhou, as it is a cluster with the largest petrol-chemical activities. Macau enjoys a special status thanks to its different governance and, as Hong Kong, it is not ranging policies of expansion. As these two cities are both relatively developed to their most, their citizens are more aware of having healthy living styles, and they give higher consideration and value to have more green spaces in the periphery of the city for leisure purposes, and they are more aware of ecological policies and sustainable behaviours.

The clearest example of such a dichotomy of different local policies is the "frontier closed area" (see image) in the New Territories between Shenzhen and Hong Kong: 2800 hectares of peripheral rural landscape that have been strongly transformed in the past 30 years, and used ever since the post-WorldWar period as a border control zone between the two cities. In this area, on the Hong Kong side, no development has been allowed in the past 50 years, until Hong Kong became part of Chinese jurisdiction in 1997. After then a large infrastructure installation, as highway and railway connections, has been constructed in the area. On the other side, the fast urbanization of Shenzhen, which turned from being a fishermen village of only 30.000 people in the 70's into a mega-city of over 8 millions inhabitants in only 30 years, has been expanding until the very edge of the border with Hong Kong. The result is that one of the most densely built areas of the region is facing the largest landscape ecology of the very same area, with unique ecological and cultural settings struggling to be preserved. Green space is considered very valuable in Hong Kong policies, while in Chinese policies is rather a condition to be exploited for further urban expansions and developments.

With such a melting pot of different governance and policies carried out by the various entities (cities and a lot of political actors) gravitating around the very same Pearl River Delta, it is hard to imagine a collaboration between the different institutions on such a large scale for a program of maintenance and safeguard of the Delta environment. Especially in a booming and fast growing region as the Guangdong, it would not be realistic to imagine the preservation of the natural ecology as one of the prior points in the agenda, if not through a cross-over action satisfying at once different issues for several realities in the various cities of the PRD simultaneously.

This paper will show how a specific landscape strategy could be a solution to the environmental urgencies in question, global and local ones, like CO_2 reduction and increasing flooding problems, and satisfying the needs of an expanding metropolitan area as the PRD, providing new business opportunities, supporting the local activities, and creating the possibility of producing energy on a large scale (bio-mass and bio-fuel) and by-products for a smaller scale market and for local activities.

Global Issues and Local Problems taken into a Glocal solution

The Pearl River Delta is an endangered environment under different aspects, not only due to local circumstances but also because of global issues threatening most of the deltas and coastal regions around the world.

This paper will not carry out in detail all the problems affecting our planet, but will mention the emergencies related in the specific to the strategy proposed here, and to be taken into account while reading it.

Globally, the fast increase in population, especially in countries such as China, India and Brazil, are exponentially increasing the energy demand and consequently their production of CO_2, due mainly to industries and vehicular emissions. It has already been proven that one of the main consequences of an increase in CO_2 concentration in the atmosphere is causing the phenomenon we all know as Global Warming, which directly affects the climate of our planet provoking temperature rise. Due to this, as one of the final consequences, a general raise of sea levels occurs faster. This issue is endangering all delta areas and coastal lines of the globe.

Locally, the rapid economic development and urbanization taking place in the PRD, is rapidly increasing the risks and the potential consequences of flooding in the region. This is mainly due to the intense urbanization causing land subsidence, the disruption of the local waterscape mutating the natural water flows, and a lack of the increasing investments needed for preventive actions.

Figure 3: Studies on the sea level rise
Source: Hong Kong University of Science and Technology, 2006

According to a report by the Civic Exchange and a group of researchers from the University of Leeds, the sea levels in this area might raise for a minimum of 20 centimetres by 2050: this would mean that more than 2000 km in the PRD coastal area and a large part of the Delta plain will be vulnerable to tidal inundation, and over a million people risks to be relocated to higher areas.

On the Hong Kong side, a lot of monitoring and research is taking place , but not much action has been taken so far by the other regions of Guangdong province. In order to properly tackle this problem, a regional strategy needs to be formulated by all the parties involved at the same time. As it often happens in this cases, not all the parties share the same risks and therefore neither the same interests.

The heavy and fast urbanization of the PRD is also harming other aspects of the local environment, such as the presence and the continuity of natural areas and green corridors, the pollution of the water, and the consequent alteration of the habitat of different animal species.

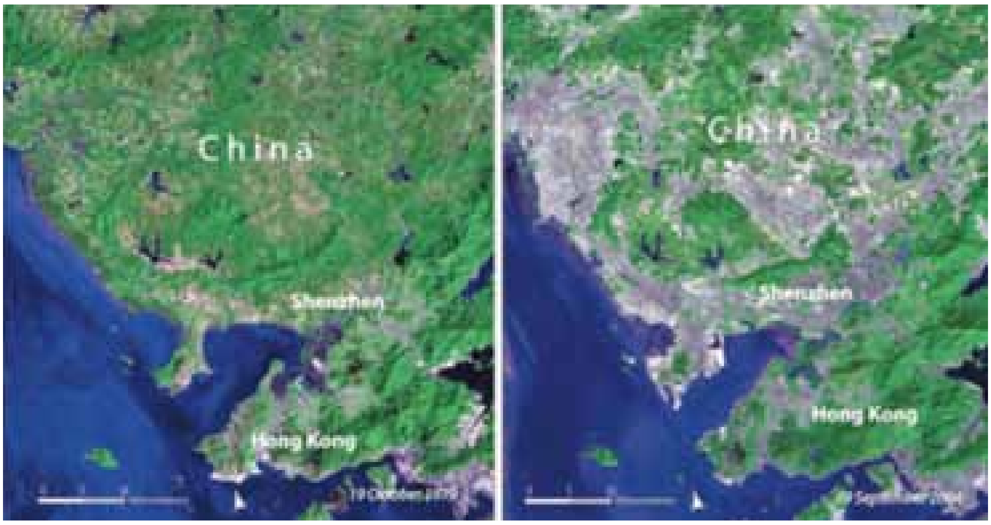


Figure 4: Urbanization in the PRD, 1979-2004
Source: Hong Kong University of Science and Technology, 2006

The rural areas finding themselves now in the peripheral area of such metropolitan cities, are considered a very important piece of land to be exploited in ways far more proficient than agriculture , fish culture or breeding, and therefore these areas, rich of rural history and culture, are faster and more often disappearing taken over by the urban sprawl. Even regarding such management of the territory, different policies can be found in the nearby, yet different, cities of the region.

We could split general thoughts into two main points of view, expressing two radically opposite positions. The first one, more practical, sees in these rural areas a perfect occasion to exploit the land and to provide urban expansion, considering the real estate value of such surfaces. The second position tends to keep their existence in their matter of facts, with their rural activities, reckoning it as a typical landscape and as one of the few cultural and historical heritage surviving in such a young and booming reality, and therefore something to be preserved, even though those territories are often not accessible to the most and nor particularly attractive.

It seems that no solution could satisfy both points of view, and if we analyze the area of the New Territories, where there has been a preservation of the landscape in the last 50 years,

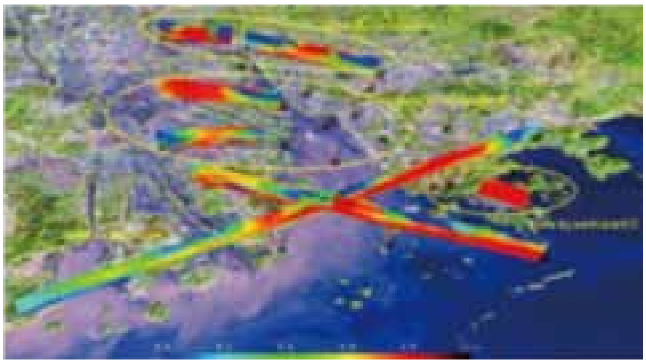
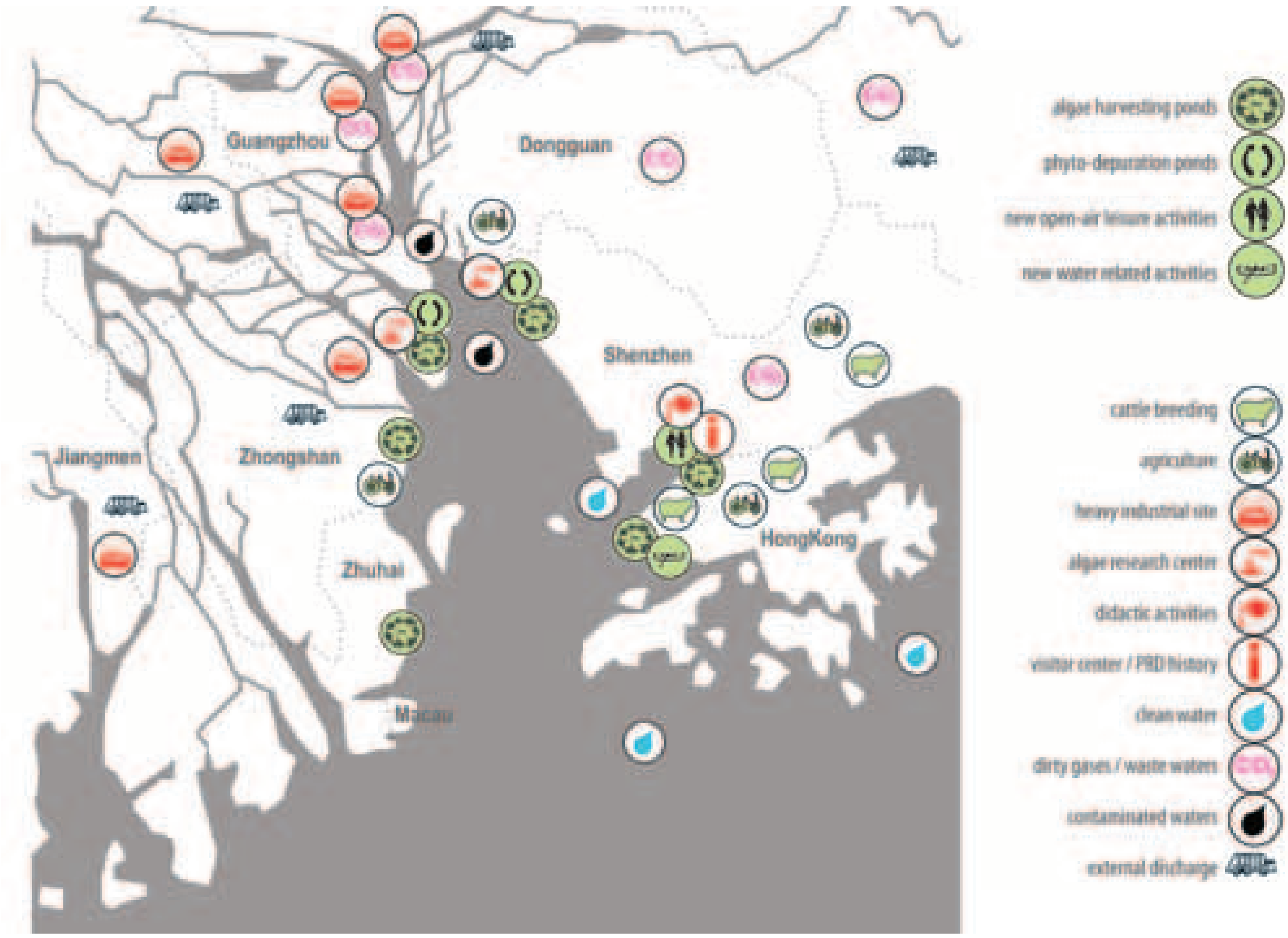


Figure 5: Air pollution simulation and analysis
Source: prof. Lin Hui, Inst. Of Space and Earth Information Service, the Chinese University of Hong Kong).

we realize that this is the result of priorities in the agenda far away from the ecological interest: the necessity of a backed-off border control area made the landscape to be kept green and non-urbanized despite of the loss of economical significance of the farms.

Re-Generation Delta deals with these issues, easing or partially solving them on a GLOCAL level, creating and inserting new flows of energy and activities in the dynamics of this metropolitan area.

Figure 6: Flows of specific interest and interactions on regional scale
Source: author's elaboration, 2012



The Site and the Land

Studying the Pearl River Delta along its coastline, some specific plots of land with the optimal characteristics and circumstances have been individuated and proposed for being regenerated into harvesting ponds. These areas were agricultural fields or fishing ponds before these cities would reach their status of "mega-city".

These areas are surviving nowadays with big efforts, without granting any specific attractions, remaining in their state of boring and unproductive reality (considering the ratio of production per square meter). Ground and water pollution play a critical role to the effectiveness of cultivating such plots of lands. Nevertheless rice or fish farming would be more effective in even larger areas set more back in the hinterland, with less risks of being overflown, and far away from polluting agents and urban areas.

The rural zones in question, individuated for an intervention, are the following:

- the "polder" fields, the former fish farm ponds and rice cultures on the border between Shenzhen (Futian) and Hong Kong (New Territories);
- the several left over areas in Shenzhen part of the Special Economic Zone (SEZ) in Futian district;
- the (formerly) cultivated island in Fuzhou/Nanshang, turning nowadays into an Industrial district;
- the small archipelago and scattered coastline in between Macau and Zhongshan.

Particular attention has been paid to the rural area in between Shenzhen and Hong Kong and it has been chosen as the main study case for this proposal.

This land nowadays is in a limbo between the progression of a city in expansion as Shenzhen on one side, and the strong will to preserve it from further construction on the Hong Kong side. The ponds and the plots in this area, on the edge of the city, are subject to different policies; they are even partly comprehended in the Special Economic Zone (SEZ), and could play a potential key role as a green bridge between the two cities.

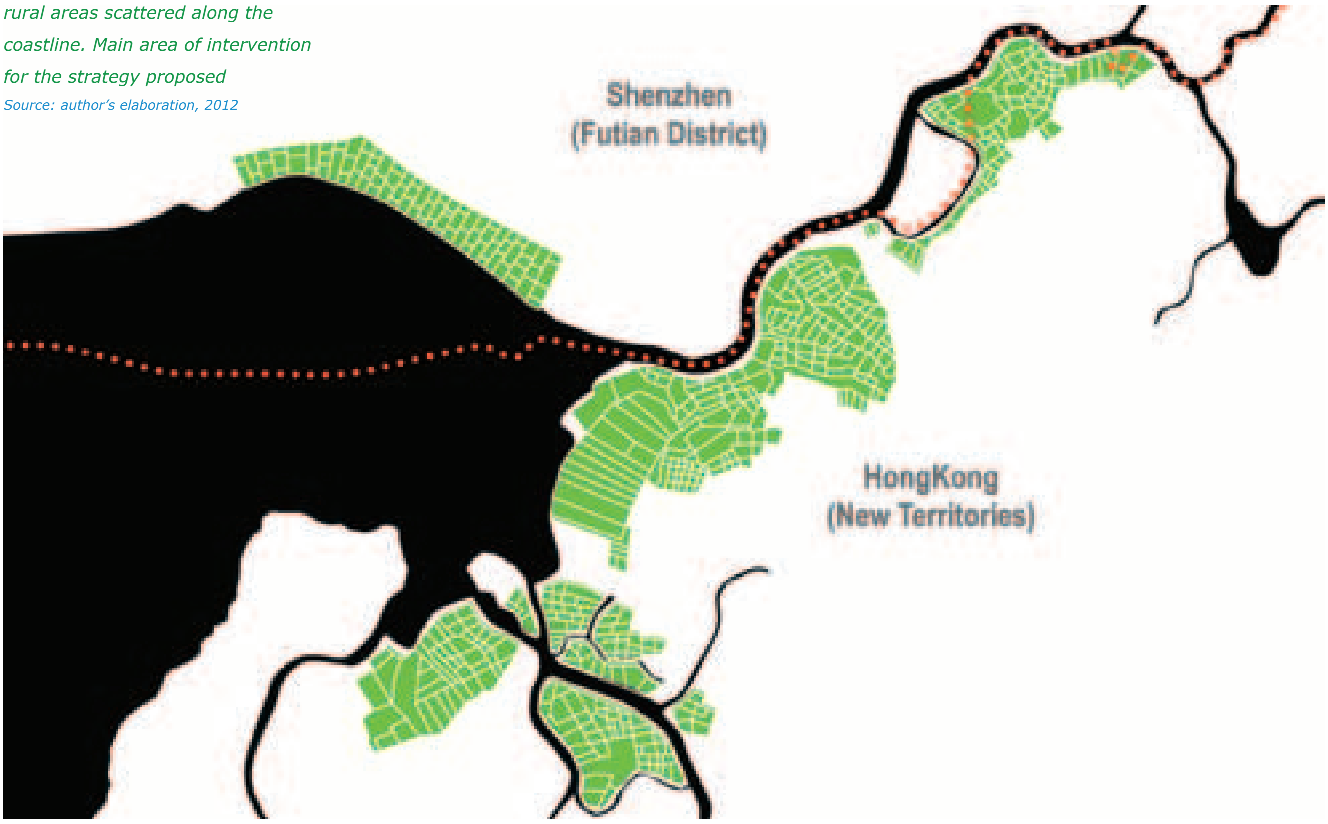
Figure 7: *Areas of intervention individuated among the still existing rural and pond areas*

Source: author's elaboration, 2012

These typologies of landscape are very iconic as well, thanks to the system of ponds, ditches and paths that are drawing an anthropic pattern on the territory, very easily recognizable.

The site chosen has an extraordinary opportunity for questioning the complexity, fragility and prospects for a new sustainable development and management of the PRD, contributing to a more global issue of CO_2 storage and reductions, promoting actions against some of the causes of global warming on the long run, while providing at the same time an infrastructure for the safeguard of the Delta (against flooding) and creating a productive landscape (biofuel and biomass production out of algae) for the benefit of the whole region.

Figure 8: On of the (still) existing rural areas scattered along the coastline. Main area of intervention for the strategy proposed
Source: author's elaboration, 2012



Algae Technology: Biofuel from Micro-Algae

Harvesting micro-algae has been proven to be the most efficient way of producing biofuel and biomass nowadays: not only the production is on average at least eight times bigger but even faster, in facts the whole process, from graft to collection and squeezing, lasts only three days.

Micro-algae grow faster and reproduce themselves only by processing the sunlight (or appropriate lighting systems for overnight production) and absorbing the CO_2, releasing oxygen in the atmosphere as a result of the photosynthesis. This process has obvious positive consequences on the surrounding environment, interacting friendly with it and its fauna and preserving their natural condition.

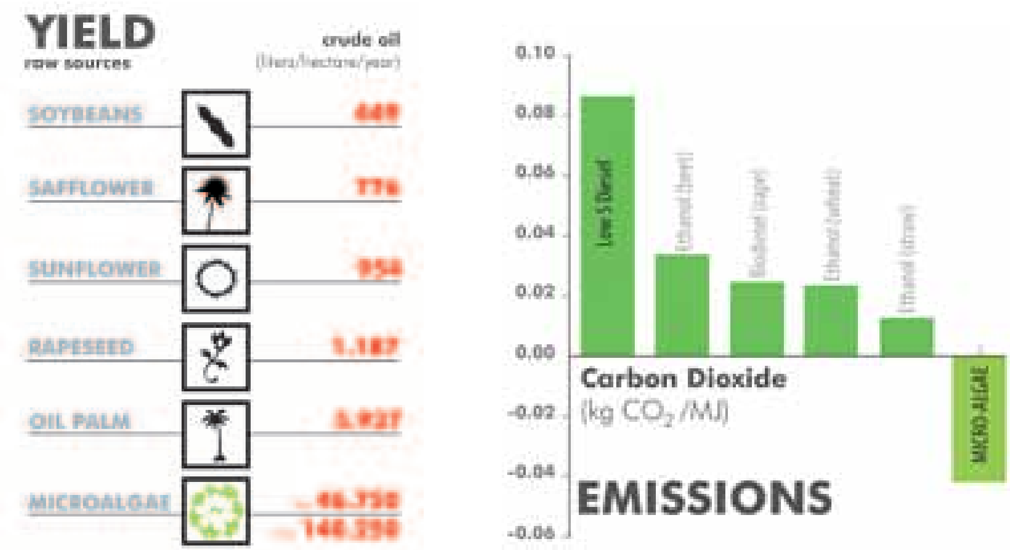


Figure 9-10: Studies about the efficiency of micro algae and the biofuel produced out of it
Source: research by University of New Hampshire, 2006

Scraps and waste from the production are raw materials rich of proteins that can be recycled directly by the rural activities in the farm lands (as cattle feed and fertilizers) or turned into a various amount of by-products, and promoting therefore the establishment of new potential activities or enriching the existing ones with the provision of ecological raw sources.

If we consider the intervention proposed here as a strategy on a broader scale, we can see in the whole PRD a great potential; all the delta areas, from Zhuhai through Guangzhou, via Shenzhen, until the New Territories, could adopt such transformation, creating a large scale metropolitan green system, ensuring not only enough outcome of resources for the productive activities of the metropolitan area, but the preservation of certain ecologies, nevertheless creating new landscapes and a better quality of water, air, and life.

The Multi-layered Strategy of Sustainable Management

Re-Generation Delta aims to create sustainable solutions on different levels: in the energy demand, in the preservation of the environment, in preventing flooding, in cleansing water and air, and creating new activities. All the energy and by-products are produced by micro-algae recycling CO_2 and pollutants, and the whole Pearl River Delta ecosystem, environment and activities will benefit from it.
Considering the farmlands and the fish ponds as artificial landscapes as well as natural machines, some specific features are found as redundant in this territory, usually differing just in matter of sizes. Thanks to the repetition of such landscape elements (as ditches, dikes and canals), a general strategy of transformation can be easily applied, exploiting both the existing water system and the landscape structure.

The large size of the ponds are optimal for being turned into harvesting ponds, because what is important is the actual surface exposed to the sunlight rather than the volume of water available.

Filling up the ponds with water could be easy since water is already organized within a defined system, with direct connections in and out the fresh water from either the rivers or the sea. Due to the existing texture drawn by the system of canals and its organization, the construction of the new ditches and canalizations will be much less expensive than it would be anywhere else.

Figure 11: Simulation of the new algae ponds landscape applied in one of the intervention areas (border between Shenzhen and Hong Kong)

Source: author's elaboration, 2012

General positive effects:

- preventing the disruption of certain coastal areas and the natural dynamics endangered if these were overtaken by urban sprawl instead;
- prevent, manage and exploit the pollution affecting the PRD;
- provision of clean water and biological fertilizers for the surrounding agricultural activities;
- creation of a climate-proof infrastructure working as ditches to prevent flooding;
- mitigate the loss of biodiversity and the exaggerated urbanization (causing land subsidence), leaving the areas as non-constructed, turning them into productive landscape and leisure scientific parks;
- an integrated strategy to implement the governance of the Delta beyond political borders.

Taking advantage of the all the CO_2 emissions available in the PRD (derived from industries and productive sites), would ensure a continuous supply of CO_2 to be processed by the new system. The infrastructural ditches will be able to host a system of tubes directly linked to some CO_2 storage silos, where the emissions from local emitters will be conveyed and from where it would be pumped into stream to reach the algae ponds. Such CO_2 storage and distribution system is inspired by the CO_2 Storage Network realized in The Netherlands and in Belgium, already active and properly working. This system is partly releasing CO_2 directly inside a series of greenhouses spread in the territory, while the rest is stored underground or under the sea into former petrol extraction sites. In this case such a system would be much more effective because the capacity of absorption of algae in much higher than the one of any other plant.

At this point, the proposed system would produce biofuel reusing the polluted emissions and release oxygen in the atmosphere. It is possible in this way to turn a Problem (greenhouse gases) into a Solution (biofuel from algae). Beside the biofuel, all the outcome of such process would consist of cleaned discharge waters, oxygen release in the atmosphere, and various by-products (fertilizers, cattle food and raw scraps to possibly produce plastic, textiles, soaps and other products with). At the same time, the realization of such an intervention, would provide proper ditches to the ponds, that could work as dikes to prevent future flooding according to the worst provision of water level rise.

In these optics, such an investment would contain the urban sprawl, while ensuring a pay back to any investor, in term of money, energy, and safeguard of the inhabited areas along the coastal line.

Re-Generation Delta not only favours new activities but enhances and supports the existing ones such as agriculture, animal breeding, natural bird reservoir, and the safeguard of the water habitat.
This strategy, if applied, would preserve the asset, the proportion and the general aspects of the existing typical landscape, turning a traditional image into an innovative reality, which would be at this point even productive and attractive. This situation satisfies both the economic needs as well as the ecological ones, both the potential investors as well as the naturalists and anyone fighting for preserving the land, its meaning and its value as open and wide portion of land to be kept as such.

Re-Generation Delta speaks of transformation and renewal: a positive addition without distorting things, allowing a gradual settlement of the new infrastructure, without upsetting the existing activities, but replacing them softly. The new "infrastructural establishment" proposed could be defined as a technological landscape, a biological machine that employs the same micro-organisms that colonized this land once it was still part of the sea. Neither architecture nor landscape in the traditional sense: a surrealistic atmosphere and context while producing a self-sustaining ecology of glocal utility covering the different sites scattered around the whole coastal lines of the Pearl River Delta.

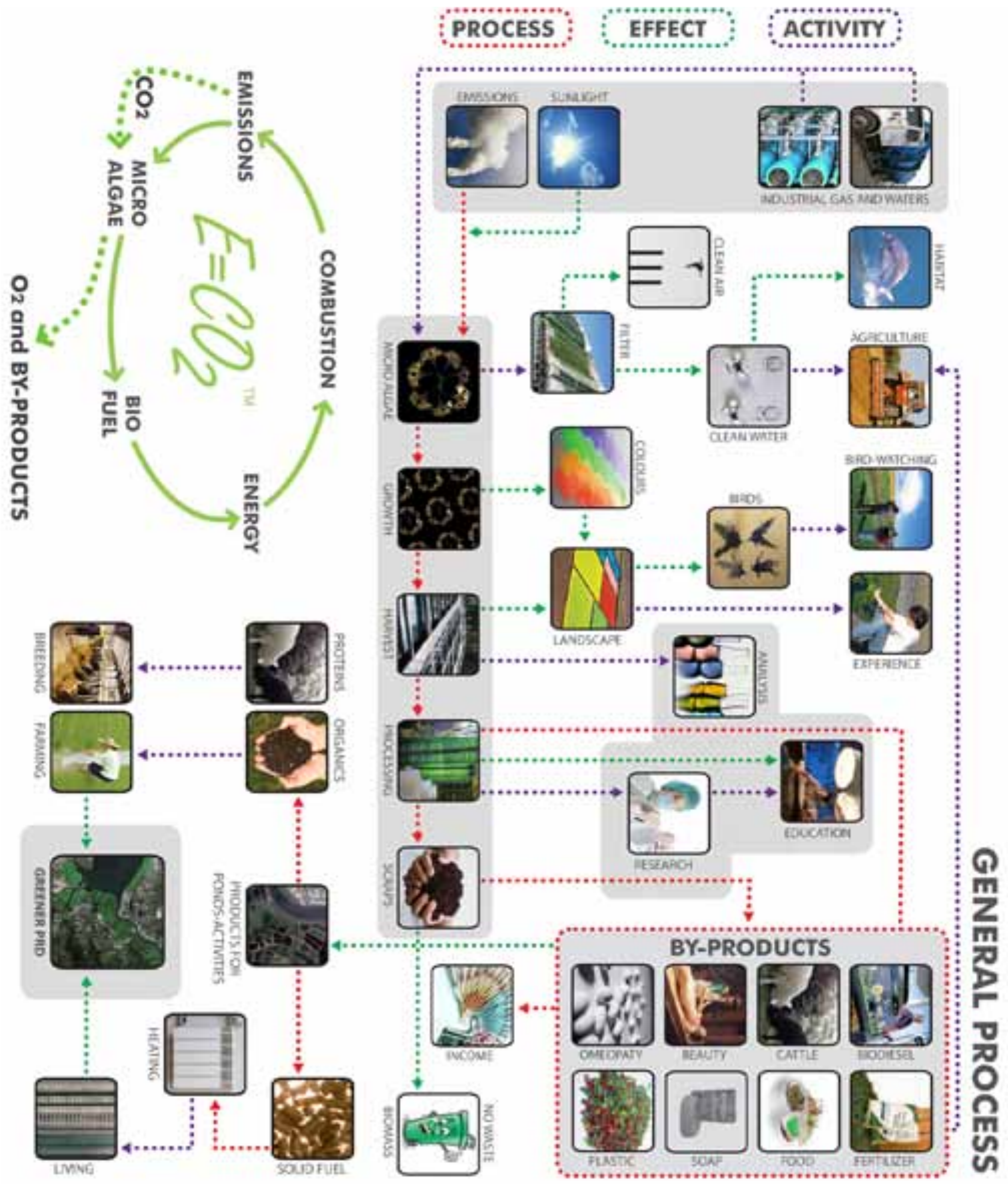


Figure 12: Energy and resources flow of the new proposed system
(Source: author's elaboration, 2012

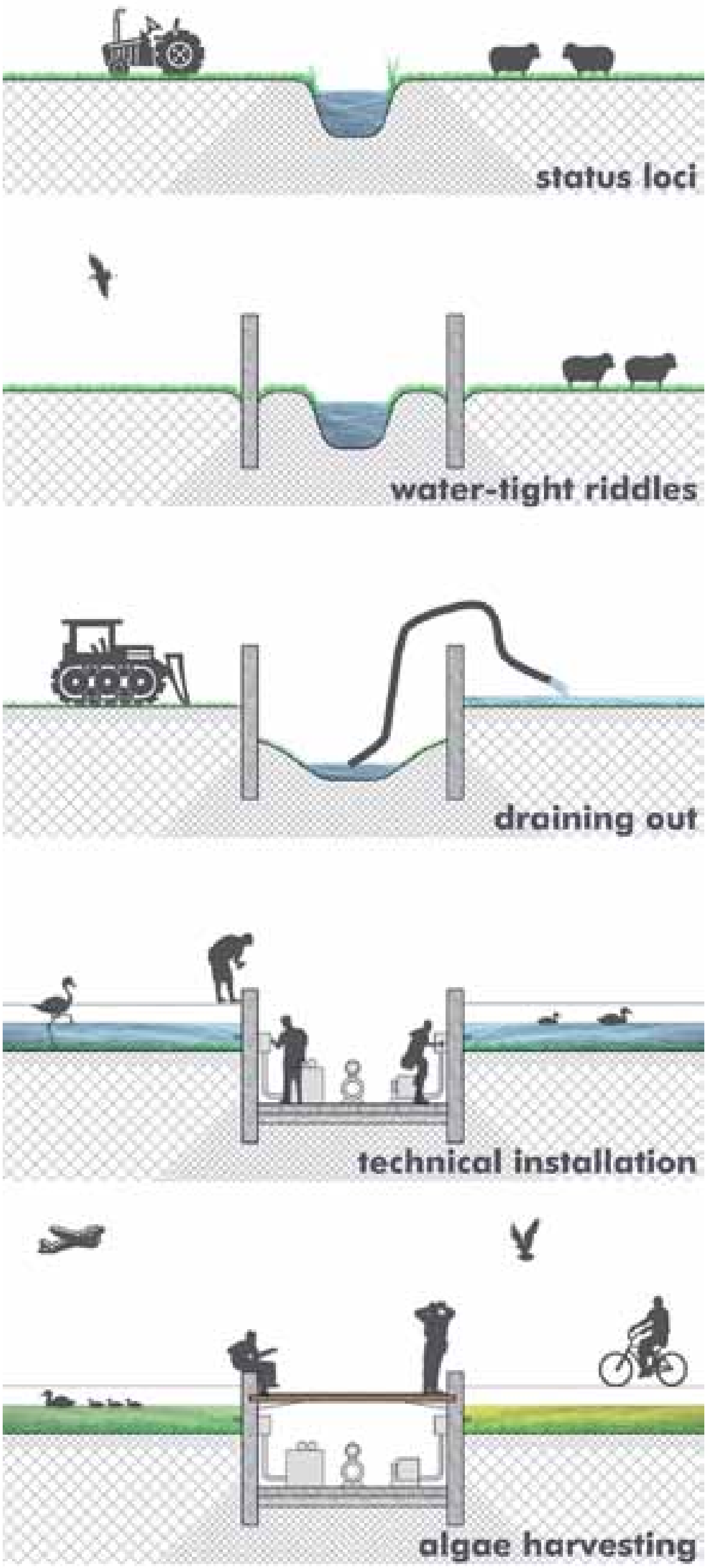


Figure 13: *Reference for the gradual realization of the ditches*

Source: "Polder Inversion", author's elaboration, 2009

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Slikken van Voorne
OOSTVOORNE
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BOKKEGAT
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SLIJKGAT
NOORD-PAMPUS
Kwade Hoek
GOEREE
Haringvliet
FLAAUWE WERK

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Balance Island

Balance Island reduces salt intrusion in the Haringvliet by creating a smooth transition from salt to fresh water while preserving the unique dynamic character of the delta

Sander van Rooij[1] | Bart van Bueren[2] | Emil Kuijs[3]

Delta Alliance Young Professionals Award WINNER!

Balance Island

Balance Island's primary function is to decrease the salt intrusion in the Haringvliet. This is achieved by creating a gradual transition from salt to fresh water, while conserving the dynamic nature of a living delta. By reducing the salt-intrusion, it is expected that the 'Kierbesluit' can be operated more effectively. The 'Kierbesluit' is a measure to stimulate fish migration by frequently opening the sluices of the Haringvlietdam. A lower salt-intrusion allows a more frequent opening of the sluices. This stimulates the migration of fish and retains a minimal salinity near the location Middelharnis, which is recognized as 'zero effect' line.

Haringvliet is a show case of this innovative Dutch Delta Technology for many other estuaries around the world. With the forecast of sea level rise and on-going salinity problems, Balance Island offers a sustainable, simple and easy to maintain solution.

1 Grontmij, de Bilt, the Netherlands
2 Waterarchitect, Rotterdam, the Netherlands
3 Imares, IJmuiden, the Netherlands

Innovating Balance Island

The Rhine-Meuse delta is a low lying and densely populated area in the South-west of the Netherlands. Climate change and sea level rise pose a risk for this area. The delta is an important agricultural area and includes the Rotterdam harbour and industries. In the next century the Netherlands should therefore make steps to make themselves more climate robust.*

At this moment the estuarine natural dynamics in the Haringvliet Lake is limited by hard infrastructure forming rigid borders between salt and fresh water. New policy, the 'Kierbesluit' will be implemented to facilitate fish migration and partially restore natural tide by keeping sluice gates in the Haringvlietdam open longer when the tide comes up. Critical issue in the implementation is the resulting salinization of water in the Haringvliet due to inflow of seawater and consequences for drinking water, irrigation and industrial water. Balance Island aims at reducing salt intrusion and restoring natural estuarine dynamics and ecology by creating a semi enclosed estuary. By constructing a series of sandy islands the flow path of the tide is manipulated in such a way that it becomes larger than the tidal length. Mixing of salt and fresh water is increased and retention time enlarged. Balance Island is a naturally stable solution in sand, following morphology. This makes it possible to grow with sea level rise. The dynamic transitions from dry to wet and salt to fresh water provide optimal conditions for high estuarine natural (nature2000) values, rare species, excellent nursing grounds for fish and feeding area for birds. Balance Island moves the dynamic boundary between land and water seawards. This increases safety and creates opportunities for, restoration of natural dynamics, nature, recreation, aquaculture and industry. Design varieties include piers, harbours and aquaculture to increase economic and recreational options.

* *(Deltas in Times of Climate Change. Comparative assessment of the vulnerability and resilience of 10 deltas, Delta-Alliance report nr 1)*

Occasion and introduction

The concept of Balance Island is to counteract the disruption of natural delta dynamics. A team of young engineers from Grontmij, Imares and Waterarchitect worked on an innovative solution to reduce salt-intrusion in the Haringvliet caused by the 'Kierbesluit'. A new estuary is made in front of the current Haringvliet inlet by creating a new island through sand-suppletion in the mouth of the Haringvliet delta.

By creation of the island the tide is forced to flow a longer distance from the sea the Haringvliet dam through the main tidal channel the ' Slijkgat'. This turns the area into a 'mixing basin' for salt water with fresh water discharged from the Haringvlietdam. Therefore this new estuary reduces the salt-gradient from the water coming into the Haringvliet lake at high-tide. The reduction of salt enables the Haringvliet-sluices to open more frequently

Figure 1: Location Haringvliet

in order to stimulate fish-migration. The new estuary with a gradual transition from fresh to salt water is a unique habitat for brackish flora and fauna, which had become very rare in the Netherlands.

The development of Balance Island makes use of the natural dynamic of the area. In earlier times the natural dynamics in this area have been severely disrupted by human activities, such as the closure of the Haringvliet delta and effects of the Slufter (depot), Maasvlakte and Maasvlakte2 (harbours). This has resulted in a change of currents, waves and tides in which channels and sandbars have become unstable. The landscape is changing continuously until a new dynamic equilibrium is reached. Several final stages are possible; one of them is a new estuary. By creation of Balance Island through sand nourishments, we stimulate nature to become in balance with natural processes in an accelerated rate.

The kierbesluit

Historically, the Haringvliet area was a delta in open connection with the sea. To prevent the hinterland from flooding, the Haringvliet was dammed in 1970. This changed the Haringvliet area into a fresh-water lake. An area without the tidal influence it once knew. In addition to benefits such as fresh water supply there were also disadvantages. Because of the low current the lake started to accumulate pollution from upstream. Together with the lack of tidal influence this had a negative effect on the quality of both flora and fauna. Arrangements were made between the Rhine-Meuse countries in 1999 to stop to the degradation of nature and the increase of pollution. Germany and Switzerland started constructing fishways and France stopped dumping salt from their salt mines. The Netherlands agreed on restoring the connection between the sea and the river.

Fish specie	Effect "Kierbesluit
Three-spined stickleback	+++
Allis Shad	++
Twaite shad	++
Hounting	+++
Lampern	+
Smelt	++
Atlantic salmon/Seatrout	+++
Sea Lamprey	++
Flounder (juvenile)	+++
Glass eel	+++

The degree of benefit is gicen by 0 (no change; + (small benefit in abundance); ++ (reasonable benefit in abundance); and +++ (significant benefit in abundance)

***Table 1:** Effect of implementation of the 'Kierbesluit' on fish species.*
Source: Vismigratie in de Rijn-Maasdelta, Rijkswaterstaat 2011

In 2000, the restoration of the river-sea-connection was recorded in a decree (Besluit beheer Haringvlietsluizen) which became known as the 'Kierbesluit'. It was agreed that the sluices would be partially opened during flood to enable fish migration It was expected that the 'Kierbesluit' would have a large effect on various species of fish (see table). Due to large scale opposition expected budget exceeding and delays; the decision was withdrawn in 2010. Lacking a suitable alternative the 'Kierbesluit' is now executed in its most basic form. Execution of the 'Kierbesluit' results in the controlled opening (and closing) of the sluices in such a way that no salt water intrusion is occurring east of Middelharnis. This creates new challenges to parties West of this location such as agriculture and industry. The intake of drinking water by water company Evides needs to be moved to prevent intake of salt water.

Balance Island is Building with Nature

Balance Island is a sandy barrier of about 5 km long and 500 m width that will be placed on the shallow zone in front of the Haringvliet to create a new estuary. With this, the island is not a goal by itself, but a means to make the estuary.

The creation of Balance Island uses the 'building with nature' philosophy to join the natural development of the area. The goal is to not only mitigate the effects of Balance Island, but to use the natural dynamics of the area to help create the solution. This way a dynamic equilibrium is created of which Balance Island is part.

The front delta offers a unique opportunity for the restoration of typical brackish ecotypes. Next to creating the estuary, Balance Island therefore aims to restore as much as possible estuarine nature in the mouth of Haringvliet. Balance Island is constructed from sand and is to be an integrated part of the natural processes. It will stimulate the natural system of sandbars and channels. As a result, the river mouth regains part of its original character as a dynamic and healthy delta.

Mixing salt and fresh water

One of the most important characteristics of estuaries is the salinity gradient (lit 1). This gradient has a large influence on the occurrence of different organisms. Such areas with a transition from salt to fresh are rare in the Netherlands. They are only still present in the Eems and Schelde. Their existence is under pressure from shipping, dredging and pollution. The conservation objectives of mudflats and salt marshes are under pressure by decreasing of acreage.

The mouth of the Haringvliet has potential for estuarine nature of high quality. In the current situation the abrupt fluctuations in salinity are too large to accommodate typical brackish water species. During the discharging of freshwater from the Rhine and Meuse into the estuary, the river-mouth becomes predominantly fresh. This water flows away quickly with the ebb tide. When the tide rises the sluices close and salt water flows from the North Sea into the mouth of the Haringvliet. In this process the whole area up to the Haringvlietdam fills up with salt water. Due to the large fluctuation in salinity, it is too difficult for brackish water species to thrive in this area. Balance Island provides a more constant and gradual transition from fresh to salt.

Figure 2: Salinity in estuary

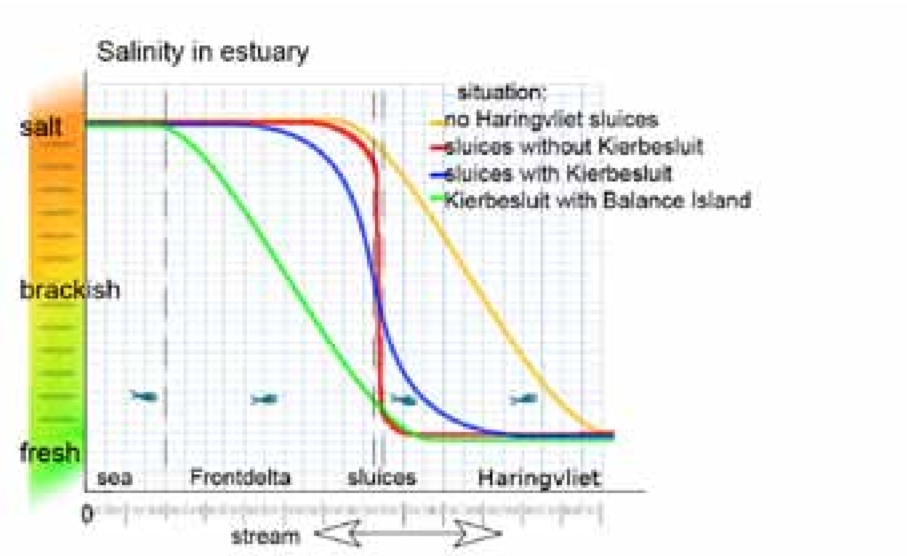


Figure 3: Other potential locations in Zeeland

Tidal excursion

The gradual transition from salt to fresh is achieved by extending the tidal excursion length. The tidal excursion is the distance that a water particle travels in a single tidal movement. In the Netherlands this distance is about 10 km. Currently the mouth of the Haringvliet is much smaller than these 10 km. Therefore in a single low tide all the discharged fresh water flows out of the area. With a following high tide the area fills with salt water. By partially blocking the flow, the tidal distance can be extended to more than 10 km. In this way fresh water will remain in the estuary during low tide. During the next high tide the fresh water mixes with the incoming salt water, creating a brackish estuary.

Double reduction of salinity

The salinity in the outer delta is largely determined by the mixing of seawater with fresh water from the Haringvliet. For estuaries in general, salt water penetration distances are commonly 10 to 100 km (lit 2). The penetration depends strongly on the shape of the estuary and the fresh water flow into the estuary. A rule of thumb for the Dutch situation is that the salinity decreases 30% by every 10 km. With the construction of Balance Island the tidal distance becomes approximately 10 km (distance from Oudorp up to the Haringvlietsluizen). The density of seawater offshore is approximately 1020 kg/m^3. It is expected that the weight will decrease to 1015 kg/m^3 when it travels the distance of 10km towards the Haringvlietsluices. The density of fresh water is 1000 kg/m^3. Fresh water is lighter than salt water. When salt water and fresh water meet, salt water tends to stay below the fresh water, this is called a 'salt-tongue'.

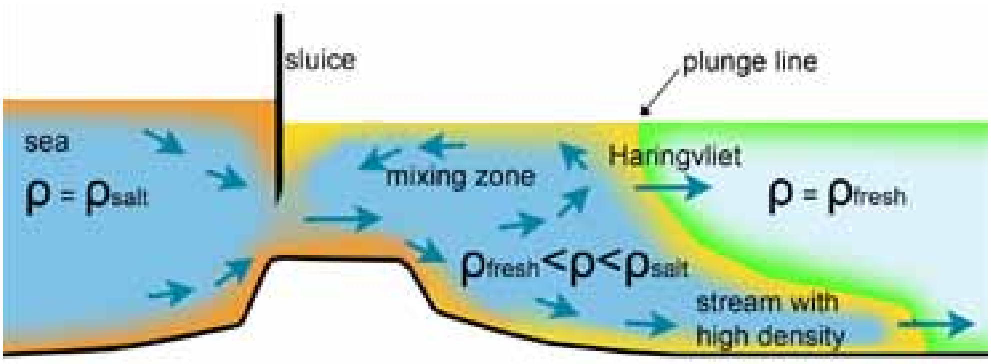


Figure 4: Passage of seawater through locks

The amount of intrusion of salt water is proportional to the difference in density between salt and fresh water. If the water on the outside of the Haringvlietdam contains less salt, the 'salt-tongue' will penetrate less into the Haringvliet when the 'Kierbesluit' is executed. Supposing that the salinity in the area outside the barrier decreases by 30%, the salt intrusion will also decrease with approximately 30%. An intake test at the Haringvliet (lit 3) showed that the salt intrusion is approximately 10 - 13 km. If the salinity on the outside of Haringvlietdam is decreased by about 30%, then it can be expected that the salt penetration decreases to about 7 to 8 km and that the (average) salinity in the salt-tongue decreases from ca 1020 to 1015 kg/m^3. There is thus a double reduction. The salt water flows less far into the Haringvliet, and the incoming water is less salt.

The Haringvliet

Origin and character of the Haringvliet

The Haringvliet was created during the St. Elizabeth flood of 1421. During this storm low-lying polders flooded and a direct connection between Haringvliet and rivers was created. From this the Haringvliet and Hollandsch Diep were created. The outer delta got largely composed out of the sediments taken from the flood. Since the Haringvliet was open to the sea, salt water reached deep into the land. In front of the Haringvliet two large channels were created, the northernmost called 'Rak van Scheelhoek' which also was the largest, and the southern 'Slijkgat'. During the 19th century, the tidal basin gradually diminished by land reclamation and the damming of river arms. As a consequence, also the channels in the outer delta got gradually smaller. Various locations have shoals at intersecting channels and in the river mouth. These were formed where water diffused into smaller channels.

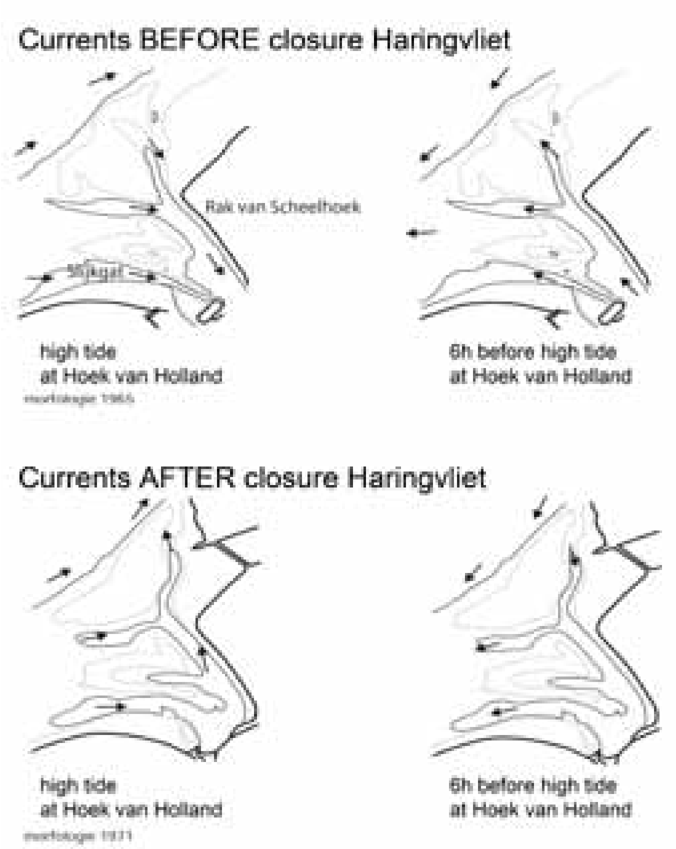


***Figure 5:** Currents before and after closure of Haringvliet*

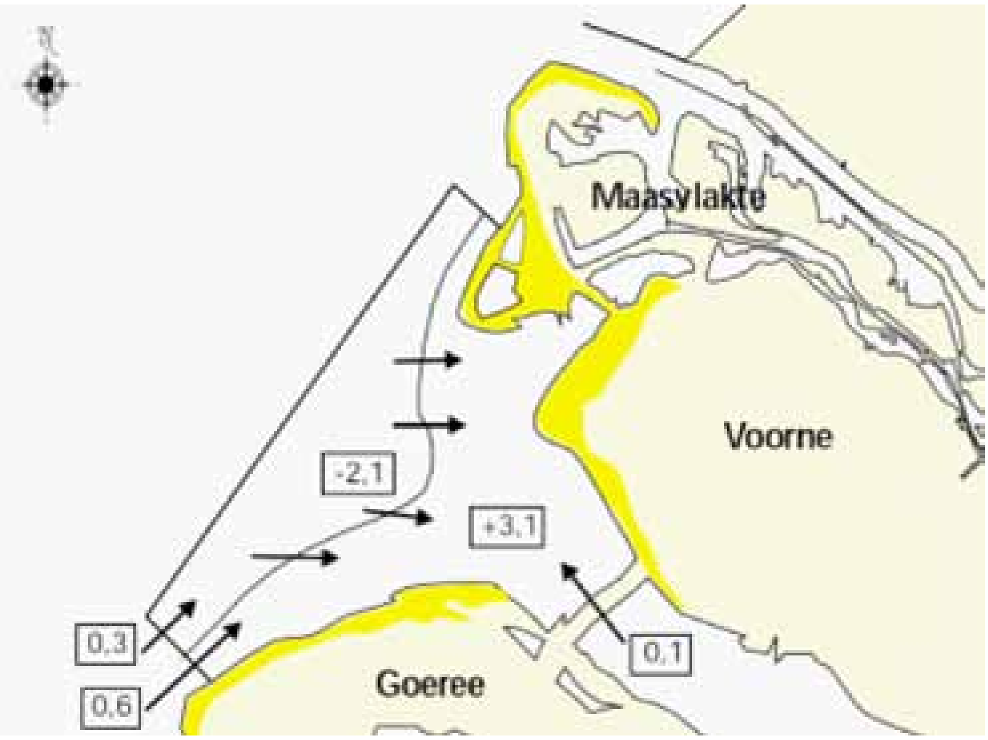


Figure 6: Current situation

Closure of the Haringvliet

After the flood-disaster in 1953, the famous Dutch Deltaproject was implemented. The closure of Haringvliet was part of the project which was finished in 1970. From that moment on, only fresh water was discharged into the sea and the tidal basin disappeared completely. The mouth of Haringvliet transformed completely. Its tidal volume is reduced by 85%. The disappearance of the tidal flow means the sediment was no longer transported by the channels to the sandbars, but deposited in the channels and on the southern shores. The northern channel of Rak van Scheelhoek disappeared almost entirely and most part of the southern Slijkgat as well. The deposits on the southern shore are known as De Kwade Hoek, an area which is still growing.

The growth of De Kwade Hoek pushes the Slijkgat north, creating a characteristic S-curve in the channel. The Slijkgat is currently the only navigable shipping route in the mouth of the Haringvliet. The Slijkgat needs to be dredged annually to keep its depth. Resulting from the decreased tidal influence, influences from waves became dominant in this area and the channels became flood (inflow) dominated instead of ebb (outflow) dominated (lit 4). The net transport of sand is in east direction. Hereby the sand is brought up higher in the coastal profile. This change in development after the completion of the Haringvliet dam is still on-going. The average diameter of the channels is decreasing and sand is deposited in the channels and on sandbars and intertidal area. As a result of the Haringvliet closure, the tide dominated outer delta is transformed into an arc shaped row of sandbars along the coast. This is caused by the decrease of tidal currents and the natural tendency of the coastline to close and straighten itself. With sufficient sand, it will create a coast arc just like the Holland coast. Too little sand will result in a dent in the coastline, suspended between the fixed points of the Europoort and Goeree Overvlakkee.

The present day mouth of the Haringvliet

In the present day situation the mouth of the Haringvliet basically consists of two channel systems; The Northern part with the Hindergat and the mudflats near Voorne, and the Southern part with the channels Slijkgat, Bokkegat and sediments from Kwade Hoek. In the middle of the area, lies the Hinderplaat. This plate was -and still is- moving towards the land. The West side on the Hinderplaat is more or less in balance with incoming sand transports. The sand transport is here directed southwards in the surf zone, while flood tidal currents transport sand on top and over the northern part of the plate (lit 4).

During high river discharge, the sluices discharge about 9000 m^3/s. Although during normal discharges, about 61% of the water flows through the Slijkgat, with peak discharges the water will flow over all channels and sandbars. At peak discharges sand is transported through the Slijkgat in the direction of the sea. Where channels end, and at the junction of channels, the flow rate drops and sand is deposited. This is how shoals develop in the waterway. The channels are dredged annually to a depth of - 5.5 m below sea level (NAP) to keep the channels at depth for ships. On average, around 260,000 to 90,000 m^3/year is dredged (lit 5). It is expected that the dredging effort will increase in the coming years (without Balance Island).

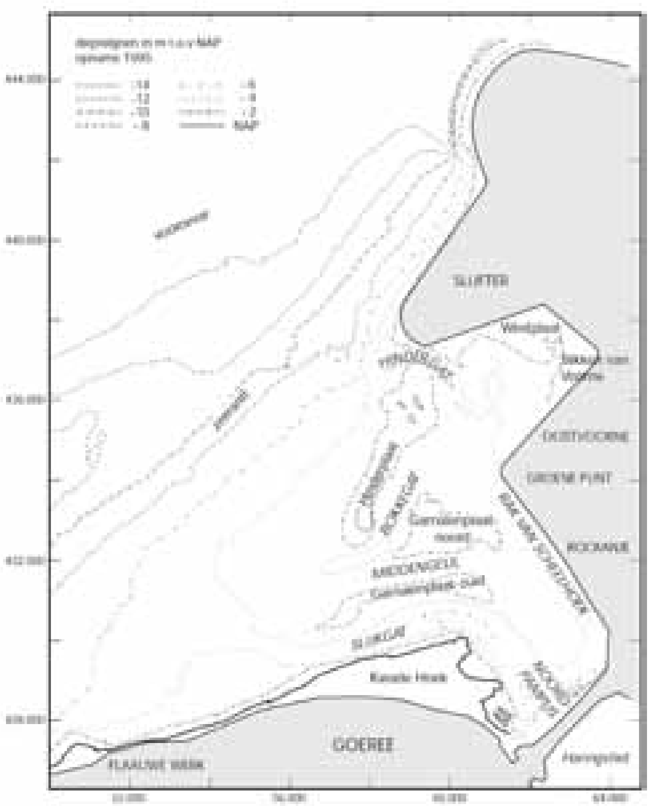


Figure 7: Overview of channels and plates in the mouth of the Haringvliet. Source: Van Vessen, 1998. (lit 4)

The Haringvliet Lake

Within the Haringvliet the constructed dam had serious consequences. The transformation from open delta with inflowing tide and salt water, to a closed fresh water lake had major implications for nature. Saltwater species disappeared and the number of fish drastically reduced. Some species like the sturgeon, Shad and Flint are now virtually non-existent in Dutch waters. Some species, like the salmon, migrated from the sea through the Haringvliet into the Rhine and Meuse to spawning grounds upstream. This is now seriously hampered by

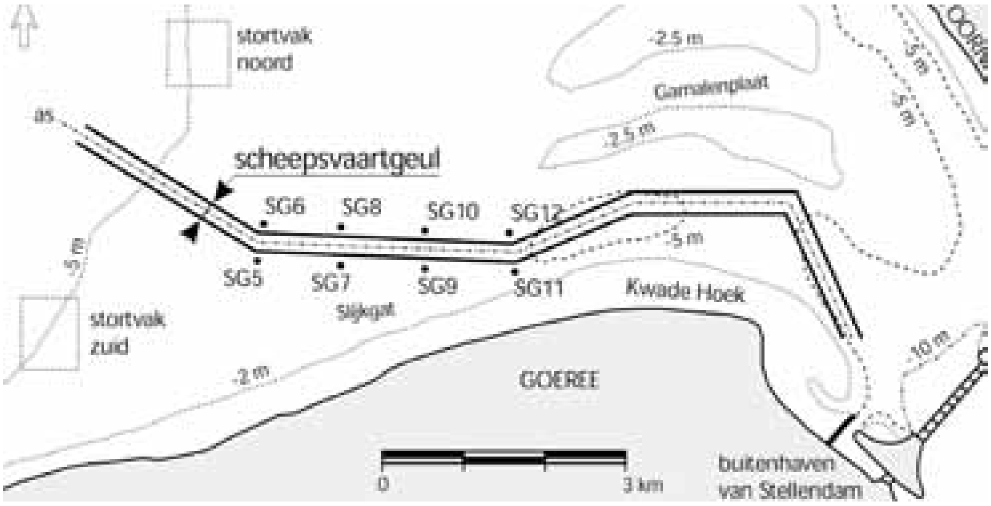


Figure 8: Shipping channel in the Haringvliet, it is dredged annually to a depth of 5,5 meter below sealevel

the damming of the Haringvliet. Contaminations such as heavy metals are deposited on the bottom of the Haringvliet because flow rates are low here. The absence of tidal differences on the banks of Haringvliet has caused the disappearance of typical vegetation such as Rush Buntings, Reed Buntings and Willow Pilot whales.

Future of the mouth of the Haringvliet

The mouth of the Haringvliet changes continuously. This is partly the result of the closure of the Haringvlietdam. Also new impacts are expected; from the Kierbesluit, the completion of Maasvlakte 2 and the effects of climate change.

Maasvlakte 2

The construction of Maasvlakte 2 has implications for the morphology of the mouth of the Haringvliet estuary of the Haringvliet. Environmental Impact Assessment-studies (MER) show that the construction of Maasvlakte 2 will increase the tidal wave. The existing basin shape enhances the flood, making high tide 20 cm higher and low tide 20cm lower. The effects on morphology are unclear.

Climate change

The Technical Advisory Committee for Flood Defence forecasted in October 2002 larger impacts from waves on the coast in the near future. The Kustvisie 2050 (lit 6) states that measures are needed to maintain safety at the location Flaauwe Werk at the island Goeree. At present, the Flaauwe Werk and the coast at Voorne are appointed as weak links in the coastal defences. Expectations are that the construction of Balance Island will lower the impact of waves on the coastal defence. The future increase of sea level will also affect.
The Kierbesluit; higher water levels will increase salt intrusion and result in a change of the opening and closing regime of the sluices.

Dynamic equilibrium

The Delta in the South-West of the Netherlands is a dynamic area. Sediment is deposited under influenced of tides, waves and currents in the delta of rivers. The deposits in the shallow regions, on the sandbars, and the channels together form the delta. This area changes continuously as a result of changes in tide, wind, river discharge, etc. The climate and the tide are more or less constant. Therefore, the region changes continuously around a certain state of equilibrium, which is called a dynamic equilibrium. The damming of the Haringvliet disturbed this dynamic equilibrium and since 1970 the estuary is still changing to a new dynamic equilibrium.

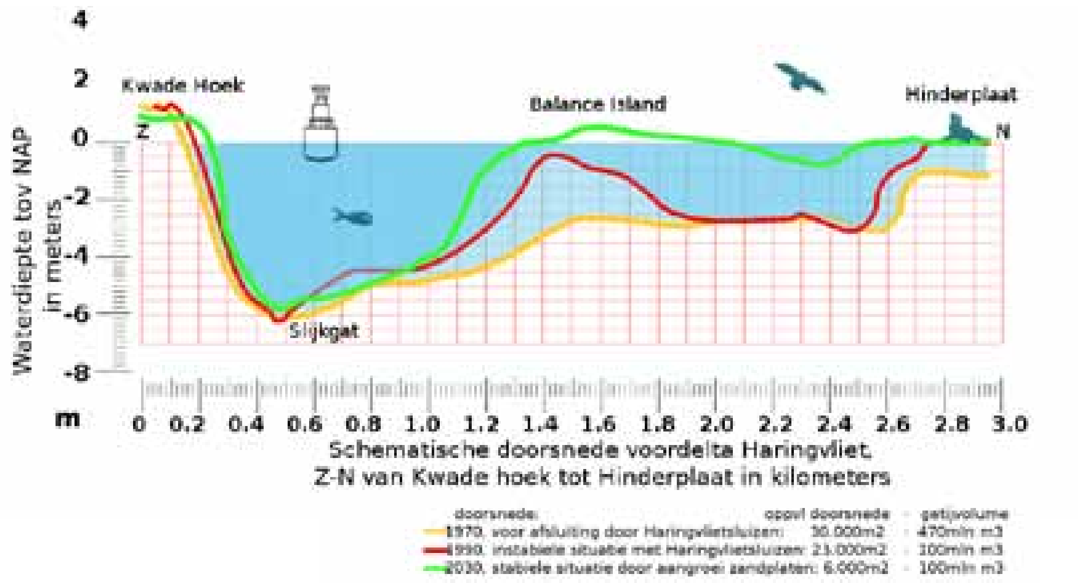


Figure 9: *South-North section of Frontdelta Haringvliet*

Final stage

How the final dynamic equilibrium will look like, is hard to predict, and the estimated time for the delta to reach the equilibrium is estimated to be between decades up to centuries. In its present state the mouth of the Haringvliet is adapted between 40-80% to the hydraulic changes that occurred as a result of the construction of the Haringvlietdam. Earlier research found 4 possible final stages that may all result in a dynamic equilibrium (lit 4). With the choice of Balance Island one of these final stages is chosen. Building (part of) Balance Island will accelerate the development towards a new dynamic equilibrium.

The relation between the dimensions of channels and sandbars and the amount of tidal flow has been thoroughly investigated. A relationship was found between the tidal prism (the amount of water flowing in and out with high and low tide) and transport of sand (lit 7) or the surface of cross-sections of channels (lit 8). The relationships show that the Hindergat already reached a stable equilibrium in which sediment is passed through. The Slijkgat is still not in balance, and becomes shallower to reach a new equilibrium.

Tidal flow in the mouth

The equilibrium size of the channels and the amount of water passing through the mouth of the delta cannot be explained by the tidal prism alone. Water flows around the Hinderplaat and smaller mudflats, rather than just in and out during tides. When the tide comes up through the southerly located Slijkgat and Bokkegat, water is still flowing out through the northern Hindergat. During lowering tide water flows out through the Slijkgat, and at the same time in through the Hindergat. Because of this channels are larger than the tidal prism (lit 4) would predict.

Shape of Balance Island

When the development of the mouth of the Haringvliet is observed, it can be seen that the current Hinderplaat was created by a shoreward movement of shallow sandy deposits. This resulted in a concave shaped plate, known as a coastal arc. This form arises when a sandy coast is partially protected by hard structures such as rocks or piers. The so-called pocket beaches are the best known example, but also the Dutch coastline "hangs" on different places between hard structures. Empirical studies proved a relation between the wave climate and the shape of this coast arc. The predominant Northwest and Southwest winds in the Netherlands result in a structure shown in the following figure (lit 9). The Hinderplaat shows this shape is indeed stable. Therefore this shape is also used for Balance Island.

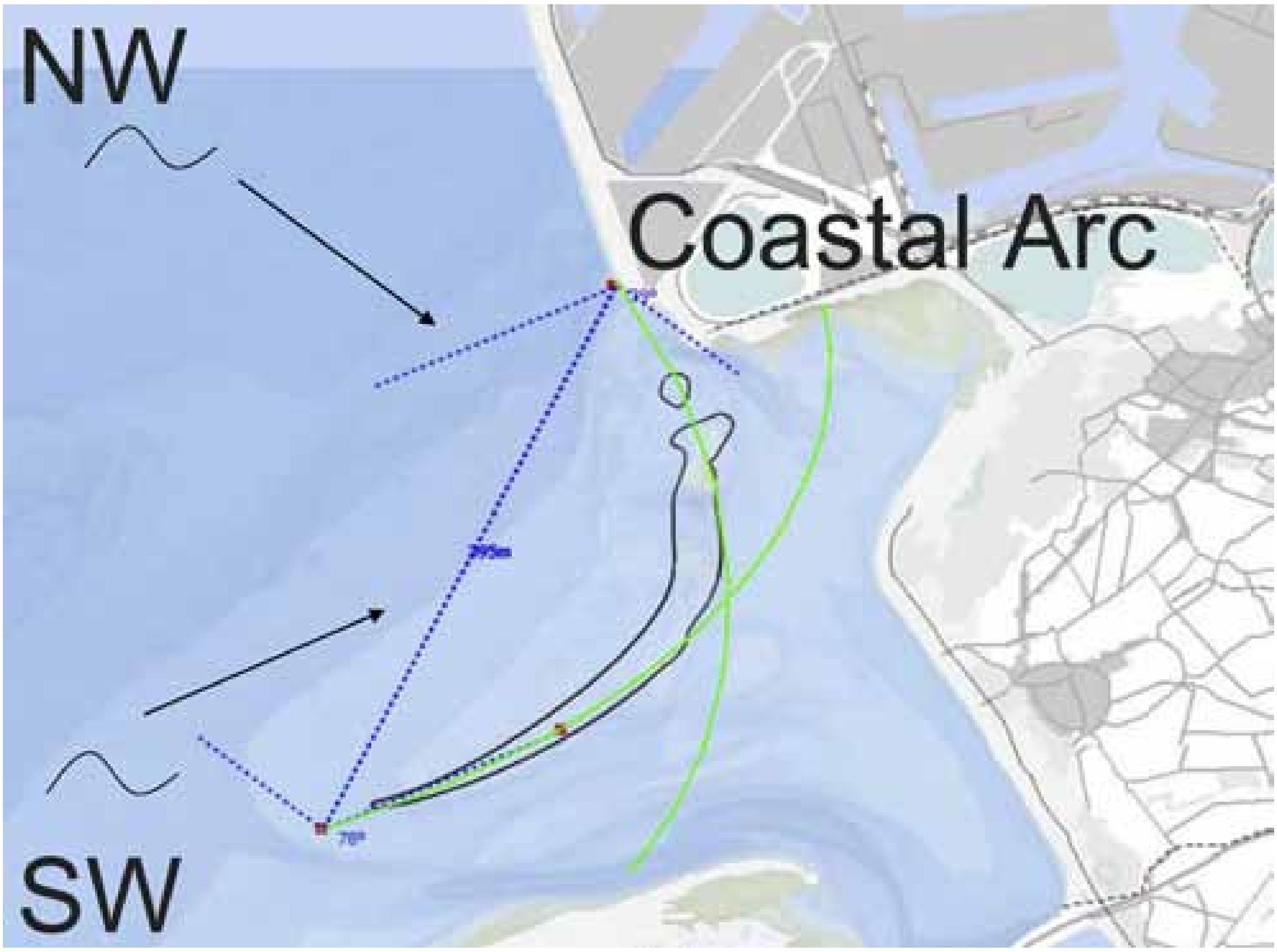
Effects of Balance Island

Balance Island has been designed in such a way that it fits within the dynamic equilibrium of the mouth of the Haringvliet system. Despite the island has effect on the hydrodynamic and morphological conditions of the Mouth. Balance Island has a sheltering effect against waves, which results in a reduction of wave height inside the estuary. The tidal current concentrates in the Slijkgat where the increase in flow velocities is expected to deepen the channel.

Balance Island is not a static and unmovable object. By constructing Balance Island as a sandy and largely unprotected island, it becomes part of the dynamic system. The southern point will most likely be the most dynamic. As a result of the exposure to tide and wind driven waves the tip can easily erode. On the other hand sand is also transported towards and deposited around the tip.

Sand is being brought to the island from inside the channels and from the coast of Goeree-Overflakkee. This is the same ‘supply line’ that provides the growing Kwade Hoek with sand. The area of Kwade Hoek is typified by a waving coastline with large scale sand structures that move westwards. When after the construction of Balance Island a balance is found between supply and removing of sediment to and from the channels and sandbars, the sand transport will be redirected largely around the mouth of the Haringvliet and supply Balance Island with sand. Similar to the island coast of the Wadden Sea in the north of The Netherlands, the tidal currents keep the channels such as the Slijkgat open.

***Figure 10:** Stable coastal shape with northwestern and southwestern winds*



Ecology Haringvlietmonding

In Habitat types

In the current situation, the Haringvliet estuary is an area of international ecological significance due to the presence of estuarine dynamics, channels, mudflats and salt marshes. The Haringvliet estuary is therefore part of the Natura 2000 are "Frontdelta". A large part of the estuary consists of channels and sandbanks which are constantly under water (habitat type 1110). Because there are many worms, shellfish and crustaceans in shallow seawater it is an important foraging area for fish, fish-eating birds such as Red-throated Divers, Gulls, Terns and seals.

Furthermore, the mouth of the Haringvliet has a large acreage of intertidal sandbars present; shallows and mudflats that are regularly flooded by salt water (habitat type 1140).The sandbars and mudflats house high densities of soil animals, which are important feeding areas for ducks, including Common Shelduck, Widgeon, Teal and many waders such as Oyster Catcher, Pied Avocet, Redshank, Eurasian Curlew and Dunlin. In the winter, these sandbars are of great importance for wintering birds. The high dynamic intertidal mudflats are used as resting and drying place by species such as the Tern and Cormorant. The sandbars in the mouth of the Haringvliet are also important sites for Common and Gray Seals. A large proportion of the total Dutch front-delta intertidal sandbars are located at the Haringvliet front delta. For this reason the Haringvliet has an important function in reaching the conservation objectives. With the construction of Balance Island this intertidal habitat will grow.

Nursery

Balance Island will restore the fish-nursery in the Haringvliet. Restoring the fresh-salt gradient will result in a more stable system in which estuarine species can thrive again. Because of the continuous water flow, the shallow zones are very rich of nutrition and therefore can function as breeding ground for fish. This also attracts birds like many types of Terns and increases breeding success. The Little Terns population had little breeding success in recent years.

The benthos-community at Balance Island

The bottom (bound) community is an important link in the estuarine ecosystem. This so-called benthos serves as food for fish, birds and others. Benthos is not very mobile and is therefore a good indicator of stress caused by pollution and changing conditions such as fresh-salt transitions or temperature changes. Benthos is therefore often used to monitor

Photo by Steve Geelhoed

the health of an ecosystem. A pulsed discharge, like is now occurring from the sluices in the Haringvliet, causes a sudden change from salt to a freshwater system. This can have major implications for the benthic ecosystem and can locally cause mass mortality. A lot of water was discharged in the winter of 1994 and killed most of the cockles (Cerastoderma edule) in the mouth of the Haringvliet (lit 10). Expectations are that large water discharges will occur more frequent in the future, causing serious threats to the local ecosystem. In comparisons between the Haringvliet of the 1960s and the current Haringvliet it is evident that there is a sharp separation between the brackish system and the fresh water Haringvliet now. The mouth now is a typical marine system, while in the 1960s brackish water species also occurred in this area (lit 11).

Directly next to the sluices of the Haringvliet the benthos community is becoming a monoculture, the only specie found here is the Tubificid Worm (Paranais frici) (lit 10).The water and bottom hold a high concentration of dead organic material, caused by dead flora and fauna which were unable to survive the strong fresh-salt transition.

The main change for the benthic system caused by the development of Balance Island is expected at the mouth of the Haringvliet. It is expected that this area will change from a marine system into a typical estuarine system. The water coming from the Haringvliet transports water rich of nutrients. This food comes available when the sluices open, with the Kierbesluit. Because of Balance Island this nutrient-rich water is not directly discharged into the sea, but will stay longer in the estuary. The many unique habitats can benefit from this. It is expected that in this area not only the marine species will thrive, but also typical brackish water species will return.

East from Balance Island silt-rich sandbars will develop. This area will accommodate typical marine species, such as; American razor shell (Ensis directus), Nephtys, Spiophanus bombyx, Shell Tubeworms (Lanice conciliega) and Cockle (Cerastoderma edule). These species are now also very abundant in the present front delta (lit 11). Also typical brackish water species are expected, such as the Baltic Tellin (Macoma balthica), the Multi-colored Centipede (Nereisdiversicolor), Mud Worms (Boccardiella ligerica and Polydora Ligni) and the Common Shrimp (Crangon Crangon). Compared with the current situation, it is expected that over the whole gradual fresh-salt transition there will be a higher biodiversity. This change is expected to be beneficial for the entire local ecosystem, in which the benthic community also serves as a food source for higher order animals such as birds and fish.

Nature 2000 legislation and regulation

The mouth of the Haringvliet is part of the Haringvliet Frontdelta, a protected area that is part of the European Natura 2000 network. Natura 2000 is a network of European nature reserves and aims to protect vulnerable plants and animals with their habitats. These areas are covered by the Natura 2000 Nature Conservation Act 1998.

This law sets specific targets for the preservation and restoration of environments (habitats) and animals (listed species) in the Natura 2000 areas. Activities in Natura 2000 areas, which might cause a negative effect, require a license. For this paper an initial assessment is made on the potential negative effects of Balance Island. The assessment is based on the Natura2000 conservation objectives, the Management Plan for Frontdelta and the online impact indicator of the Ministry of Economic Affairs, Agriculture and Innovation (lit 13). The government (Geduputeerde Staten) will ultimately determine whether a license is provided and whether a habitat test should be performed. The impact indicator combines information on the sensitivity of listed species and habitats, with possible disruptions that may occur due to activities in Natura 2000 areas. The analysis made here is based on all the activities that might overlap with Balance Island. In this way all possible effects are included. These activities include: dams, weirs, coastal dike reinforcement and extraction of gravel and sand. The following diagram shows the Natura2000 conservation objectives for habitats and listed species for the Frontdelta.

Impact on habitats

The most obvious change is the decrease of permanent flooded Sandbanks (H1110) which will be replaced by shallow mud and sandbanks (H1140 and H1310). In relation with the Natura 2000 objectives, the new situation appears to have an improvement of many habitat types. In this perspective it can be concluded that Balance Island reaches the Natura 2000 habitat targets.

***Table 2:** Effectenindicator, Ministerie van EL&I*

Source www.synbiosys.alterra. nl/natura2000/gebiedendatabase.aspx?subj=n2k&groep=9&id=n2k113&topic=effectenmatrix (1 februari 2012)

Habitat type		**Habitat directive species**	
H1110	Permanently flooded sand banks	H1095	Sea Lamprey
H1140	Mud and sand Flats (tidal)	H1099	Lamprey
H1310	Brackish pioneer vegetation (Sampshire)	H1102	Allis Shad
H1320	Spartinion maritimae	H1103	Twaite Shad
H1330	Marshes and salt meadows	H1364	Grey Seal
H2110	Embryonic dunes	H1365	Common Seal

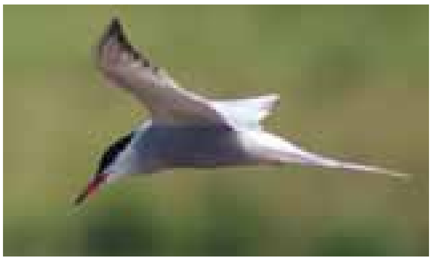
Birds					
A001	Red-throated Diver	A054	Pintail	A141	Grey Plover
A005	Great Crested Grebe	A056	Shoveler	A144	Sanderling
A007	Horned Diver	A062	Scaup	A149	Dunlin
A017	Cormorant	A063	Common Eider	A157	Bar-tailed Godwit
A034	Eurasian Spoonbill	A065	Common Scoter	A160	Eurasian Curlew
A043	Greylag Goose	A067	Common Goldeneye	A162	Redshank
A048	Common Shelduck	A069	Red-breasted Merganser	A169	Ruddy Turnstone
A050	Widgeon	A130	Oyster Catcher	A177	Little Gull
A051	Gadwall	A132	Pied Avocet	A191	Sandwich Tern
A052	Common Teal	A137	Ringed Plover	A193	Little Tern

(Management plan delta 2008)

Impact on listed species
In addition of the assessment on habitats, it is possible to determine the effects on birds, fish and seals. The habitat target species Sea Lamprey, River Lamprey, Allis Shad, Twaite Shad, Gray Seal and Common seal are not (yet) included in the impact indicator. The analysis below is therefore based on the Natura 2000 conservation objectives as formulated in the Management Plan of the Frontdelta.

Fish
The Sea Lamprey, River Lamprey, Allis Shad and Twaite Shad have Natura 2000 population improvement targets. This improvement will depend mainly on the opening of the Haringvliet sluices (Kierbesluit). Higher flow rates in the Slijkgat and Hindergeul caused by Balance Island are not expected to be any obstacle to the migration.

Common Seal
The Common Seal uses tidal flats in the delta as places to rest and the Seal is very sensitive to any disturbances. Nationally the Common Seal population is good, but still the population in the delta is low. Expansion of the resting area will facilitate the raising of young seals. Balance Island contributes to this, but it should be taken into account that construction works of Balance Island should not be done during the nursing season (May-August), to limit disturbance.


Photo's by Steve Geelhoed

Birds
The Eurasian Spoonbill and Pied Avocet are very sensitive to any mechanical effects. This should be taken into account for the construction works. The Ringed Plover, Sandwich Tern and Common Tern are very sensitive to optical distortion. Further disturbances are related to the supply of food. Birds depend on the supply of shellfish, fish and benthic fauna in the area. Changes herein can be caused by a change of stream, different flooding frequency or changes in soil, can all affect the bird population.

The Tern and Common Tern are foraging in the Haringvliet estuary. Construction work can cause disturbance through sight and turbidity in the water and may have a strong negative effect on these species. The Common Tern and Sandwich Tern are visiting the Frontdelta only in the summer, mainly from April to September (lit12).

The construction of Balance Island will cause temporarily turbidity in the water. Construction work during the winter months will have the least negative impact. Shallow coastal areas will be sand-sprayed to construct Balance Island. This will reduce the amount of permanent flooded mutflats. The Black Scoter, Red-throated diver, Stopper and the Eiderduck depend on this habitat type (1110). It is expected that these birds can still find enough other places for rest and food.

The amount of birds has been counted in the Frontdelta in 2004 and 2005. It showed that the largest numbers of Common Scoter occur in the areas Bollen van de Ooster and Bollen van Nieuwe Zand. The largest numbers of Red-throated Divers in the foredelta were located near the Brouwershavense Gat. Other areas with large concentrations of birds are the head of Schouwen-Duiveland, the head of Goeree-Overflakkee and the angle of the Brouwersdam near Goeree-Overflakkee (lit12). The decrease of habitat type 1110 in the mouth of the Haringvliet will not cause any significant effects for these species.

The Scaup population in the mouth of the Haringvliet is part of a larger population that resides in the Haringvliet. The Scaup uses the Haringvliet mouth mainly to rest, while Topper Ducks forage in this area at night. The Frontdelta is an important resting and foraging area for Eiders during the winter months. The Eider is a clam-eating Sea-duck with a preference for shallow waters. The effects on the decrease of habitat type 1110 for the Scaup and Eider should be investigated further.

Significance of impact

A rating system is developed to rate the significance of negative effects in the front delta (lit 14). This system was originally developed for Maasvlakte 2, but will work the same for Balance Island. Briefly summarized the method rates three values:

- decrease is less than 1% of the area or population in the affected area: the effect is not significant;
- decrease is more than 5% of the area or population in the affected area: the effect is clearly significant;
- the decrease is between 1% and 5%, the judgment depends on the context.

This assessment is used to estimate the negative effects for Balance Island. The surface loss of habitat H1110 is less than 0.2% of the total area of the habitat type in the front delta. Therefore, according to this assessment system it has no significant effect. The increase in mudflats and sand flats is more than 5%, which is a significantly positive effect, but the assessment system checks only on negative effects. The development of embryonic dunes is so rare that no percentage can be given. For other significant effects of Balance Island, it is necessary to also analyse the population of the listed target species in the area. Possibly the loss of H1110 caused by the construction of Maasvlakte 2 should be included.

Effects elsewhere

The changing dynamics in the Haringvliet estuary might affect other Natura 2000 sites besides the front delta. This is already valid for the dunes near Voorne and the Dunes of Goeree and Kwade Hoek. The increased flow velocity at the Slijkgat could potentially affect sand nourishment of the Kwade Hoek and maybe areas at Voorne as well. These possible effects require further study.

__Table 3:__ Review of current state and effect Balance Island with respect to Nature2000 targets.

Habitat type in frontdelta		LSI (present day)	Balance Island
H1110	Continuously flooded sandbanks	–	–
H1140A	Mud and sand flats	–	–
H1140B	Mud and sand flats	+	N2000
H1310A	Brackish pioneer vegetation	–	+
H1310B	Brackish pioneer vegetation	+	N2000
H1320	Spartinion maritimae	– –	N2000
H1330	Salt marshes and salt meadows	–	N2000
H2110	Embryonic dunes	+	+

Design and function

Various designs of Balance Island are made, all within the constraints posed by the dynamics of the delta. The designs vary in the maximization of the nature, tourism or minimal construction cost.

Basic variant

In its most simple design, Balance Island is built as a coastal arch. It is connected to the Hinderplaat. The Hinderplaat itself is preserved and untouched because there is no need to raise this plate and because this is a resting area for seals. Balance Island will be nourished up to a height of just below the level of high water. This will force high tide to flow through the Slijkgat. Waves, currents and wind will probably raise Balance Island in years to follow. This variant requires an estimated volume of 3 million m^3 sand nourishment and has potentially the lowest construction cost.

Archipelago

A second design of Balance Island consists out of a chain of small islands and individual banks. The banks are adjacent to the Hinderplate. Working with separate islands enables the use of zoning, which allows the southernmost island to be open for recreation and variation in height per plate, which favours nature development.

Nature optimized design

The Nature optimized design is optimized to stimulate the development of rare habitats. Balance Island creates 120 acres of intertidal mudflats and sand flats, and 16 acres of dunes. By creating differences in height and vary with the (naturally present) amounts of shells in the nourished sand, a very diverse area is created. This area has a variety of habitats and gradients in height, flooding frequency and salinity. In the present day situation, most tidal marshes will be flooded during high tide, therefore they are useless as breeding habitats. The increase of intertidal area will make the Haringvliet estuary more valuable as resting and foraging place for many species. The dunes which will arise on Balance Island become a suitable nesting spot for Tern species (as Tern, Common Tern and Little Tern), the Little Gull, Beach Plover and Kentish Plover. The Sandwich Tern, Little Tern and Tern prefer the bare ground, preferably with shells (lit 1). The Kentish Plover and Dunlin require beaches or dunes to breed, which will also be sufficiently provided in this design-variant. The absence of predators like the fox and the absence of human disturbance make Balance Island a very suitable breeding habitat.

For the emergence of a new dune foot and embryonic dunes, the width of the beach is of importance. A beach width of 60-80 meters will cause embryonic dunes to erode during storms, while a beach of 150-300 meter width the embryonic dunes will grow (lit 15). Balance Island will be 300-500m wide at its widest point; here are the highest parts of Balance Island. The landscaped dunes will grow at the widest points. At narrower points they are expected to erode and mudflats and salt marshes will develop.

On these dunes that are rarely flooded embryonic dunes can develop. This habitat type consists of pioneer-dunes with vegetation of Sand Couch (Sporobolus virginicus) in varying densities, alternating with bare sand or flood line characteristic vegetation. These grow on places with saline groundwater, which are only flooded at high tides. At higher places, that do not flood anymore with seawater, the influence of rainwater increases. A fresh water lens can develop here. Fresh water lenses develop at a height where the salt-brackish groundwater does not have any influence at ground level and fresh water infiltrates the dune. Here Maram typically develops in a habitat type known as white dunes.

The Nature optimizes design is designed to ensure sufficient dynamics through sand sprays and floods to ensure that vegetation does not get the upper hand. By creating sufficient height, flooding in the nesting season is prevented.

Nature recreation

This design-variant of Balance Island offers opportunities for development in combination with recreation. In the most natural variant, it is intended that the influence of human presence is limited as far as possible in order to maximize the natural value. In order to allow people to enjoy the natural beauty, a small 'passers' marina with a lookout is constructed on Balance Island. Such a structure has been built before in the IJsselmeer (De Kreupel).

***Figure 11:** Basic variant*

***Figure 12:** Archipelago*

Figure 11

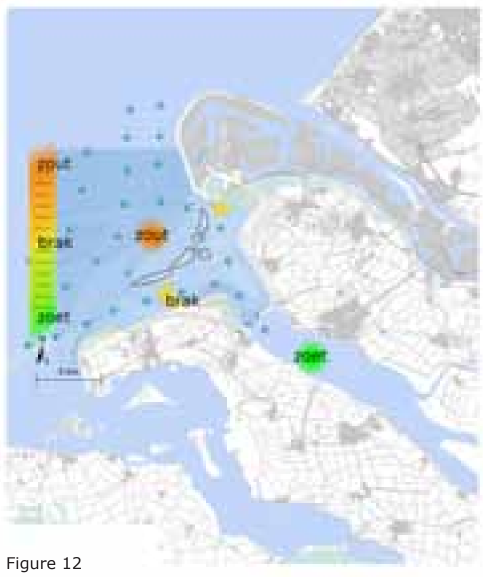


Figure 12

Mega breakwater

The design-variant mega-breakwater focuses on tourism with an iconic breakwater-structure. In addition, the water flow will be concentrated more into the Slijkgat, potentially improving the Balance Island in its function to stabilize the Slijkgat-channel and prevent salt intrusion. One of the existing dams at the head of Goeree is upgraded to a mega-breakwater of 1200m in length. This location called the Flaauwe Werk is considered as a weak link according the Coastal Vision 2050 (lit 6). The mega breakwater creates a growing beach which protects the Flauwe Werk from wave-impact. The dam itself will also get protected by the growing beach and therefore the breakwater is low in maintenance. The mega-breakwater of 1200m

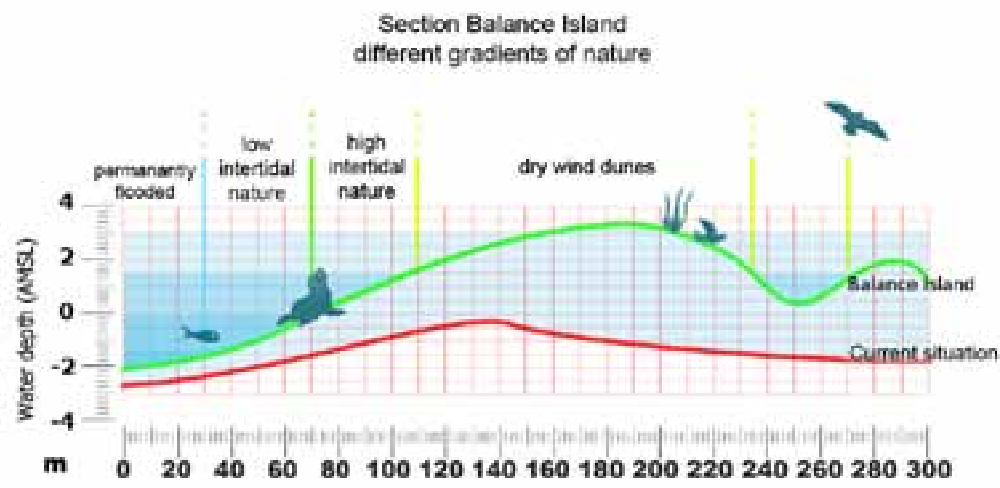


***Figure 13:** Section Balance Island different gradients of nature*

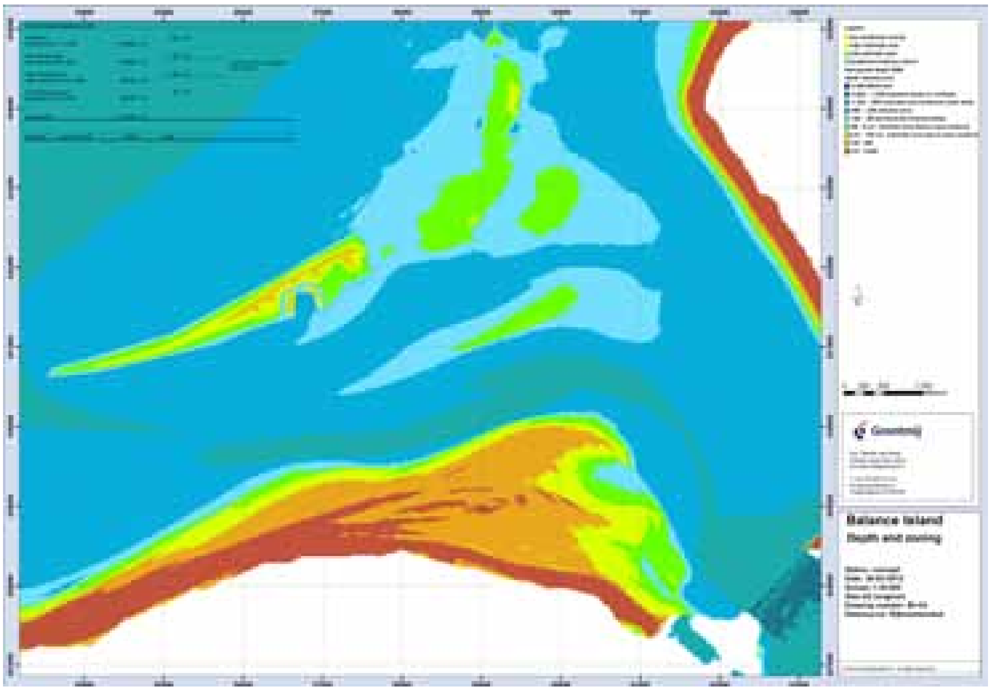


Figure 14: Nature optimized design

is estimated at 6 million construction costs. Further research is required to estimate the return on investment time. The dam provides annual savings on dredging the Slijkgat and coastal security on this location.

Mega breakwater as touristic attraction

The mega breakwater is located at the touristic area of Hoofddorp and can easily become a tourist hotspot. The West beach has an ideal orientation for sunshine and provides a cosy bowl for beach visitors. The East side of the breakwater is a sheltered area ideal for a sea-marina. Interviews with the recreation authority South- Holland gave insights on a demand for a sea-marina of at least 300 places. The dam itself could become a boulevard with a hotel and conference centre as an Icon for Dutch Delta Technology.

Aquaculture

Estuarine areas have a higher productivity of plants and animals compared to the open sea. Additionally, these areas have fewer effects from waves. This makes these areas very suitable for the production of salt harvests such as shellfish and seaweed. Balance Island offers opportunities for all forms of aquaculture. Aquaculture can also be linked to tourism. Fresh and locally produced salt harvests can be directly sold to local restaurants or shops. Types of aquaculture that have limited influence on the surrounding area are accepted in nature2000 areas. This could be for example the cultivation of shellfish or seaweed.

Shellfish production

For several years already many initiatives are launched for an accelerated transition from the current seabed-harming Musselspat fishery to a more sustainable way of fishing. A more sustainable way is to capture Musselspat with specially designed installations. These systems are designed to allow spat to attach themselves on a special surface where they can easily grow. These installations with spat can then be put in special Mussel grow plots. One of the techniques is submerged longlines, which are proven to be successful already at the Oosterschelde. Balance Island creates a relatively calm area where these proven techniques can be applied. Growing Mussels in this calmer estuary is many times easier than at open sea, which reduces risks and makes production more profitable.

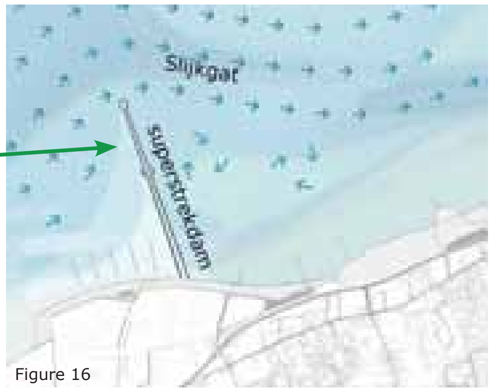


Figure 15: Recreational possibility

Figure 16: Positioning of the Mega breakwater opposite Balance Island

Seaweed cultivation

Seaweed is growing rapidly and is rich in protein, phosphate and other potential resources. It can be used as raw material for various products such as animal food or biofuel. Commercial cultivation of seaweed has not been realized yet in the Netherlands, but pilot projects have already started in the Oosterschelde (Schelphoek). Different species and methods are researched to enable sustainable commercial farming. In addition, it also examines new applications for seaweed. Cultivation of seaweed in open water on a commercial scale is new in the Netherlands and offers chances for Balance Island as a potential pilot location for the first commercial cultivation of seaweed or combined cultivations.

Shellfish as protection

It might be practical to reinforce small parts of the island. This can be at the fairway or at the head of the island for example. Banks or baskets of Oyster shells dampen the wave impact. Oyster larvae attach themselves to mature shells, where they will grow mature themselves, this creates a living reef. The reef both limits erosion in a sustainable way and increases biodiversity.

Figure 17: Artist impression of the Mega breakwater

Economic feasibility

To demonstrate that balance island is a feasible innovation, a social cost benefit analysis has been made (SCBA). The analysis has been performed within the existing Dutch legislation and regulations. The analysis gives a view at possibilities at other locations as well.
Social costs en benefits

The analysis is based on the Nature optimized design. In this design more sand is nourished than strictly necessary with the goal of increasing nature values. In the design the 'passing' marina (for a brief stop) is incorporated. A term of a hundred years is overseen, assuming construction in the year 2020. The used price levels date from of 2012. For both costs and benefits a discount rate is used of 5.5% (2.5% plus 3% risk premium). It is assumed that the investment-phases are: 2017 (25%), 2018 (50%) and2019 (25%).

Costs

The cost which are taken into account are: construction and design of the island and the marina and maintenance costs. The construction costs of the island are based on a calculated volume of sand with an estimated price of 6 Euro per m^3. This price is estimated based on recent works on the project "Zandmotor" (sand engine) and average prices for nourishment in the coastal maintenance. The cost of the marina is estimated by Grontmij based on experiences with the construction of nature reserve and marina "De Kreupel" in nearby IJsselmeer. See table below for results.

Benefits

The benefits from Balance Island come for a large part from an increased value of the ecosystem and savings on maintenance of Slijkgat-waterway. The expected costs for compensatory measures as a result of the Kierbesluit can partially be saved from the expected salt reduction. Some benefits could not be calculated due to large uncertainties.

Cost	Amount (Euro)
Engineering	310.000
Dredging	100.000
Construction of underwater dams	100.000
Construction of protective quay	950.000
Construction reeds and vegetation	300.000
Construction observation post	165.000
Construction jetty	320.000
Total marina	**€ 2.255.000**

Table 4: Construction cost marina and economic value ecosystems in the Netherlands

Subecosysteem coast of Haringvliet	Value [Euro/ha/year]
Coastal Waters	5.798
Intertidal mud and sand	11.153
Beach	7.272
Intertidal wetland	11.628
Dune	24.563

Value ecosystem

The increase in the value of the ecosystem is based on the report 'A pilot study in the consequenses or an open Haringvliet, Scenarios for changes in ecosystem services and Their monetary value' of the Wageningen University (lit 17). The table below shows the values for different subecosystems on the seaward side of the Haringvliet. These sub-ecosystems give direct and indirect contribution to human welfare and are called ecosystem services. These ecosystem services can be divided into; commission services (the funds we receive from nature, including fish), regulating services (such as coastal protection, erosion prevention) and cultural services (including recreation, education, art). The construction of Balance Island gives a shift in ecosystems. Balance Island produces 99 hectares shallow coastal zone and 16 hectares of embryonic dunes. The shift in ecosystem services result in a profit of 880,000 euros per year.

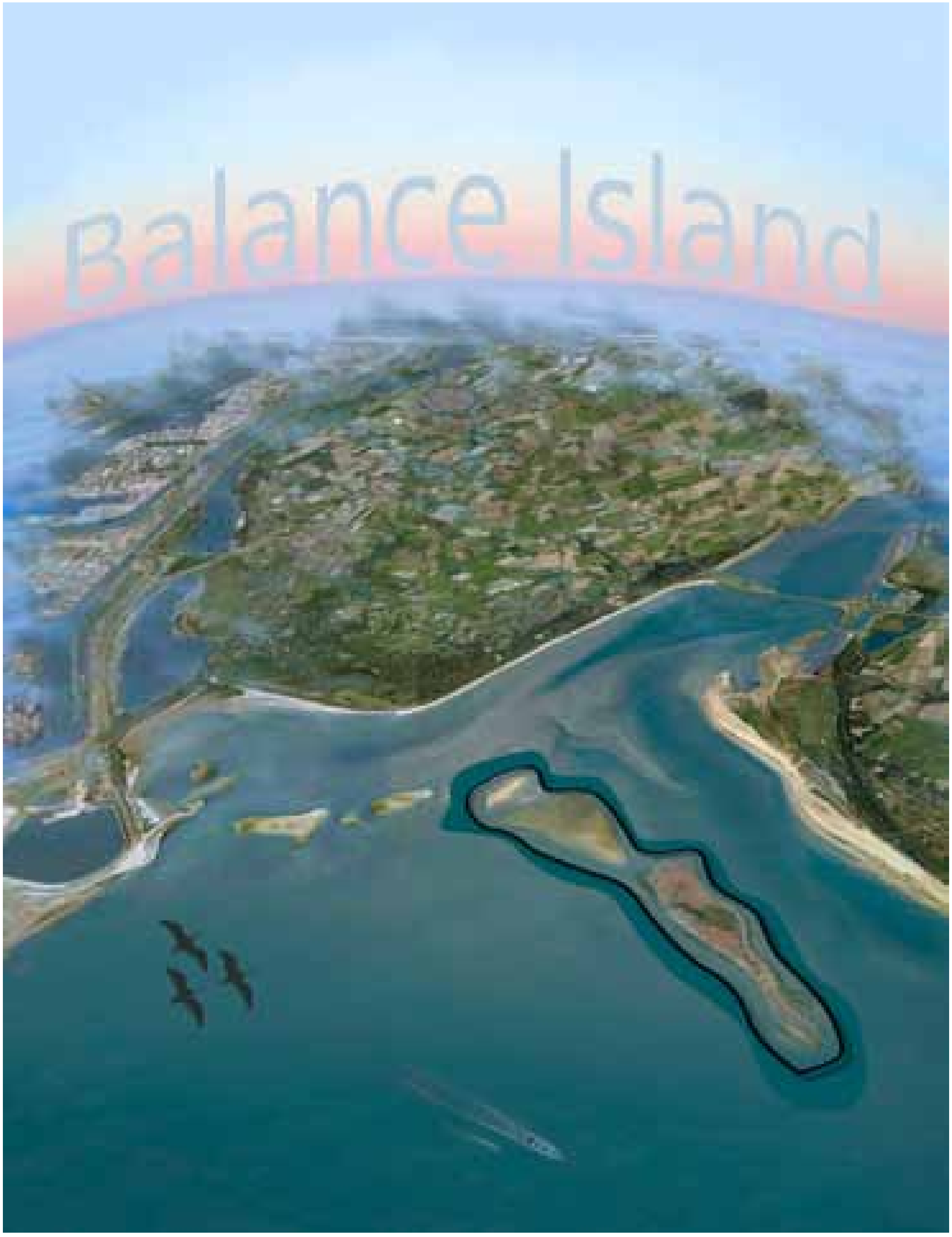


***Figure 18:** Impression of Balance Island*

Reduction of channel maintenance

The expectation is that Balance Island has a positive effect on the Slijkgat-waterway maintenance. By concentration of the flow in the channel it deepens. Interviews with the Port of Rotterdam showed that the Port Authority spends annually €600,000 - €1,000,000 on keeping the channel at -5.5m below sealevel (NAP). These costs are additional to the regular maintenance cost of the Dutch ministry of transportation and watermanagement to keep the area -4m below sealevel (NAP). It is assumed that these additional costs will be saved.

Compensation Kierbesluit

The implementation of the Kierbesluit has led to a number of commitments by the government for compensatory measures. These alternative (financial) measures should compensate for salinization of drinking water. One of the measures is replacing the inlet points. For the waterworks Evides this displacement cannot be avoided because of the low salt tolerance for drinking water (150 mg/l). For Agriculture, higher tolerances are allowed, but crop dependent. 300 mg/l is the upper limit. Until this concentration, crops like potatoes show no detectable damages. The area does not have many salt-sensitive crops. The actual economic damage caused by Kierbesluit cannot be calculated since crop yields are dependent on too many aspects such as intake regime, crop choice, watering method and salinity of the haringvliet.

Therefor the savings from Balance Island cannot be calculated. A rough estimation is that about half of the compensation money can be saved, this is 20 million euro. No annual compensation for loss off yield is calculated, although likely to be beneficial.
Coastal maintenance.

To protect the Netherlands from the sea the coastline needs to be kept in place, this costs 12 million m^3 of sand nourishment per year. The mouth of the Haringvliet contains a lot of sand and does not require much sand. 1,3 million m^3 of sand was nourished at Voorne and 1,9 million m^3 of sand at the island Goeree since 2001. At Voorne and along the northern coastline of Goeree nourishments also have the purpose to increase safety. Voorne and the Flaauwe Werk are weak links in the coastal defence system; the Dutch coastal protection assigned those two places to be reinforced coming decade.

In the past 40 years more than 10 million m^3 of sand was nourished on the beach or as reinforcement of the dunes. The last reinforement was in 2010 (lit 18). At the Flaauwe Werk this is about 5 million m^3. Balance Island reduces the wave load and the coast and probably leads to a higher level of safety. Because also the "sand hunger" in the area decreases this might lead to less required nourishments. Since the system is very dynamic, it is not clear yet how much can be saved by constructing Balance Island.

Moreover, the effects on the coast are not the same everywhere. Voorne has a sheltered position at Northwestern winds, and will be sheltered by Balance Island at Southwestern wind. The effect from Balance Island on the Flaauwe Werk is a shelter at Northwestern winds, but the Flaauwe Werk does have a direct interaction with Balance Island regarding flow, tide and waves. The eastern head of Balance Island is principally unprotected and growth and movement of banks can have an effect on the coastline.

This might require some fine-tuning to shape an optimal situation. The cost for this is roughly estimated to be 600.000 euro. This is equal to the estimated saving on coastal maintenance cost by Balance Island. These are therefore not calculated as savings in the analysis.
The SCBA shows that balance Island has a positive score. The value of the ecosystem increases, the dredging expenses go down and there are less mitigation measures necessary for the 'kierbesluit'.

Feasibility

The construction of Balance Island is done with existing techniques used for shoreline maintenance, construction of ports and islands similar techniques will be used as in the project 'Zandmotor' project, which involved the nearshore nourishment of a peninsula. Sand is supplied by dredgers who supply sand from the bottom of the North Sea. Nourishment at areas with a depth of more than 5 meters is most easy. A dredging vessel can just open its cargo compartment to drop the sand on the spot. However, Balance Island mainly consists of nourishments in shallower water. For shallow water press-lines can be used and "rainbowing", in which sand is sprayed. Also bulldozers and excavators can be used if the area is nourished high enough above sea level. This way of working is more labour intensive and therefore more expensive.

The execution of the work can hamper shipping. The major shipping routes go from sea to Rotterdam and experience little disturbance. Local fishing and boating experience more disturbance. The application of Balance Island takes several weeks and requires good weather. It should therefore be performed outside the storm season. As a result of the work plumes of fine silt may occur. Environmental impact assessments for Maasvlakte 1 and 2 have shown that these are temporary and usually disappear within a tidal cycle.

***Table 5:** Outcome social cost benefit analysis*

Balance Island	
social cost benefit analysis (CSBA	(mln. €)
Investment costs	-26,7
Management and maintenance	-10,9
Reduction in Dredging expenses	10,9
Reduction in mitigation costs for Kierbesluit	19,0
Total Contant Value Costs	**-7,7**
Increase in economic value	(mln. €)
Total Contant Value Economy by change in ecosystem	16,0
Total SCBA balance	**8,3**
fit-cost ration	**2,1**

Next steps

Substantiation

The project Balance Island was carried out by a team of young professional. Several interviews were held, including Rijkswaterstaat Public Works, Recreation Board Zuid-Holland, waterworks Evides, Water boards, TU Delft and local fishermen. Students from Delta Academy Zeeland used Balance Island as a study-project, with team-Balance Island as teachers. From all this was concluded that people have many different conceptions of how the natural system will respond to Balance Island and which goals the island should serve. Basically all interviewed parties showed enthusiasm of the potency of this innovative plan.
The functioning of Balance Island as salinity buffer requires further investigation. Hydraulic modelling can demonstrate which salt reduction will be achieved and under what circumstances. In addition, in this way the shape of the island can be optimized and the morphological changes can be estimated better.

Potential

The Balance Island is developed for the Haringvliet in the Netherlands, but the concept of Island Balance can be applied to other locations. Nearby the Haringvliet in the Dutch province Zeeland there are several potential locations which can be improved by Balance Island(s). New islands offer opportunities for coastal protection, tourism, aquaculture and salinity reduction. But even outside the Rhine-Meuse Delta opportunities through Balance Island are expected. Deltas around the world deal with similar challenges in which Balance Island can aid.

Figure 19

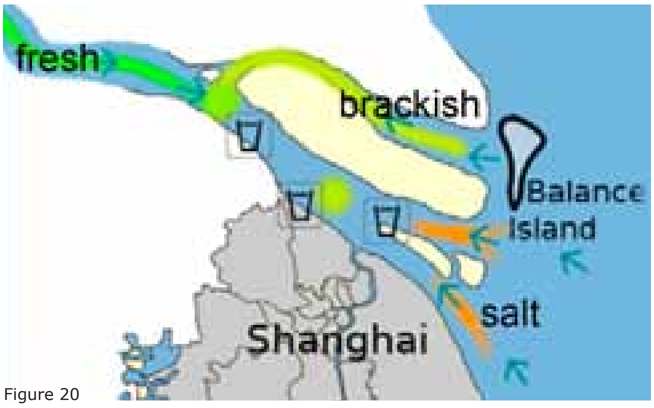


Figure 20

Figure 19: *Salt water flows up the northern mouth during dry season*

Figure 20: *Shanghai Balance Island could prevent intrusion*

One example is the Yangtze River, which is an important water source for Shanghai. During low river discharges, seawater infiltrates the river system. Fresh water inlets, crucial for city and agriculture, are threatened by the salt water. The saltwater flows deep into the northern mouth of the Yangtze River and flows back as brackish water through the Southern mouth. Three out of four of the largest freshwater intake points are in this Southern mouth. During low river discharges this can cause serious freshwater scarcity. As possible solution a Balance Island can be introduced at the Northern mouth. The small sand banks here can be enlarged to a Balance Island. This allows the Northern estuary to retain more fresh water and block upcoming seawater. This variant of Balance Island Shanghai is very interesting for further research. Other potential sites around the globe might be found in the Mekong delta, Hudson Bay and Amazon; all deal with similar challenges as the Rhine-Meuse Delta.

Project group

Acknowledgements

This report is the result of a team of young professionals from Grontmij, Imares and Waterarchitect. This team had not been able to do this without the help and support of many helpful and specialized people who often contributed without self-interest by sharing information, feedback, knowledge, network and motivation.

We would like to express our gratitude to everyone who contributed to the development and promotion of Balance Island.

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Bird photo's

All photo's of birds have been made available by mr. Steve Geelhoek, for which we would like to thank him

Areal photo's Dutch Coast

https://beeldbank.rws.nl, Rijkswaterstaat

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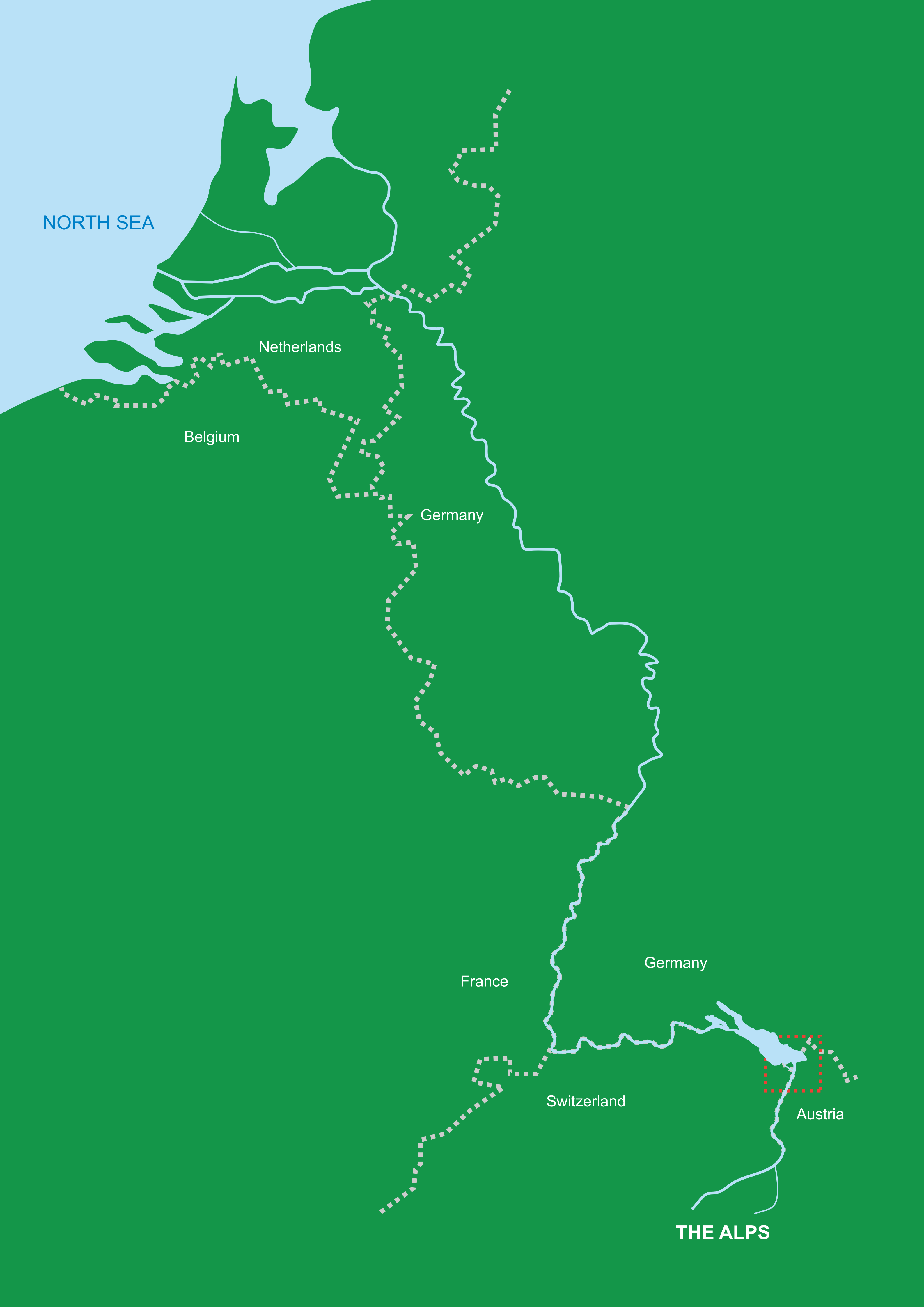
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Switching trajectories in the Alpine Rhine Delta

Liesl Vanautgaerden[1] | Matanya Sack[1]

Project statement

The confrontation between beautiful nature, encroaching urban development and the hard reality of floods with massive sedimentary deposits, is showing the actual limits of environmental governance and design in the Rhine Delta on Lake Constance. Thinking outside the box of traditional water engineering and landscape design, the project integrates a broad palette of measures for high-water control, water buffering, sedimentation management and biodiversity into a single development concept for the entire delta area. As part of a large-scale territorial project, the scarce land resource is transformed by a reversed engineering of a new water trajectory in order to strengthen both landscape performance and appearance. Sustainable water-based living, wastewater treatment, options for energy generation purposes, productive land rehabilitation, and an extended nature reserve encouraging eco-tourism, are examples of latent and new resources that emerge.

1 *ETH Zurich (Swiss Federal Institue of Technology) and Bluelands*

Rhine Delta (context)

The Rhine rises in the Swiss Alps and then flows through Switzerland, Austria, Germany, France and the Netherlands to the North Sea. It is one of the longest and most important rivers in Europe, at about 1,300 km, with an average discharge of more than 2,000 m^3/s. For decades, the watershed problematic has been a challenge in the Rhine basin and subsequent engineering works have attempted to 'correct' the river profile.

The first river segment, the Alpine Rhine, mouths at Lake Constance, at the border between Switzerland and Austria. Investigation on how the Alpine Rhine has been canalized, reveals a formerly dynamic delta landscape that has become increasingly static over the last hundred years. Civil engineering interventions have negated the natural processes of tide, inundation and drainage inherent to the river and lake, by transforming the site with modern flood defence measures, land use infrastructures, agriculture and urbanization. In 2001, the construction of the 'polder dam' along the entire Rhine Delta shoreline, approximately 8 km, created a permanent separation between the delta area and the lake, regulated year-round by pumping stations along the shore.

Figure 1: Alpine Rhine River to Lake Constance

Source: Adapted from http://be.bing.com/maps/

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The New Rhine Canal (problematic)

River engineering has its limits

Despite the 'corrected' river profiles of the Old Rhine (local drainage) and the New Rhine Canal, major environmental and climate challenges remain, which if left unaddressed, will have significant consequences for the Lake Constance region. In fact, the delta area is a manifest broadcast for trends in climate variability. While the frequency of flooding has steadily increased in recent decades culminating in the floods of 1999 and 2005, the spring of 2007 saw paradoxically an all-time low level of the lake, resulting in new half-kilometre broad shorelines where water once stood. At the moment water discharge fluctuates between 40m^3/sec and 3100m^3/sec and water flow is expected to increase by 30 per cent, exceeding the New Rhine Canal's capacity, including its floodplains (figure 2).

Sediment deposition

The Rhine Delta is also the final destination of a broad valley network of rivers and streams through which a huge amount of sediment migrates from the Alps and finally pan-out in Lake Constance. The Alpine Rhine carries each year 2,5 million cubic meters of sediments to the lake (it means 1 sqkm has each year a land level rise of 2,5m). The sediment deposition is underscoring the limited capacity of the Rhine Canal, filling and raising the level of the canal and settling at the canal mouth where it hinders water passage. As the river aggrades the canal, the flood risk increases, keeping the delta a flood prone area.

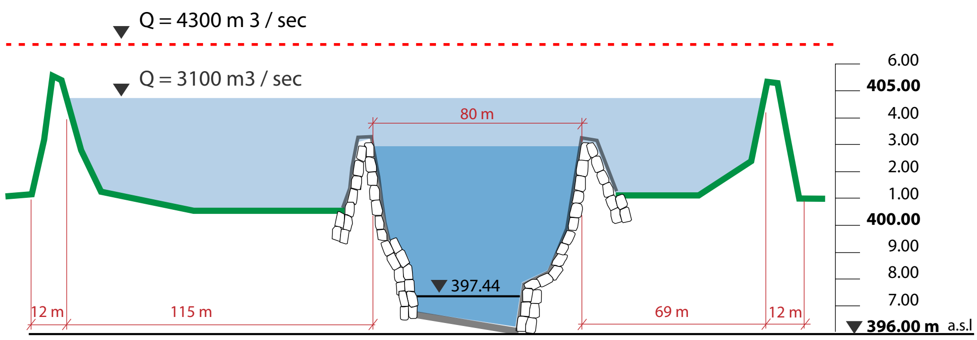


Figure 2: Section of the New Rhine Canal in the delta area: expected water flow increase to 4300m3/sec
Source: http://www.alpenrheinschule.net/alpenrhein/elements/content/2006-01-15.0020113731562046125_0/2006-01-30.2819113862769978415_0/2006-01-16.2922113744336283916_0/base_view?month:int=10&year:int=2011

Figure 3

Figure 4

Figure 3-4: The distribution of sediments deeper into Lake Constance
http://www.rheinregulierung.at/kms/media/uploads/pressemappe.pdf

Threat to drinking water quality

Lake Constance is a major resource of drinking water, used by more than 4 million people mainly in south-western Germany. The large load of sediment deposition has a significant impact on key parameters. To govern the lake water quality, dams have been built to lead the Alpine Rhine river plume with sediments to the deepest part of Lake Constance. Yet, to deal with the sediment deposition at the canal mouth, these dams have been prolonged several times into the lake as shown in figure 5. It is said that the New Rhine Canal is growing annually by 23 m due to the deposition of sediments. Crossing from Austrian territorial water into Germany, it is increasingly affecting the drinking water quality by distributing fine sediments over growing areas in the lake.

Figure 5: *The 'corrected' river profile over time*

Source: Bluelands, adapted from historical maps (Siegfried map & topographic maps)

Urban development

The efficiency of several decades of water engineering projects has supported on-going and random urbanization in the Rhine Delta. As a result, the municipalities of Fussach (3,675 inhabitants, population density 309/sqkm) and Hoechst (7,697 inhabitants, population density 367/sqkm) are characterized by continued sprawl of the fringes into landscapes now faced with an uncertain future (figure 6). In addition to the recent events attributed to climate change, which have had a significant impact on the potential use of this large-scale landscape environment, development pressures tend to weaken the special characteristics

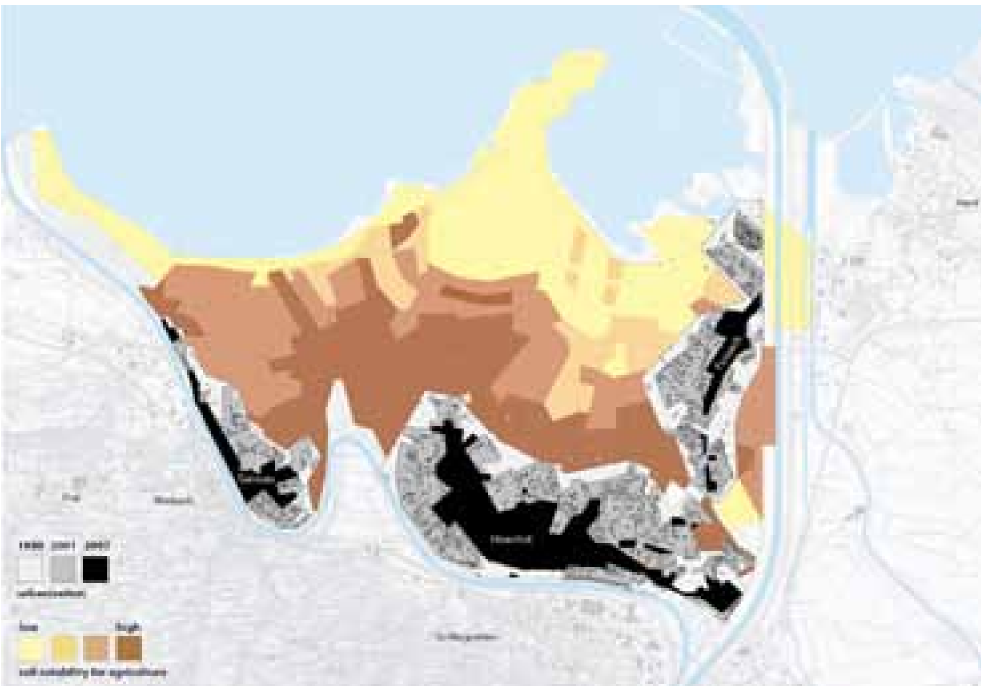


Figure 6: *Urban development is growing rapidly and on the most productive land*

Source: Bluelands

Figure 7: *A continuous plane of changing patterns; the distance to the lake shore is read as an inheret quality*
Source: http://www.vorarlberg.at/english/jpg/aerialviewoftherhinedelta.jpg

of the site. With the construction of the New Rhine Canal, water has been detached from the urban surrounding and no longer plays a meaningful role in its structure. Tools of perception to capture views, depth and movement in this beautiful nature have been neglected.

The Rhine Delta Nature Reserve and vast agricultural landscape (potential)

Environmental assets

Although the delta has been heavily modified by water engineering works, urbanization and agricultural use, it still hosts areas with high environmental value. The most important of these areas is the Rhine Delta Nature Reserve, which extends from the mouth of the old Rhine, the original estuary near the Swiss border, over the mouth of the New Rhine Canal to the east. It is the largest wetland on Lake Constance with an area of 2,000 ha, of which 2/3 are water surface and only 1/3 land (see figures 7 and 8).

The nature reserve is characterised by semi-wild landscapes and habitats that make a particular contribution to biodiversity. It comprises pockets of alluvial forests, marshlands and litter meadows, reed beds, mudflats and shallow water. Over 300 hectares of water meadows are maintained in near-wild condition, providing a habitat for orchids, rare wildflower species, small animals and meadow birds. The estuary lowlands provide a wide variety of sheltered habitats for numerous species of birds and butterflies.

In particular, the delta ranks among the important breeding and rest areas for birds. More than 300 rare types of birds live here. Extensive areas of calm water provide significant spawning grounds for fish, thereby generating a food source for great flocks of aquatic birds. Many of these are migratory birds, who breed in the far north of Europe and fly south in autumn. They are drawn to undisturbed areas of water, where they rest and search for food. Moreover, two migration routes are meeting each other at the Rhine Delta, which results in a great variety of rare species of birds (e.g. Waders, Mergansers). These conditions make Lake Constance the most important winter habitat for aquatic birds in Austria.

Landscape assets - poetic piece of riparian territory

On the grounds of its exceptional flora and fauna, the Rhine Delta is a wetland of international significance (Ramsar site). Part of the nature reserve is a priority habitat under the EU Habitats Directive and Bird Protection Directive, and designated as a Natura 2000 Special Protection Area.

However, it is much more than that. This semi-wild delta area not only provides essential habitats for rare species, it also represents an exceptional landscape resource and recreational facility for human visitors. The Rhine Delta, measuring approximately 3000 hectares, is a vast poetic piece of riparian territory. The huge site features an extremely subtle topography operating within a 5-meter range, with dikes, roads, and drainage canals providing the largest height differences. Within this flat open space, it is possible to see the Alpine ranges circling the entire lake to the south, east and north. The boundaries of the delta are clearly drawn by three very different but intertwined water elements, together highlighting the area as one coherent whole. The lake, the Old Rhine and the New Rhine Canal are indeed very different in nature, each having a specific dynamic and connection to the surrounding. The inner vastness of the area is further emphasized through gradually changing patterns. Urban orchards are followed by productive fields, which transform into marshlands all the way to the nature reserve and the shoreline. The uniqueness of the site becomes even

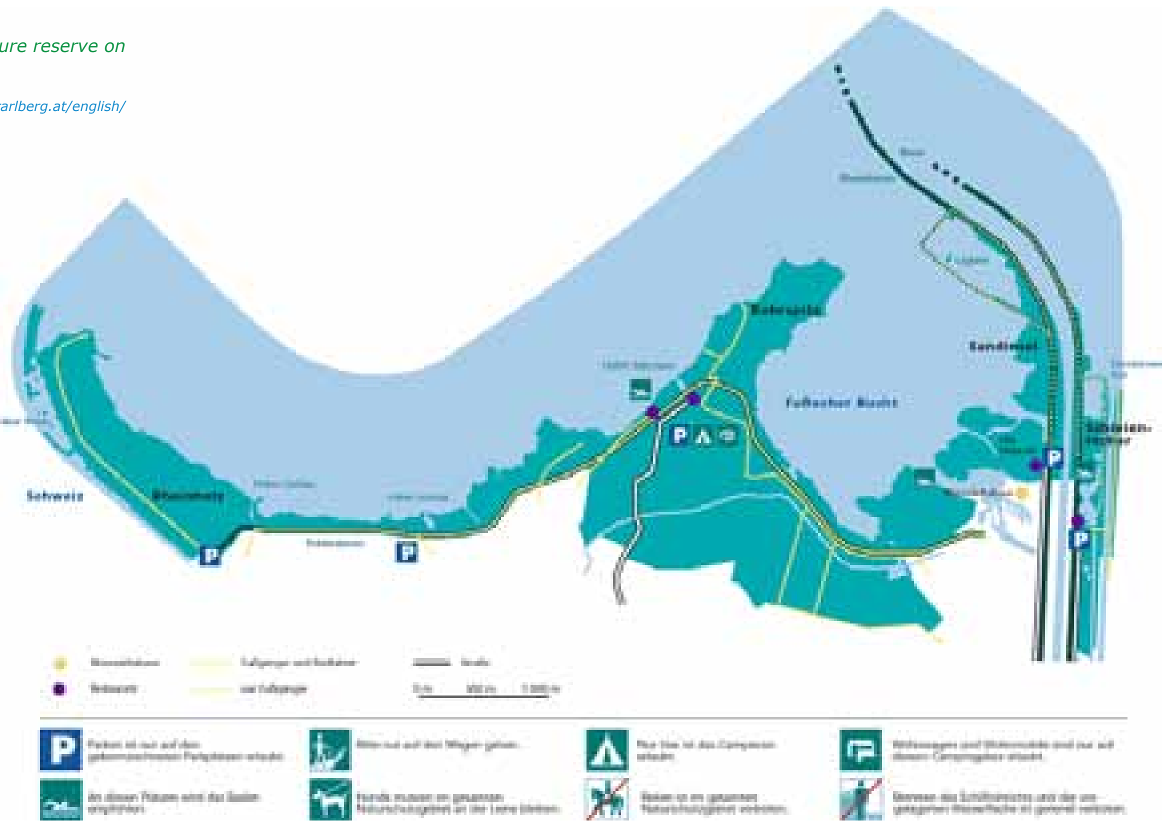


Figure 8: *The nature reserve on Lake Constance*

Source: http://www.vorarlberg.at/english/jpg/layout.jpg

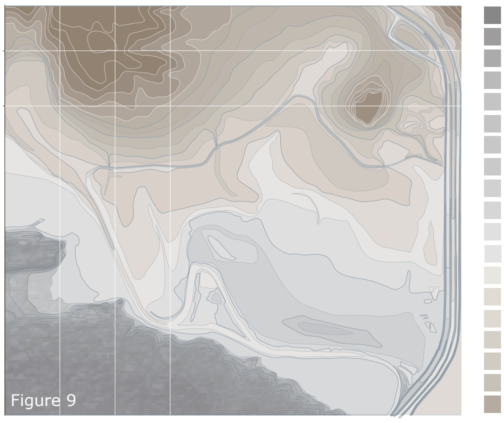
more apparent when perceived in the lake context where mountains tend to rise quickly adjacent to highly urbanized shorelines. One is thus aware of the distance to the lake, which, emphasized by long visibility and openness, becomes an inherent quality of the delta area.

Relinking nature and Rhine river through reversed engineering of a new trajectory (strategy)

The project Switching trajectories in the Rhine Delta implements a series of environmental and climate adaptation measures to ensure a more resilient delta region. In view of the actual inefficiency of the New Rhine Canal, its limits for further corrections and the expected increase of water flow, the construction of a new water trajectory takes centre stage (see figures 9 and 10). It is conceived as a reversed engineering work that triggers an integrated development project operating on a large territorial scale. Gradually changing from a highly engineered construction into a stream with natural state, it accommodates accordingly the flooding risks, the sedimentation processes and the environmental assets as the region continues to develop.

A multi-scalar approach (method)

The Rhine Delta problematic is seen as an opportunity to offer a new spatial vision for the area as a whole. Its future sustainability is addressed at regional, local, as well as more detailed scales, to deal with the wide range of development challenges. These include the various development pressures that threaten to diminish local resources, as well as latent opportunities to create new resources for future generations. In order to adapt to these multi-scalar impacts across environmental, economic and dwelling sectors, the project develops a succinct method of incorporating both perceptual and factual aspects of site information. Based on a combination of system analysis and landscape sectional studies, fieldwork and 3D modelling, it moves back and forth between general vision building on a large territorial scale and specific local characteristics. (See figures 11 and 12)



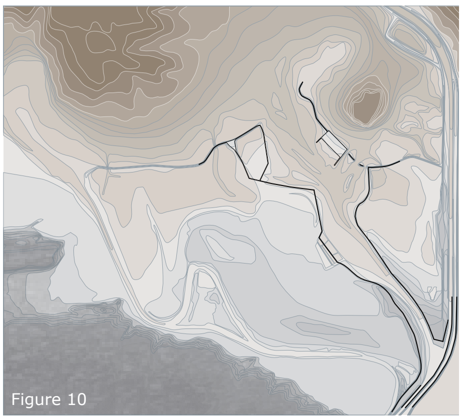
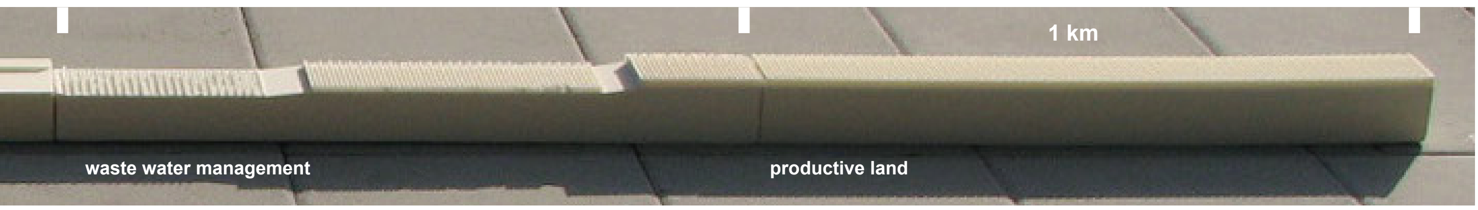


Figure 9: Existing topography
Source: Bluelands, extracted from topographic map

Figure 10: Working with topography: construction of the new trajectory
Source: Bluelands

Figure 11: Design explorations through 3D modelling
Source: Bluelands



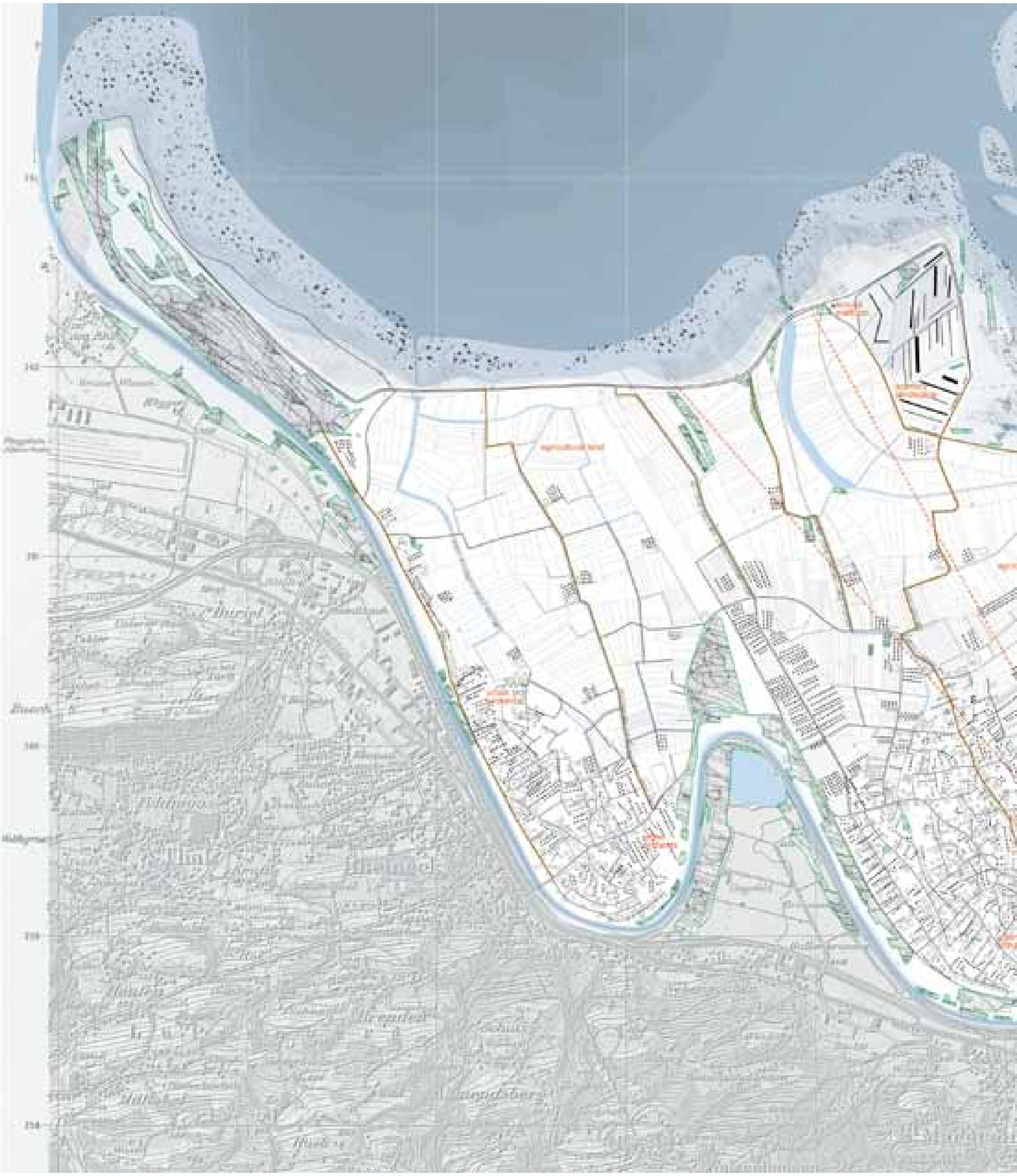


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Figure 12: Structural Plan showing a development vision for the delta area as a whole

Source: Bluelands

Line of least resistance

In order to plan the new Rhine River trajectory, the project seeks a path of least resistance: using limited land resources and energy to return space to the river. Therefore, height levels were weighed against environmental qualities, the suitability for agriculture of neighbouring parcels and opportunities for urban development. In particular, the new trajectory was developed by evaluating the necessary slope and water flow, the available digging depth and the possible section width, which is restrained by existing urban development. It offers at every stage a local section that takes these criteria into account as shown in figures 13 and 14.

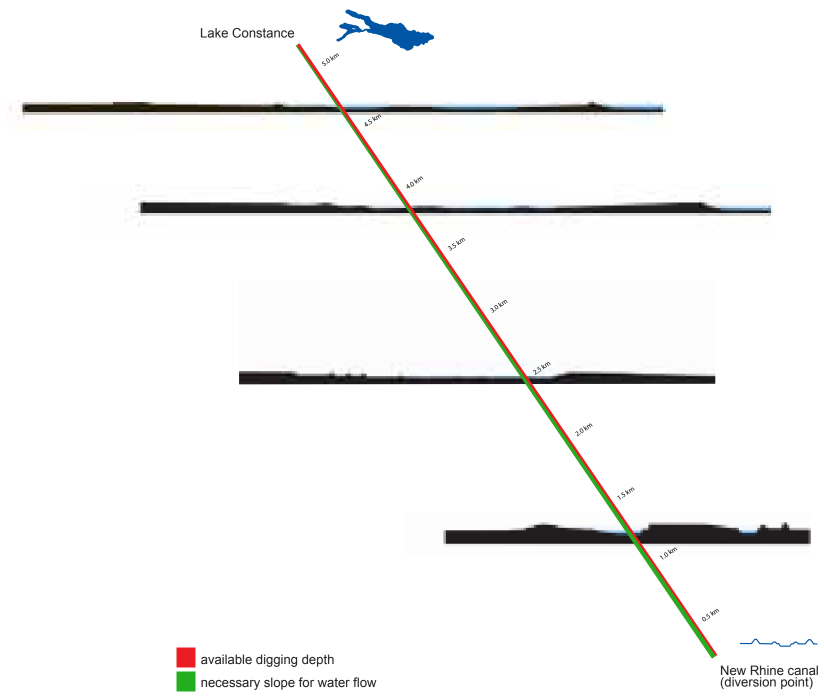
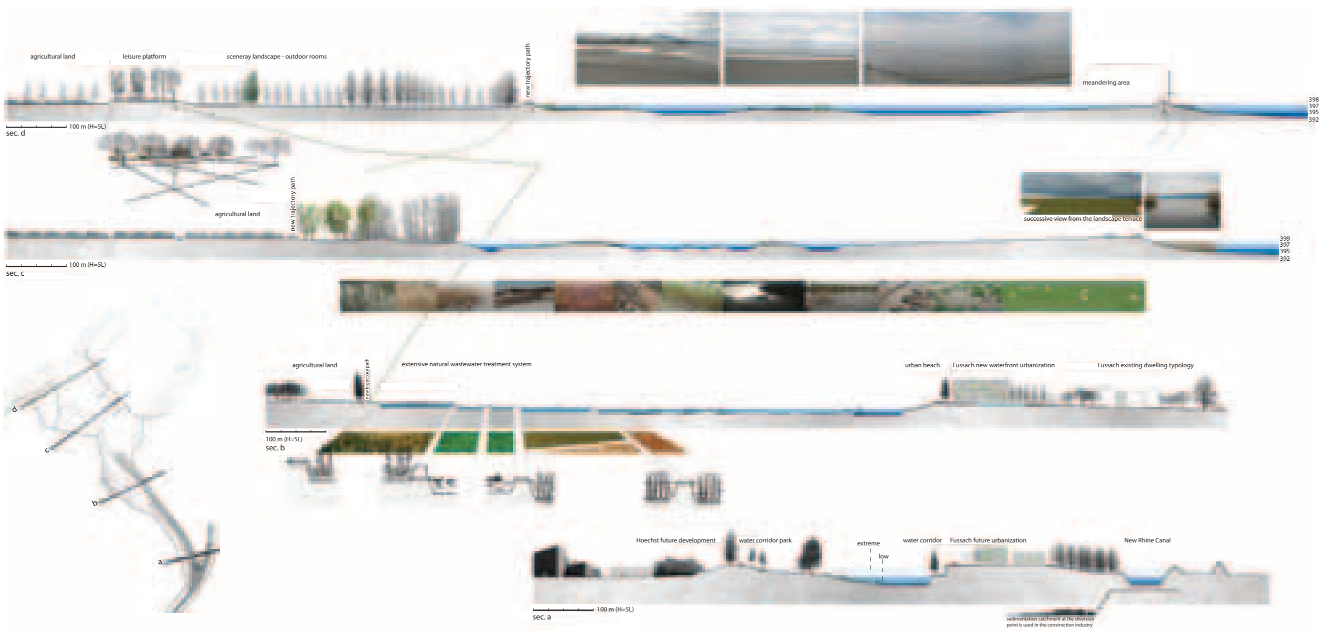


***Figure 13:** Transverse sections investigating the line of least resistance*
Source: Bluelands

***Figure 14:** Sections along the new trajectory showing new interfaces between water and land*
Source: Bluelands



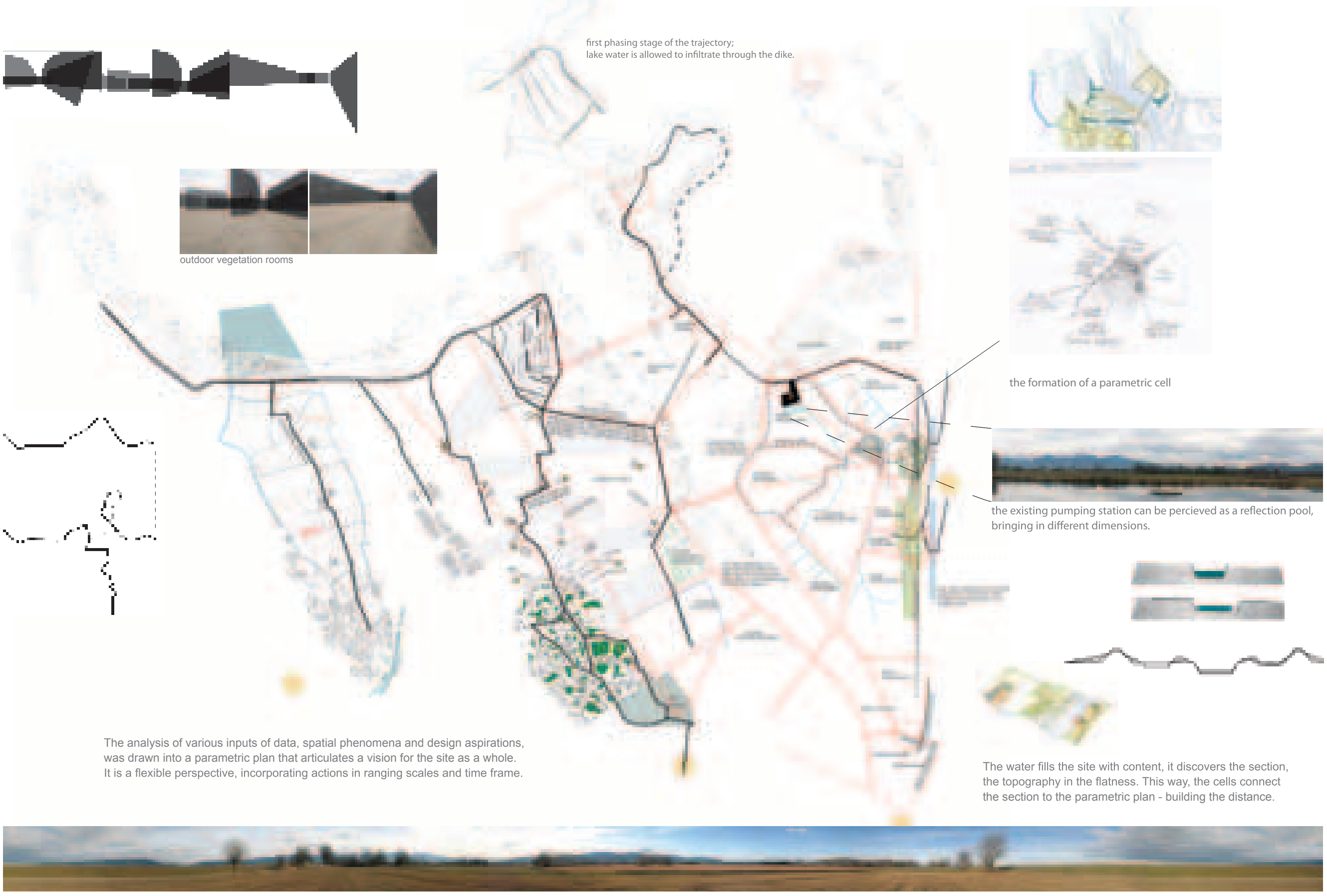
"Cellular" structural pattern for future land use

Landscapes often contain unique elements, local spatial phenomena or configurations that represent exceptional opportunities for sustainable landscape design. It has been the premise of the project to integrate such design explorations at a finer scale into the planning process for the delta area as a whole. In particular, the project includes following design aspirations: the disclosure of the existing New Rhine Canal as an impressive structuring element of the landscape on a larger scale, strategies to sustain the nature reserve, thoughts on movement through the site, as well as required infrastructure, program, connections and views. What results, is a layered spatial development concept that embraces change as part of a "cellular" structural pattern for future land use - all within a reimagined Rhine River corridor (see figure 15).

The cellular pattern starts from local aspects, values and challenges in order to create a large-scale system in which environmental and experiential inputs can fully develop. It is composed of a connecting topography layer and structural layers that reveal future design opportunities, hinting at possibilities for preservation and development at the same time. As shown in figure 14, four landscape sections crossing critical points, align the layers with one another. While this development concept obviously does not solve every area in the Rhine Delta, it does relate short-term strategic actions with long-term perspectives. This is considered crucial in the design of large-scale landscapes, where processes of change are taking place gradually.

Figure 15: *Parametric plan*

Source: Bluelands



A more resilient delta (effects)

Water management

The project explores the landscape as the most important means of improving water storage, supplementary to the water buffering in Lake Constance. Water storage in the Alpine Rhine Delta is considered highly effective as it is at the top end of the catchment area and flow regulation therefore benefits the entire Rhine basin. The focus is on restoring and strengthening the buffering capacity of the landscape in order to address climate challenges of more extreme water discharge fluctuations, and on contributing to the environmental quality and safety of this flood-prone area.

While flood prevention schemes and urban development have, in the past, led to the Rhine River being enclosed in concrete and hidden, other measures, such as creating more room for the river, are considered. Starting from the detected path of least resistance, the New Trajectory applies effective high-water control and water buffering by gradually changing its canal section from a highly engineered intervention into a stream with natural state; an area in which nature can take its course (figure 17). Together with the existing New Rhine Canal, this reversed engineering construction handles both low to extremely high water levels, between 40m^3/sec and the expected increase of extreme water flows to 4300m^3/s (see figures 16 and 17). At a smaller scale, it also creates room to develop sustainable waste water systems. For the village of Hoechst for example, an ecosystem of lagoons is utilized to transform wastewater into freshwater. As shown in figure 14, the constructed wetlands are artificial shallow ponds, reproducing the natural degradation processes and nutrient uptake with the help of aquatic flora and fauna.

Figure 16: *Low water level (Nov.-Apr.)*
Source: Bluelands

Figure 17: *Extreme water level (50 yrs. interval)*
Source: Bluelands

Figure 18: *Construction of the new water corridor: from engineered to meandering*
Source: Bluelands with collage adapted from Mathur, A. & da Cunha, D. (2001) Missisipi floods: Designing a Shifting Landscape. Yale University Press, New Haven and London

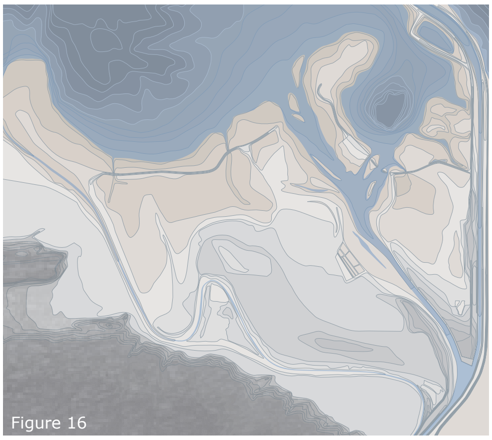


Figure 16

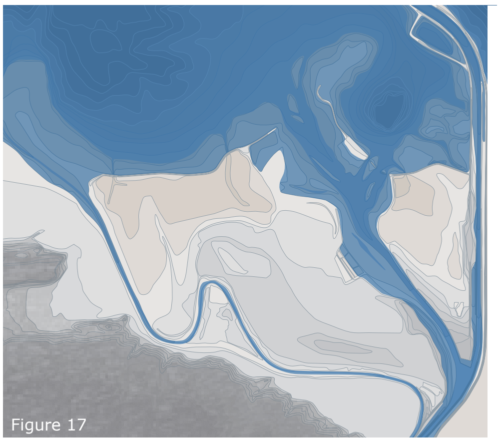


Figure 17

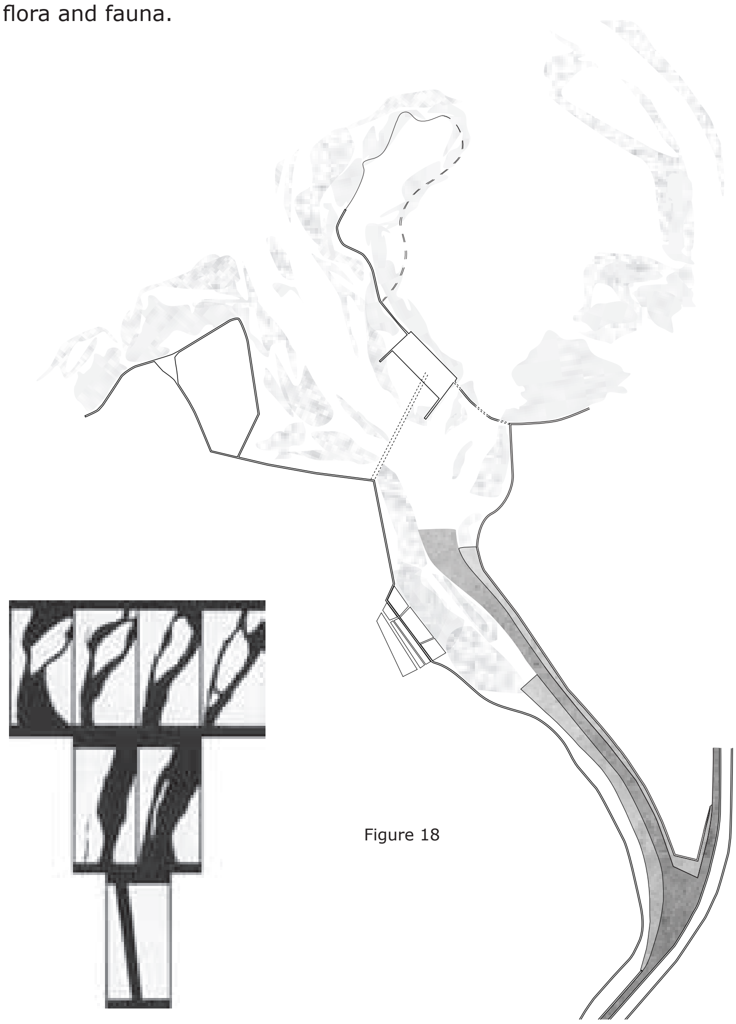


Figure 18

Sedimentation management

Changing from a highly engineered intervention into a meandering river, the New Trajectory obviously incorporates, for both environmental and economic reasons, the process of sedimentation that naturally occurs in the delta. When the water enters the new construction, at the diversion point, heavy sediment is trapped and managed for construction (see figures 13 and 14). The smaller particles are carried further and settle in the meandering areas where river and lake meet and water velocities and turbulence tend to decrease (see figure 20). By allowing the sediment to deposit locally for further extraction and land build-up, the project limits the sediment load eventually washed into the lake and its impact on the lake water quality. It also makes the transformation of a typical Rhine Delta problem visible into a useful and diverse new landscape.

Halt and reverse inland biodiversity loss

The reconceptualization of the river landscape and new shoreline heightens the experience of the continually changing delta that becomes host to an even richer ecosystem than what exists today. In addition to meeting existing reeds, the New Trajectory creates seasonally diverse water situations in order to increase the plurality of habitats. It expands the floodplain for both Rhine and Lake Constance where river and lake are allowed to interact in a more natural manner. The project thus retrieves and incorporates a seasonal and dynamic dimension to the delta area whilst attracting the qualities of the nature reserve deeper inland (See figures 19 to 21).

The project focuses on processes of change and ecosystem creation, in comparison to preservation and protection, which pertain to the identity of the Rhine Delta where manmade ecologies define the present-day biodiversity. Maintenance of near-wild meadows and reed areas, agricultural management, sand deposits or previous floods, have created

Figure 19: *Inland extension of the nature reserve*

Source: Bluelands

natural habitats that contribute to the great diversity of species. These habitats of plants and animals are mostly only maintained if semi-wild cultivation is undertaken. In a similar way, the New Trajectory materializes a balance of manmade and natural forces in various levels of the uncontrolled/controlled and engineered/elemental. It incorporates both temporal and engineered river edges, tides and sediment-related variations, to epitomise a gradient of programmatic and ecological diversity.

Social practice and appropriation of space

The New Trajectory is conceived as an infrastructure that operates beyond its technical section. It induces new landscape qualities that penetrate and restructure the urban by offering new edge conditions, views and connections. The same applies to the existing New Rhine Canal where a reduced water discharge allows partial reclaiming and unfolding of flood plains and dikes. As shown in figures 22 and 23, they create together a new topography where multiple

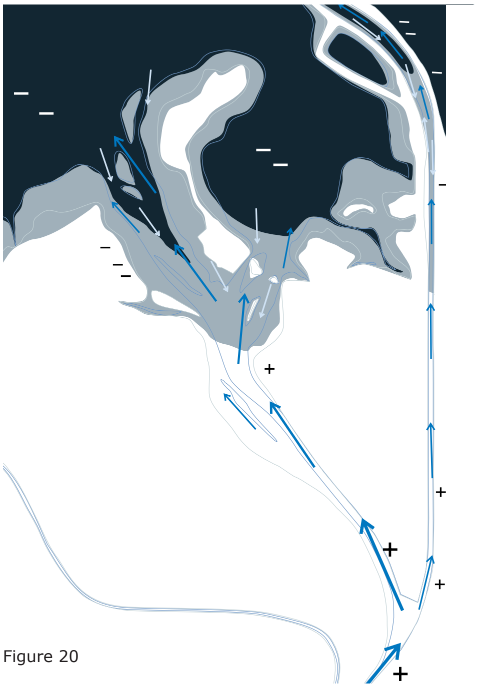


Figure 20

Figure 20: Water velocity: two water systems meet
Source: Bluelands

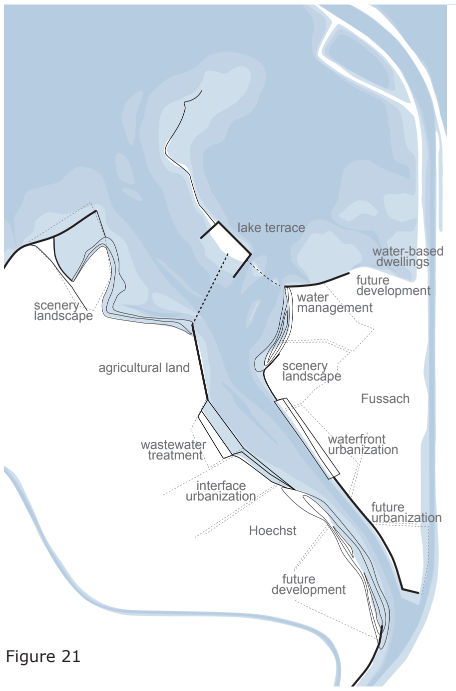


Figure 21

Figure 21: New edge conditions between water and land
Source: Bluelands

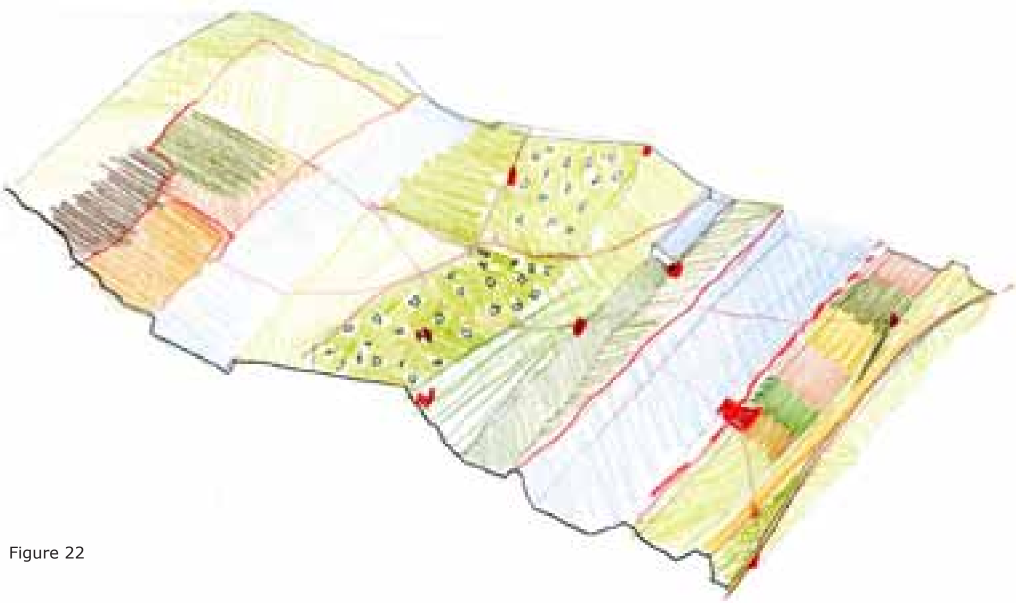


Figure 22

Figure 22: Topographic system penetrating the towns and generating new relations between water and land
Source: Bluelands

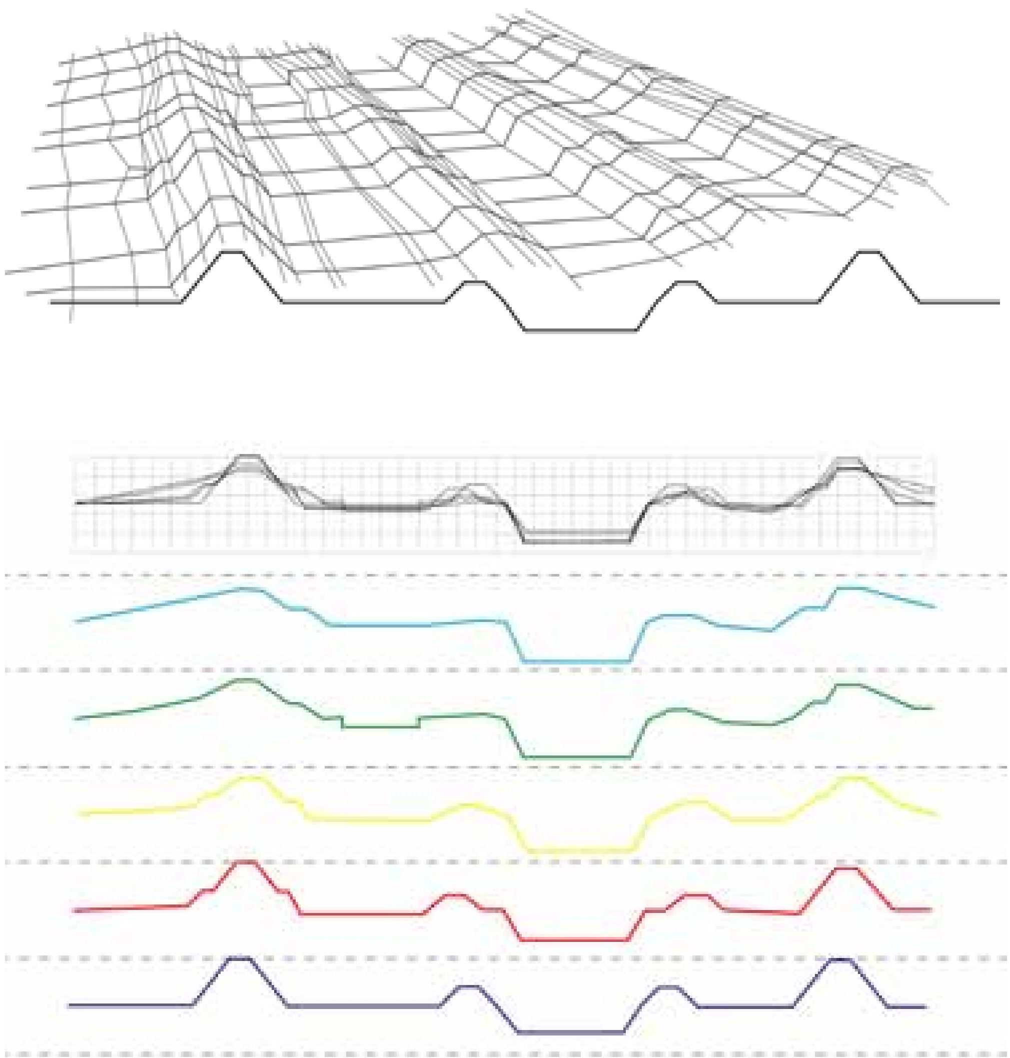


Figure 23: Transformation of the New Rhine Canal section
Source: Bluelands

landscapes negotiate between nature, water and land, and in which infrastructure is operative and intertwined. Centred on the idea of processes, this integrated vision of the whole is offering a diversity of typologies to sustain dwelling and working in the delta area and respond to future demographic and economic changes.

By turning the pastoral, preserved, and static lands of the Rhine Delta into a series of intertwining landscapes and alternate ecologies, the project generates a strengthened contemporary landscape identity specific to the dynamics and qualities of the area. Scenic pathways and cycle routes closely tie together varied areas of biodiversity, (water-based) leisure activities and recreational facilities (see figure 12). The higher the water level, the more paths it covers. As a result, the movement and behaviour of users of the site become subject to the natural dynamics within the delta area.

Through increased visibility and accessibility, encouraging greater usage and ownership and clarifying the function of every part of the open space, opportunities for social behaviour are significantly increased. Moreover, the diversified Rhine Delta will inspire people to discover how the place came to its current state and how it will continue to evolve. The re-naturalised and newly accessible river corridors will then form a more central part of local everyday action and environmental commitment.

Economic performance and resource efficiency

The Rhine Delta as a whole is the basis and the core structure for the development strategy, putting the lake area on a path to a resource-efficient and sustainable growth. On the one hand, the project enhances and restructures existing qualities and socio-economic activities. On the other hand, a strengthened local identity and image is envisaged by developing the New Trajectory as a line of least resistance, using limited land resources and energy to give the necessary room to the river. The territorial approach of the project also detects latent opportunities to create new resources for future generations, making it possible to explore innovative avenues of development. Possible long-term effects include sustainable water-based living, wastewater treatment, the development of hard infrastructure for energy generation purposes and sedimentation industry at the diversion point, productive land rehabilitation, or an enlarged nature reserve for eco-tourism, unique in the context of Lake Constance.

To ensure the long-term viability of this rural delta area, the project thus puts forward a territorial competitiveness scenario for a gradual revitalisation and restructuring of the Rhine Delta of which the environmental quality and resilience will be consistently higher. Local identity is at the core of the territorial strategy, which makes it possible for unused or neglected resources to regain their value and to give rise to unique products resulting from unusual combinations of different elements and sectors. It encompasses, for instance, agricultural modernisation within the perspective of managing the delta area, its natural resources and recreational opportunities. While the project envisions (organic) farming on the most fertile land, it is no longer solely confined to its food-producing function.

Figure 24: The New Rhine Canal is re-claimed, allowing new uses, connections and views
Source: Bluelands

Improved environmental governance (challenge)

Territorial project – mobilising territorial capital

The premise of the project is that a large-scale landscape development is needed to adapt the Rhine Delta to climate change, to refine and restore its hydraulic and sedimentation patterns and alter urban growth accordingly. It therefore adopts a territorial approach that evaluates local capital in an integrated manner, surpassing the sectorial development policies of agriculture, tourism, community measures, etc., that rural areas are usually only acquainted with. Key element of this territorial strategy is the systemic vision of the whole that represents a framework for supporting environmental and climate synergistic actions. It recognizes which distinctive features can be enhanced as well as what interactions need to be created between scattered elements. In the dispersed inhabited and flood-prone delta area, isolated measures that do not form part of a systemic approach have appeared to be not conclusive.

Landscape architecture is probably the discipline capable of dealing with the incredible scale of landscape, of time and complexity and of delivering a comprehensive design approach for sites like the Rhine Delta. Yet, such major hydrological projects require broad political support and its actual development depends on the long-term willingness of the players involved. Territorial capital does indeed not only refer to the assets of the area (activities, landscape, heritage, know-how, etc.), but also depends on how people imagine their future.

While 'Switching trajectories in the Alpine Rhine Delta' may seem utopian at the outset, the point of departure is the concrete situation, constraints and challenges. In order to serve as a catalyst for the future, the project needs to transform into a territorial programme that allows shared analysis and vision-building, grasping phases, sequences, and the time needed to fully implement measures, and their progressive impact on the area.

Project of projects – incorporating human resources

As a means of shaping, defining and consolidating the project over the long term, the spatial development concept of the 'cellular structural pattern for future land use' plays an important role (figure 15). Rather than offering a finite design, it represents a planning approach to align bottom-up dynamic with top-down project implementation. By integrating actions in ranging scales and time frame within the overall transformation of the Rhine Delta, it shows a flexible framework with room for manoeuvre and design by the players themselves. Opportunities for joint local action range from smaller scale recreational initiatives to projects of waterfront urbanization. Each time, public and private figures will be invited to become part of a local partnership to broadly negotiate and develop these smaller scale projects, which, extracted from the inherent complexity of the area, will be easily understood. This gradual process of participation and evaluation through successive experiments makes it possible to refine a vision of the whole that is well positioned within time and space. Respecting the existing responsibilities of stakeholders, this open-end strategy also achieves solidarity and economy of means by policy coherence and joint actions.

EU integrated project – integrating policy instruments

The Rhine Delta on Lake Constance, with its 3000 hectares located on the border between Switzerland and Austria and across from Germany, is an extraordinary laboratory in large-scale landscape management and environmental governance. Lake Constance is under a common responsibility of all three riparian countries, but there is no legally binding agreement as to where the boundaries lie. Moreover, a huge variety of international, national, regional, and local bodies exist that, each from a specific expertise, aim to govern the region in view of environmental and climate challenges. However, as today's complex challenges like climate change do not respect rigid boundaries, new types of governance are required to improve implementation of effective development strategies.

Therefore, the objective of the project should also be understood as to catalyse changes in policy development and implementation by providing an integrated solution to environmental challenges. In this sense, it fits under the new type of EU projects that operate on a large territorial scale and in a cross-sector manner, called "Integrated Projects". These territorial projects are to improve the implementation of environmental and climate policy and their integration into other policies, especially by ensuring a coordinated mobilisation of diverse Union, national and private funds. A project like 'Switching trajectories in the Alpine Rhine Delta' could be sourced from Union funding programmes like the LIFE programme, in particular the sub-programme for Climate Action, together with other financial instruments like the Structural Funds, which prioritize climate change and cross-border cooperation, in addition to national and regional sector funds.

Figure 25: *In between waters*
Source: Bluelands

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Figure 26: A new vision for the Rhine Delta

Source: Bluelands, aerial image from http://www.vision-rheintal.at/fileadmin/VRuploads/PDF/Downloads_A-Z/Karten_Bilder/Orthofoto_2006.pdf

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Widoro
Sumberejo
Purworejo
Pacitan
Nanggungan
Pucangsewu
Menadi
Bangunsari
Tanjungsari
Mentoro
Baleharjo
Arjowinangun
Sirnoboyo
Kayen
Sidoharjo
Ploso
Kembang
Sukoharjo
TELENG BAY

E

Optimizing evacuation planning for tsunami mitigation in Pacitan using geographic information system

A case study in Pacitan District, East Java, Indonesia

Fitria Nuraini Sekarsih[1]

Abstract

The city center of Pacitan is one of the vulnerable areas for tsunami. It is surrounded by hills. If tsunami happens, the hills can be the safest place for evacuation. Unfortunately, Pacitan is surrounded by two rivers that could cause the evacuees to be trapped in the city. The limitation access and evacuation time to go to the hills make the evacuation process cannot run optimally. The evacuees need another solution, evacuation to the building called vertical evacuation.

The final purpose of this research is to analyze the optimum evacuation planning for tsunami mitigation using GIS. In general, the research method simulates the evacuation by using horizontal and vertical evacuation. The result shows that ninety six percent of the people in Pacitan will run to the hills if tsunami happens. The evacuation site prepared by government, just cover the evacuees about 6.41% in the day or 9.93% at night by using worst case scenario. Horizontal evacuation method cannot run optimally with the exits facilities.

For vertical evacuation, it needs low or very low risk building. The risk condition in this area just 9.3 % with very low risk and 3.4 % with low risk. By using those building and its improvement, it can cover about 10,650 people worst case scenario. Total number of evacuees who cannot get access to the shelter both in horizontal evacuation and vertical

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evacuation in the worst case scenario is 36,409 evacuees during the day and 39,213 evacuees during the night.

Introduction

The Southern coast of Java Island is located in the subduction zone between the India-Australian Plate and Eurasian Plate. Collision between these plates results in the endogenic activity in that zone being very dynamic. As a consequence, this area is very vulnerable to earthquakes (Mardiatno, 2008). Under seawater earthquake with vertical dislocation is the one factor which causes the tsunami. Consequently, under seawater earthquake in southern coast of Java can be a sign for a tsunami warning.

Pacitan which located in Southern Coast of Java Island is the most vulnerable area. Coastal area has always been the most preferred location for settlements, since they provide the attractiveness and economic opportunities (Dewi, 2010). The cities face many coastal hazards like sea level rise, abrasion, sedimentation, and tsunami.

Tsunami disaster is very rare, but the impact of the damage influences very wide spread area (Tanaka, 2011). After the Sumatra's tsunami in 2004, it is apparent that many mitigation measures are possible to reduce and, perhaps in some cases, eliminate damage (Ramroth, 2007) . One of the important part in evacuation planning is determining the safest route and best location for evacuation.

There are two methods for tsunami evacuation, vertical evacuation and horizontal evacuation (Budiarjo, 2006). Vertical evacuation means evacuating people to higher ground or to higher floor. Horizontal evacuation is based on the hills around the coastal area. It depends on the distance, accessibility, run-up, and remaining time. Not all the people can be evacuated with this method because of the limitation of time. The government needs another way, called vertical evacuation. The vertical evacuation focuses on the buildings that can be functioned as shelter to protect the evacuees immediately.

One of the important factors in evacuation process is evacuation time. Evacuation time is defined as the available remaining time to evacuate people from tsunami hazard-prone areas to safe places before the tsunami waves arrive on the shore area (Budiarjo, 2006). Commonly, tsunami in Java is categorized into local tsunami (DKP, 2005). Local offshore tsunami would strikes the adjacent shorelines within minutes (NTHMP, 2006). From (DKP, 2005), local tsunami in Indonesia may happen 10-20 minutes after the earthquake. A near source generated tsunami is originated from a source that is close to the site of interest, and arrives within 30 minutes (FEMA, 2008).

Pacitan city is surrounded by hills on its right and left side. If tsunami happens, the hills can be the safest places for evacuation. Unfortunately, Pacitan is also surrounded by two rivers, Teleng and Grindulu Rivers that make most of the evacuees are very dependent on the bridge. If the bridges collapse because of the earthquake, it means the evacuees are trapped in the city. The other solution is vertical evacuation. As a center of Pacitan district, automatically Pacitan has public buildings such as school, hospital, market, office building, etc. that can be developed as Evacuation Shelter Building (ESB) if tsunami happens.

In tsunami evacuation case, the local authorities strongly recommend the evacuation process by walking (Sugimoto, Murakami, Kozui, & Nishikawa, 2003). The average walking speed in disaster evacuation is largely depending on age, physical strength, health, and degree of handicap (Sutikno, Murakami, & Wijatmiko, 2010). Sugimoto, Murakami, Kozui, & Nishikawa (2003) calculated average walking speed in disaster evacuation. From the research, the evacuation speed 0.751 m/s can be used for modeling the evacuation process. On the other hands, Sutikno, Murakami, & Wijatmiko(2010) calculated the average velocity of normal walking speed on the plain surface is 1.17 km per hour.

In Aceh, many people used motorcycles to evacuate. Motorcycle is the most popular personal transportation. Cars are still expensive and not all families are able to afford it. A single household can have many motors. When the evacuees want to evacuate by using motorcycle, traffic jam on the road will occur (Tanaka, 2011). The same condition happens in Pacitan where many people use motorcycle as main transportation. Learning from tsunami Aceh, it is better to make a route and evacuate people by walking.

Integrated remote sensing and Geographic Information System (GIS) can be utilized to determine the best location for evacuation. Evacuation plans are commonly created by choosing main roads (Laghi, 2007). The best routes are used to determine the safest places for evacuees. High resolution image like Quickbird can be used to identify the existing facilities, houses, populations, damage infrastructure like gases station, etc. Not only just for a moment after earthquake attack the city for saving live, but GIS is also used to select public buildings for vertical evacuation. Those public buildings can function as places for taking care of the victim, accommodating the evacuee, public kitchen, education, etc.

Research area

The research area totals 4696 ha. It is located in the city of Pacitan and surroundings. In the west, east, and north it is dominated by hilly area and the south is Hindia Ocean. Figure 1 shows the research area.
Pacitan District is one of 38 districts in East Java Province. It lies between 110º 55’ - 111º 25’

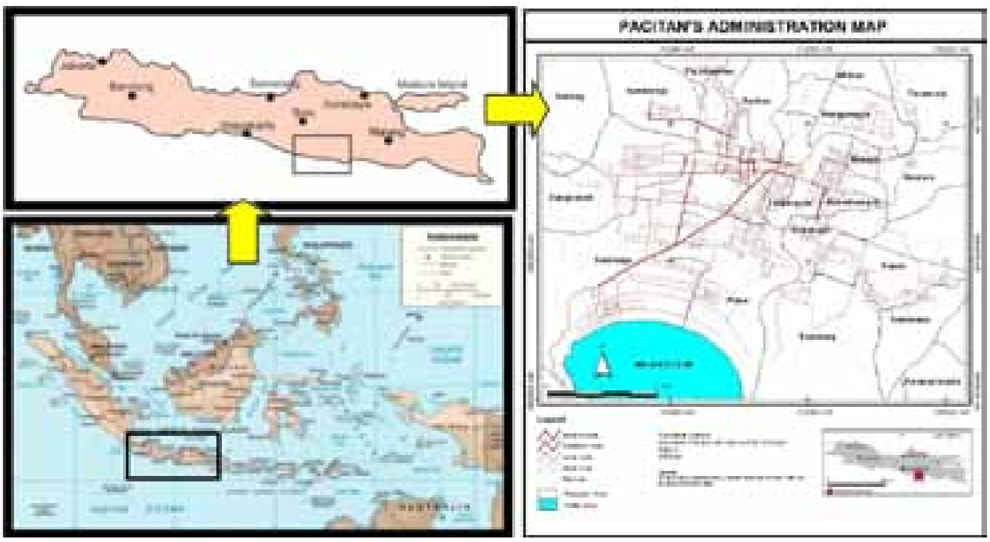


Figure 1: Research Area
source: data processing, 2011

E and 7º 55’ - 8º 17’ N. Pacitan has 138.987,16 Ha wide area. The majority of these areas are hills, mountains, and steep ravine in the mountain range. In the administrative district is divided into 12 districts and 171 villages. The administration boundaries in Pacitan District are Wonogiri District in the west, Hindia Ocean in the south, Ponorogo District in the North, and Trenggalek District in the east.

Research Design

Research design

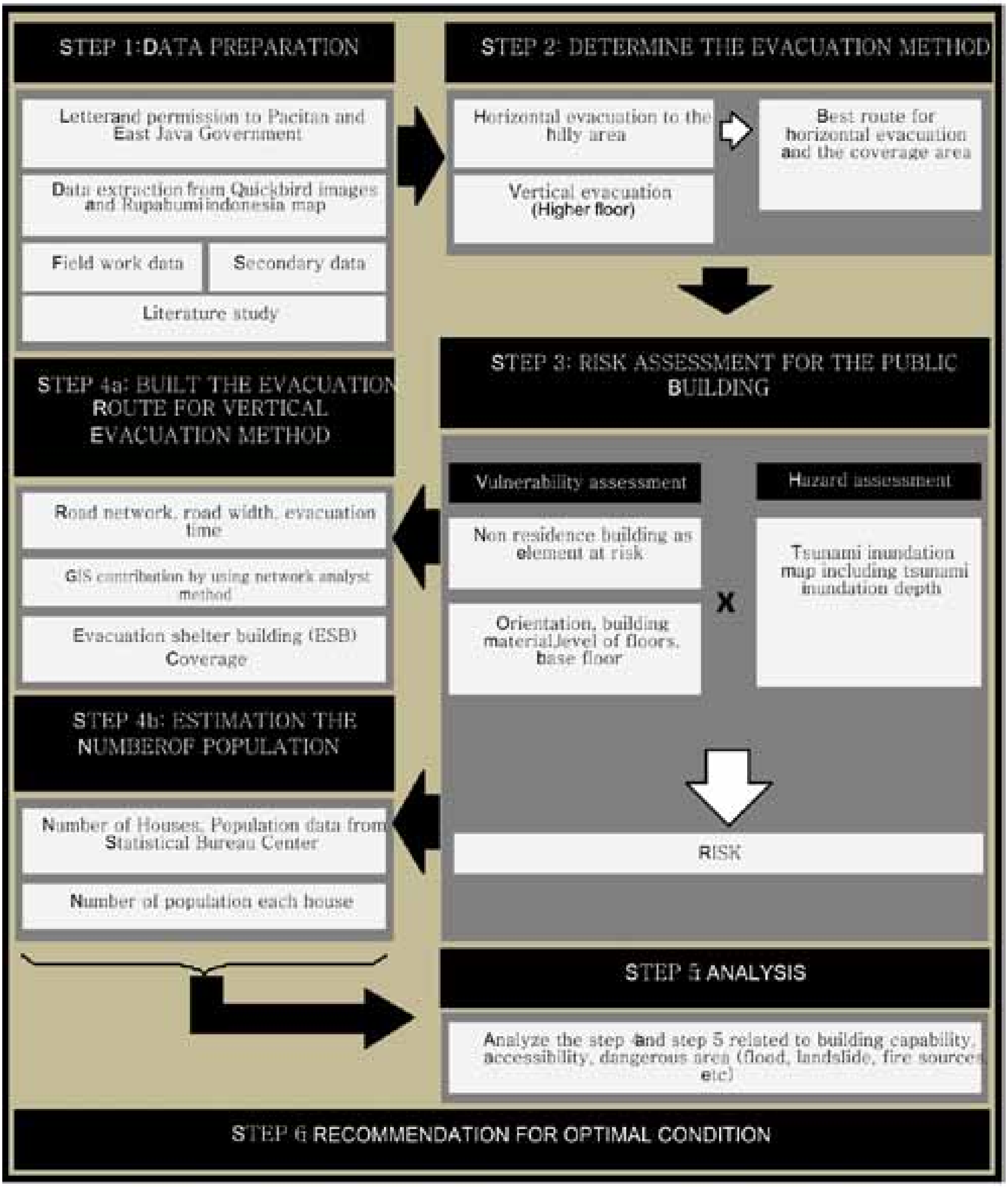


Figure 2: Research Design

The final purpose of this research is to analyze the optimizing evacuation planning for tsunami mitigation using GIS. In general, the research method consists of several parts, they are:

1. Data preparation (Rupabumi Indonesia map, 1:25.000 scale, sheet 1507-431; Quickbird Image 0.6 meter resolutions, recording in 2006; tsunami hazard potential by using Mw. 8.5form Mardiatno (2008); Pacitan in figure2009 and 2010; total number of students and teachers from Dinas Pendidikan Pacitan (Pacitan Education Agency 2010); number of Pacitan's officers from Badan Kepegawaian Daerah (Local Employment Agency 2010); and road network.
2. Determining the area that is covered by horizontal and vertical evacuation method within limitation evacuation time. It is recommended to use vertical evacuation in the areas located in the hills that are not possible to reach.
3. Risk assessment public buildings. It depends on the element at risk (building) and tsunami hazard. The factors that influence the vulnerability are building material (BM), base floor (BF), building level (BL), and building orientation (BO) and the hazard assessment depend on the tsunami inundation depth.
4. Building the evacuation route for vertical evacuation method and estimating the number of population. This includes the number and density during day and night scenario and analyzes the building capacity based on the number of population and evacuation time. In this step, the final analyzing ESB based on the maximum number either day or night scenario and the worst case scenario.
5. Giving recommendations.

The research design is shown in figure 2.

Result and discussion

Based on the evacuation route and location (Figure 3), there are 13 site in Pacitan for evacuation. The sites are Jaten(open land), Bangunsari (garden), Sumberharjo (open land), Pucangsewu 1 (open land), Pucangsewu 2 (mix garden), Gantung (mix garden), Tanjungsari (mix forest),Giri Sampurno hill (open area), Purworejo (Mardi Utomo kindergarten), Mentoro (open area),Siwitan (mix garden), Sukoharjo (mix garden), and Kembang (open area).

From Mutaqin (2011), 90% of the people in Pacitan know the safe location if the tsunamis happen and 86.7 % know the route to the site.

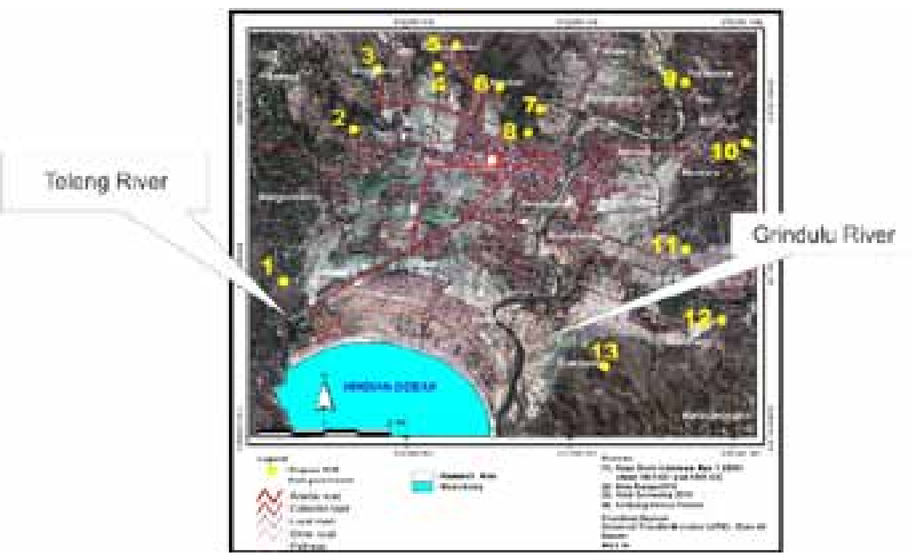


Figure 3: Evacuation site in hilly area prepared by Pacitan Government
sources: data processing, 2011; field work, 2011

Road accessibility for evacuation

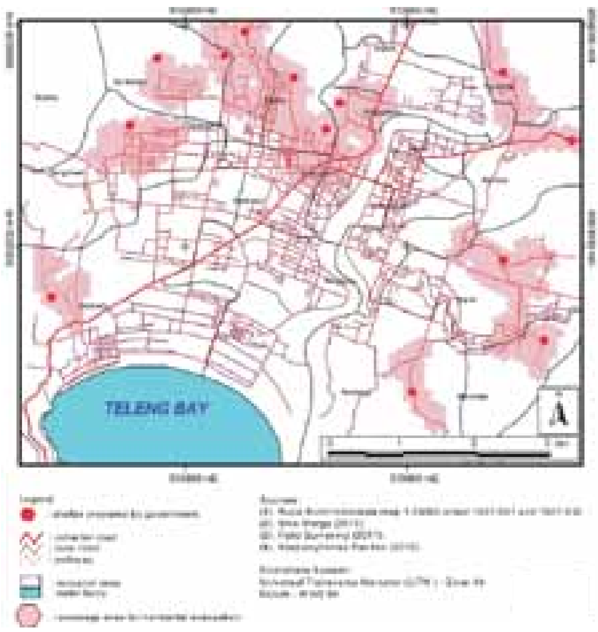
According to figure 3, most of them are hills for evacuation places. The places are not designed for long term evacuation because of the limitation facilities in it. But due to Aceh tsunami 2004, hills are the main destination for evacuation. Not only for a short term evacuation, but in Aceh 2004 they decided to stay in the hills even though tsunami was over. Tanaka (2011) said that they prefer to stay in the hills for many days because they are very afraid of the tsunami occurs.

The site and evacuation route (Figure 4) prepared by the government needs to be evaluated. The narrow coverage area makes the limitation for evacuees' access to the hills is limited. From this scenario, that's why people need another choice for evacuation, vertical evacuation method. For vertical evacuation absolutely prepare the building for an evacuation site.

A

Figure 4:

(A) Evacuation site coverage area for horizontal evacuation (by using evacuees speed 0.751 m/s),



B

(B) Evacuation site coverage area for horizontal evacuation (by using evacuees speed 1.34 m/s

Source: data processing, 2011

Building for shelter

A vertical evacuation building is a building or earthen mound that has sufficient height to elevate evacuees above the level of tsunami inundation, and designed and constructed with the strength and resiliency needed to resist the effects of tsunami waves (FEMA, 2008). The ideal condition for ESB is a building with low risk. Risk is a function between hazard and vulnerability. The simulation of hazard by using Mardiatno (2008) simulation by using worst case scenario with 8.5 Mw earthquake simulation (Figure 5) and vulnerability calculation, the parameters are building material (BM), base floor (BF), building level (BL), and building orientation (BO).
Mardiatno (2008) has categorized tsunami flow depth in Pacitan in five categories (Table 1).

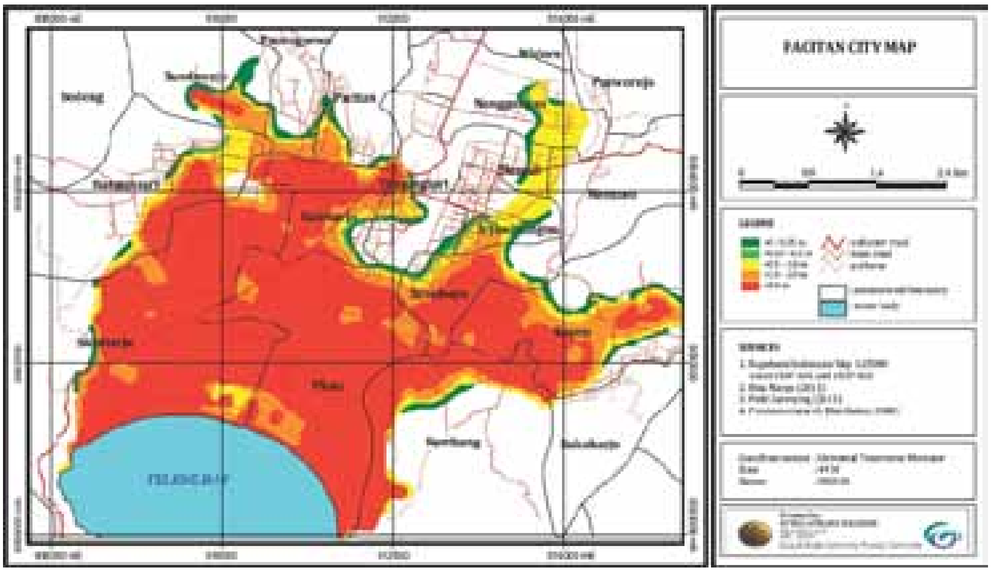


***Figure 5:** Map of tsunami hazard potential in Pacitan based on TUNAMI model using worst case scenario (earthquake Mw=8.5) (Mardiatno, 2008)*

The different flow depth gives the different impact for the element at risk. Each of the depth has different score. Score 1 is given for the lowest tsunami flow depth and 5 s given for flow depth more than 2 m.

No	Tsunami flow depth (m)	Hazard potential	Score
1	>0 – 0.25	Very low	1
2	>0.25 – 0.50	Low	2
3	>0.50 – 1.00	Medium	3
4	>1.00 – 2.00	High	4
5	>2.00	Very High	5

(Madiatno. 2008 with modification)

***Table 1:**Tsunami flow depth classification (hazard potential score)*

The vulnerability parameters are building material (BM), base floor (BF), building level (BL), and building orientation (BO). The parameters will be calculated to determine the vulnerability score (using formula 1). By using ArcGis software, the data from field surveying are analyzed. The vulnerability assessment parameters are showed in Table 2. Each of the parameters has a different score.

No.	Para-meters	Score for every parameter				
		= 1	= 2	= 3	= 4	= 5
1	BM	Reinforced concrete	—	Masonry	—	Wood Frame
2	BF	the opening building on the ground floor without moving object	—	opening building on the ground floor with moving objects	—	buildings without opening on the ground floor
3	BL	5 floors	4 floors	3 floors	2 floors	1 floors
4	BO	The long side of the building perpendicular to the shoreline	The long side of the building forming ≥ 60 ° angle to the shoreline	The long side of the building makes an angle < 600 and >300 to the shoreline	The long side of the building makes an angle < 300 angle to the shoreline	Parallel to the coastline

(Putra, 2006)

***Table 2:** Vulnerability assessment of the public building for every parameter*

The parameter calculation then calculated by using the formula 1

V = 0.256 (BM) + 0.378 (BF) + 0.233 (BL) + 0.133 (BO)..1)

The ideal conditions for public building which has lowest vulnerability score are: building material is reinforce concrete building, the building has opening on the ground floor, the building has multi floor, and the orientation of the building is perpendicular to shoreline. If the total score from every parameter is 1 for the lowest score means that the shelter is strong enough and very suitable for evacuation. If the total score from every parameter is 5, it means that the shelter is very vulnerable and not recommended.

To calculate the risk, the function of the risk is presented in Table 3. For this calculation, public building is an element at risk. The next step, the buildings which have the "very low' classification, it is very recommended for shelter.

For the shelter, a building must be strong and can withstand from tsunami attack. Buildings which have high score vulnerability are feared to collapse during the disaster. That's why, Table 4 in vulnerability's column, "Very High" risk class is given for vulnerability score 4 and 5.

***Table 3:** Calculation of tsunami risk index*

Hazard potential score	Score of vulnerability				
	1	2	3	4	5
1	2 (VL)	3 (VL)	4 (H)	5 (VH)	6 (VH)
2	3 (VL)	4 (L)	5 (H)	6 (VH)	7 (VH)
3	4 (L)	5 (L)	6 (H)	7 (VH)	8 (VH)
4	5 (L)	6 (M)	7 (H)	8 (VH)	9 (VH)
5	6 (M)	7 (H)	8 (H)	9 (VH)	10 (VH)

VL: Very Low,L: Low, M: Medium, H: High, VH: Very High

Total of the public building in the research area is about 350 buildings. The risk condition in this area with "very low" class is about 9.3 %, "low" is about 3.4 %, "medium" is about 2.9 %, "high" is about 83.1 %, and "very high" is about 1.4 % (Figure 6). Figure 7 shows the risk map of the public building. From the result, there are just 9.3 % from total of the building which has "very low" risk. This same problem situation occurred in Samudera Distric in Aceh. From Kari (2008) said that almost 90 % of buildings in the Samudera District is not appropriate as evacuation building.

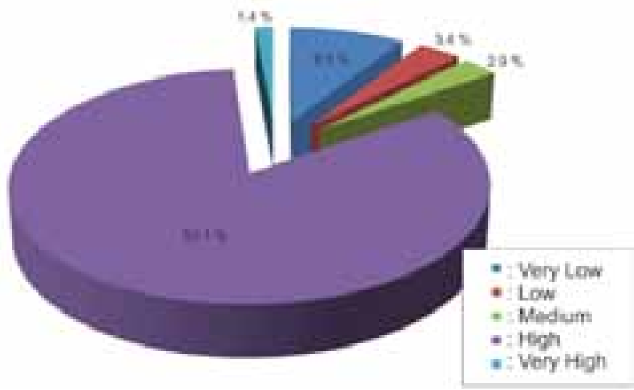


Figure 6: *Risk diagram of the public building in Pacitan City*
Source: data processing, 2011

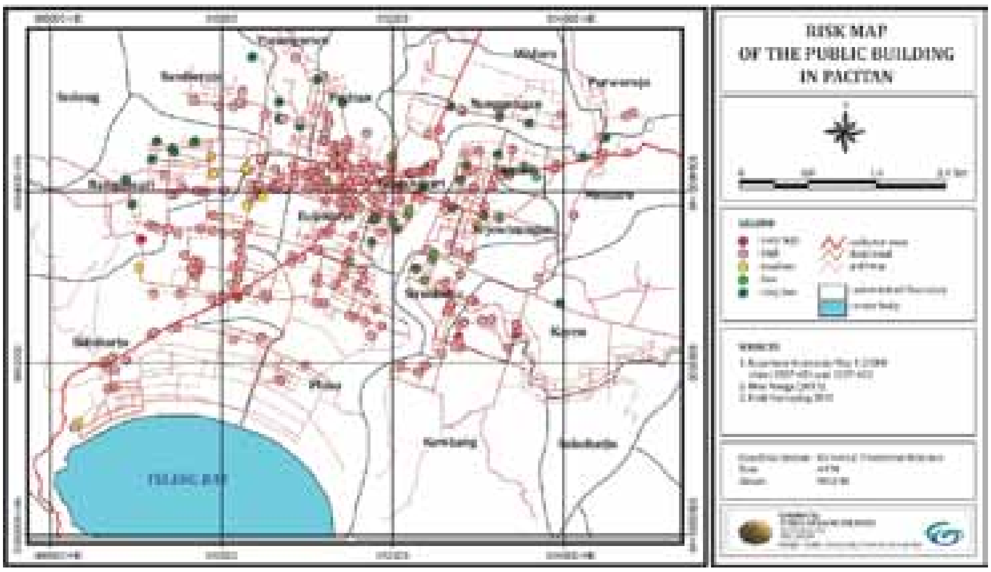
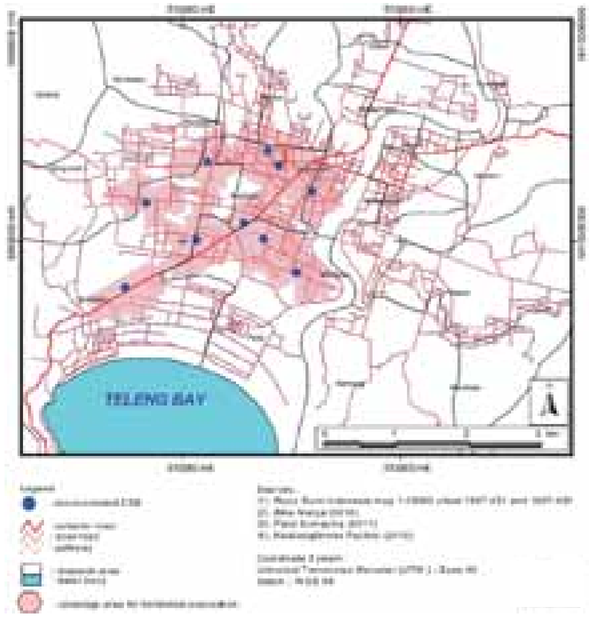


Figure 7: *Risk map of the public building in Pacitan*
Source: data processing, 2011

Not every building which has a low risk can be used as a shelter. Some buildings have a low risk because it just inundated a few centimeters or even not completely inundated. From the calculation, in the study area has "very low" risk and "low" risk classification but most of the building have single floor. It means that the building cannot be used as a shelter. The requirements of the building which can be used as shelter are small risk and consist of at least two floors. Besides building in a strategic location, close to the settlement, in the crowded area, and have good access but the risk is high, this building can be recommended as a shelter. Government can strengthen the building with the building design in accordance with the provisions of ESB and building capacity.

From the calculation of the risk of a public building for the ESB, it is obtained that there are only two buildings namely Darussalam Mosque and Court that have low risk and have more than one floor. Several other buildings also have a low risk but it has only single floor.



A

Figure 8:
(A) Evacuation shelter and site coverage area for vertical and horizontal evacuation (by using evacuees speed 0.751 m/s)

(B) Evacuation shelter and site coverage area for vertical and horizontal evacuation (by using evacuees speed 1.34 m/s)
Source: data processing, 2011

B

Table 4: Evacuation shelter and site coverage areas by using horizontal and vertical evacuation method

	Total	
	0.751 m/s (minimum)	**1.34 m/s (maximum)**
Coverage area	798 ha or 17 %	1550 ha or 33 %
Number of evacuees in day scenario	32046 evacuees or 63.73 %	43542 evacuees or 86.6 %
Number of evacuees in night scenario	23128 evacuees or 41.78 %	38937 evacuees or 70.34 %

(Data Processing, 2012)

In this case the building is not recommended for shelter. The second building is a mosque which has a medium risk, Darul Falah Mosque. Darul Falah located in city center and from the calculation has very low vulnerability but it located in inundation zone 5. After the calculation, Darul Falah Mosque located in class risk "medium".

Other buildings that have high risk but recommended as a shelter during a disaster, because the location is very strategic and it covers dense population around it, for example a school. From the calculation of the risk of public school, all of the schools in Pacitan are classified into high to very high risk. Therefore, it needs recommendation to design public schools as a shelter.

Buildings that have high risk but they are recommended as shelters commonly are schools. However those buildings need to be retrofitted and designed to face tsunami. Finally from the calculations of the analysis and fieldwork, there are 10 public buildings that can be function as evacuation shelter buildings during disaster time. The building cannot be used directly, but it needs improvement in many points of view. For example about the building capacity during day and night scenarios and how to reduce the vulnerability score.

Evacuation coverage area and its capacity

First step calculation, the number of evacuees and its capacity as a result of calculating the population density in day and night scenarios. Population in Pacitan is increasing due to the fact that Pacitan city is the center of governance, trade, tourism, and residential. People go to the city center in the day, and return to their house at night. From this condition, it is very important for modeling in day and night scenarios. For this method, there are two steps, calculating the population in the houses and calculating the population in the public building. The assumption in calculating the population in the houses is that day time is calculated from 06.00 am until 06.00 pm; the family consists of 4 members (mother, father, and two kids); in the day, mother and 1 kid in house and father and 1 kid in outside; in night scenario, all of the family member in the house. For calculating the population in the public building, the assumptions are public buildings more crowded than in the house in the day time and most people back to home at night.

As it was previously mentioned, horizontal evacuation is not optimum to cover the entire evacuees in the research area. Another method is needed to cover the evacuees, vertical evacuation. This method is combined together with horizontal evacuation to make the evacuation process runs optimally.

Similar process with horizontal evacuation method, the covered area is calculated using minimum and maximum evacuees speed. To calculate minimum coverage area the scenarios are calculated by using 0.751 m/s and for maximum coverage area by using 1.34 m/s. Figure 8 shows the coverage area using both scenarios.

The scenario (Table 4) from this chapter combines the vertical and horizontal evacuation together and evaluates this coverage area. The summary of this simulation is presented in Table 4.

Requirement of evacuation shelter

Besides the space requirement for each evacuee, space requirement also considers about capacity score for each building. Each building type cannot 100% be used for evacuation. The reason for this is that each of the buildings has their furniture inside. For example a mosque has only 78% of its space which can be used for evacuation; schools have many chairs and desks, it just 30 % from total space; an office has around 23.6 %; market building is arround 23 %; and hotel arround 26.3 % (Figure 9).

Figure 9:
Properties inside the room.
(A) Office
(B) School
(C) Mosque
Source: fieldwork, 2011

During the disaster time, the evacuees just run to the nearest recommended building and do not pay attention to capacity issues. They just need to save their lives by using 0.93 m^2 wide area. The result of this calculation shows that 9 from 10 building are not enough for the evacuation building (Table 5). After the disaster, evacuees need more space, for example to sleep, to eat, to store their stuffs .etc.

To calculate the maximum number, the worst case scenario is used. The largest number resulted from the calculation is used to analyze the minimum space of the building area. From the calculation, the capacity for the evacuees within the coverage area is not enough. Only SMK Bhina Karya can cover the totally of the evacuees. It means that most of the public buildings need to add space to accommodate all the evacuees during the disaster time.

Table 5: Capacity of the ESB by using evacuee's velocity 0.751 m/s

Building name	Number of population	space requirement for evacuation		Space available	Space requirement (m^2)	Number of people not be covered
		Space required (0.93 m^2/evacuee)	Building Area (m^2)			
SMA 1 Pacitan	5347	4972.71	16575.7	3394.65	13181.05	4252
SMK 2 Pacitan	2002	1861.86	6206.2	4406.22	1799.98	581
Darulfalah Mosque	2750	2557.50	3278.846	1546.35	1732.52	1453
Darussalam Mosque	3016	2804.88	3596	1312.97	2283.03	1914
MTS Anwar	2073	1927.89	6426.3	903.34	5522.96	1781
SMK BhinaKarya	813	756.09	2520.3	3354.28	Enough	-
SMK PGRI 1 Pacitan	1998	1858.14	6193.8	5195.56	998.24	322
SMP N 1Pacitan	9382	8725.26	29084.2	3534.66	25549.54	8241
Court	1438	1337.34	5666.695	1880.14	3786.55	961
MAN 1 Pacitan	2005	1864.65	6215.5	4140.93	2074.57	669
Total	**30824**	**28666.32**	**85763.54**	**29669.1**	**56928.44**	**20174**

(Data Processing, 2011)

By using the existent facilities with recent condition, most of the purpose shelter cannot cover all of the evacuees in its coverage area. It juts only SMK Bhina Karya which can cover the entire evacuees. From the total population that should be covered (which is around 30,824 evacuees), 20,174 are not covered. It means the recent shelter just covers 10,650 evacuees.

By using two methods combine vertical and horizontal evacuation, Table 6 summarizes the scenarios.

	Wide area can be cover	Population	
		Day scenario	Night scenario
Research area	4696 ha (100%)	50,283	55,359
Horizontal evacuation method	341 ha (7, 3%)	3224	5496
Vertical evacuation	479 ha (10, 2%)	By using worst case scenario in vertical evacuation method, it can cover 10,650 evacuees	

Data Analysis, 2011

Table 6: Scenario number of evacuees can be covered by using recent facilities

Both of the scenarios by using vertical and horizontal evacuation with minimum and maximum evacuation velocity cannot cover all the evacuees in the research area. After the scenario, the totality of the evacuees which cannot access to the shelter both of horizontal evacuation and vertical evacuation by using worst case scenario is about 36,409 evacuees in day scenario and 39,213 evacuees in night scenario.

The same situation also happens in Cilacap. Purposed ESB cannot cover all the evacuees in the coverage area. Figure 10 shows the coverage area (service area) based on the travel time and based on the building capacity. The limitation space of the public building makes the evacuation process cannot run optimum.

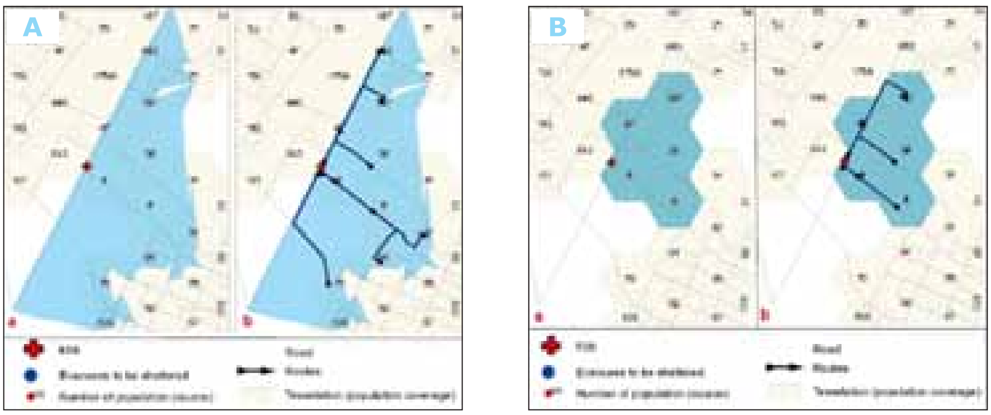


Figure 10:
(A) Service area based on travel time
(B) Service area based on the building capacity
Dewi, 2010

Optimum condition for evacuation

By using scenario with recent condition in Pacitan, the evacuation process does not run optimally if the tsunami occurs. The solutions are improved by the existent facilities and educated local people about mitigation process.

From this scenario, to get the optimum condition for evacuation are improving the design of public building for shelter (Table 7); improving the network including additional road, bridge, adding the road wide; additional shelter; and prepare the tsunami sign and information in

Pacitan. Figure 11 show the tsunami information and tsunami sign in Pacitan. All of them are need additional space and change the base floor condition with the large opening (maybe for parking area etc).

Secondly, the optimal condition for evacuation refers to the human behavior about the mitigation. Evacuees' behavior data is collected by using 100 questionnaires. The

No	ESB	Recommendation
1	**SMA 1 Pacitan**	• It needs additional space about 13181.05 m^2. • The solutions are built the new building or add the level of building. SMK N 1 Pacitan as alternative option.
2	**SMK 2 Pacitan**	• It needs additional space about 1799.98 m^2. • The solutions are buit the new building or add the level of building. Pacitan education agency as alternative option.
3	**Darul falah Mosque**	• No public building within 50 m. It needs additional space about 1732.52 m^2.
4	**Darussalam Mosque**	• No public building within 50 m. It needs additional space about 2283.03 m^2.
5	**MTS Anwar**	• If the building has 3 floors, it still needs additional space about 5522.96 m^2. • Built MTS Anwar with 4 levels or built the new building.
6	**SMK Bhina Karya**	• -
7	**SMK PGRI 1 Pacitan**	• If the building has 3 floors, it still needs additional space about 998.24 m^2. • STKIP PGRI Pacitan as alternative solution (but it built in process)
8	**SMP N 1 Pacitan**	• If the building has 3 floors, it still needs additional space about 255492.54 m^2. • Gazebo and SDN Baleharjo I as alternative solution.
9	**Court**	• No public building within 50 m .It needs additional space about 3786.55 m^2
10	**MAN 1 Pacitan**	• If the building has 3 floors, it still needs additional space about 2074.57 m^2. • Pacitan Social and Labor Agency

Table 7: Purpose ESB in Pacitan and its recommendation

(Data Analysis, 2011)

Figure 11:
(A) Tsunami information sign in Tamperan
Source: Mutaqien, 2011
(B) Tsunami information board in the public area relocate to Pacitan office building
Source: Mardiatno, 2008 and field work, 2011

E

questionnaires are given to schools, government institution, and society. The schools and institutions are Pacitan's Disaster Mitigation Agency (BPBD), Education department, SMKN 2 Pacitan, SMP IT Abu Bakar, Bappeda, STKIP PGRI Pacitan, and public.

The data is collected by using 100 questionnaires about tsunami, the tsunami vulnerable area, method to evacuate if the tsunamis happen, how to evacuate if the tsunamis happen, tsunami simulation, and the safe places for evacuation. This information is also combined with Mutaqien's (2012) datato complete the information. The results from 100 questionnaires are presented in Table 8.

Questions	Percentage	Sources
Information sources about tsunami	TV (40%), Radio (26.7%), newspaper (16.7%), others (6.6%)	Mutaqien, 2012
Experience about tsunami	No (100%), yes (0%)	Mutaqien, 2012
They know about tsunami hazard area	No (16.7%), Yes (83.3%)	Mutaqien, 2012
Are you known if the tsunami can be triggered by earthquake?	Yes (100%), No (0%)	Field work
If the tsunami happen, where they want to go to evacuate them self?	Hills (96%), high building (4%)	Field work
If the tsunami happen, how you to evacuate to the safe places	Run (20%), motorcycle (46.7%), car (30%), bicycle (3.3%)	Mutaqien, 2012
Did you ever follow tsunami drill?	No (85%), yes (15%)	Field work
Are they known about tsunami evacuation site?	Yes (90%), No (10%)	Mutaqien, 2012
Are they known about tsunami evacuation route?	Yes (86.7%), No (13.3%)	Mutaqien, 2012

(Field work, 2011 and Mutaqien, 2012)

Table 8: *Questionnaires result from Pacitan' society*

Information about tsunami most of it comes from television and from interviewing local people. Most of them know about tsunami after the tsunami 2004 in Sumatra.

For evacuation route, 86.7% people know about the route and 90% also understand where they should go if tsunami happen (Mutaqien, 2012). For the detail question, 96% people in Pacitan go to the hills if the tsunamis happen. Just 4% of the people choose evacuate site to the high building. It is very important to the government to socialize about vertical evacuation method. The government needs to prepare the recommended building for shelter and make a simulation (tsunami drill) not only for horizontal evacuation but also vertical evacuation. During the evacuation, people are socialized how to reach the ESB, which nearest ESB, what should they do to reach ESB, etc.

The government has socialized the evacuation method to the people. Car is forbidden used during the evacuation time. By using the car, congestion during the evacuation process could happen. From the data, 30% of the people choose car as a vehicle during the evacuation. This is very important point for the government to socialize intensively to the society.

Future research in another area

This method can be applied in other areas similar to the case of Pacitan City. This research tries to combine the vertical and horizontal evacuation method at the same time. Both of the evacuation methods are needed during the disaster time. Not only where the evacuees should go but also to estimate the risk of the ESB, number of evacuees of each ESB, number of uncovered evacuees using existent facilities, and in the day and night scenario.

This method combined different situations during the disaster time, for example different speed of evacuees (maybe by walking and motorcycle), different tsunami inundation etc. It depends on the local situation in the selected area.

Conclusions

The aim of this research is to make the evacuation runs optimum. The main points that can be extracted from this research are:

1. By using the existent network, the evacuation cannot run optimally both in maximum and minimum velocity scenarios.
2. Evacuation network to the hills should be prepared well because 96% Pacitan citizens' will run to the hills if tsunami happen.
3. Hills conditions which are prepared by government in Pacitan just cover about 7.3 % of the total areas by using minimum velocity scenario (0.751 m/s) and about 9.7 % by using maximum velocity scenario (1.34 m/s).The factors caused the limitation access and very narrow coverage areas are:1). Width road to the hills (most of them are 2meter width), 2). most of the hills just have one way access, 3). many roads are unconnected because of the river, field, etc
4. Public building ability to withstand during the disaster depends on the tsunami hazard and vulnerability. Hazard depends on the depth water of tsunami and vulnerability depends on the building material, level of the building, building orientation, and condition of the ground floor.
5. Totality of the public building in the research area is 350 buildings. The risk condition in this area with "very low" class is 9.3 %; "low" is 3.4 %; "medium" is 2.9 %; "high" is 83.1 %; and "very high" is 1.4 %.
6. Most of the public buildings in Pacitan are built with reinforced concrete building but most of them have "high class" risk class category. This result can be caused by the condition of the ground floor which usually has closed building without opening. Another factor is building level. If the public building has low vulnerability but it is located in "very high" hazard map, one of the solutions is to increase the building level.
7. Vulnerability of the purposed ESB can be minimized by retrofitting the building, adding the level of building, and making an opening space in the base floor for passing the tsunami.
8. The exits shelters' capacity in Pacitan is not sufficient to cover all of the evacuees. By using the exitstent facilities with recent condition, most of the shelter cannot cover all of the evacuees in the coverage area. It is only SMK Bhina Karya which can cover all of the evacuees. By using ESB, it should cover 30,824 evacuees, but 20,174 are not covered. It means that the recent shelter just can be accessed by 10,650 evacuees.
9. Space requirement during the disaster for all of the evacuees in the coverage area is about 28666.32 m2. Total building area (BA) to cover all of the evacuees within 10 recommended ESB is about 85763.54 m2.
10. The facilities found in the shelter prepared by Pacitan's Government are very limited. The sign of tsunami route to the shelter should be displayed in strategic location, road should be in two lanes, facilities and logistics in short time or long time (rest room, public kitchen, water, tent, etc).
11. Ten buildings selected by the risk score needs to be improved. The improvements imply additional space and reduce the vulnerability score to face the tsunami.
12. Ten buildings are not enough to cover all of the evacuees. The government also need to build additional ESB in the strategic location or selected the public building for ESB.

E

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F

Agriculture: A threat or solution to the Bangladeshi deltas

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Abstract

Deltas in Bangladesh are vulnerable because of climate change, sea-level rise, unsustainable landuse practices, agriculture etc. Food security is one of the main goals for the nation, because agriculture is the main source of the economy and employment. Today, agriculture in Bangladesh is in a precarious position because of continuous climate threats. Agriculture in the past has contributed to environmental degradation of deltas. In this paper, we suggest to use agriculture to protect the ecosystem. A systems thinking approach can be a perfect tool for this. Putting agriculture at the forefront of ecological protection can bring food- and water security and protect the local ecosystem. Agroforestry and agroecology based agriculture with other, non-productive crops (in terms of staple crops), like riparian buffers, mangroves, shelterbelts, etc. can regulate the river flow, increase the nutrient loads, protect coastal and riverbank erosion, attenuate flooding and reduce cyclone related damages.

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Introduction

There is a growing consensus about climate change and its catastrophic impact on mankind. One after another, new evidences unveil the interconnection of man-made changes of the environment, and how these are making the society vulnerable to climate shocks. Developing countries in general, contributed less to climate change, but are more vulnerable to the impacts of it. This results in economic, social and environmental losses. This calls for the whole world to unite to curb climate disasters, because this is not only economically vital, but also an ethical and moral imperative. Global temperature increase (0.74°C) has changed the behavior of arctic ice sheets which eventually results in melting of the icecaps. Ocean thermal expansion and the rising sea-level have a profound impact on the weather, agriculture, ecosystems, etc.

Deltas, in general, interact with dynamic lands of wilderness, forests, agriculture, urban and coastal systems. This makes deltas a fragile ecosystem. However, deltas bring a great ecological and economic value throughout the world, and host populations by providing access to fertile land and fresh water. In the last few decades, deltas were facing an unprecedented crisis of mismanagement, such as the construction of upstream dams to save water (which in turn reduces the fluvial sediment to reach deltas), or the overexploitation of ater for agricultural, industrial and domestic purposes. Furthermore, sea level rise has contributed to an increase in the frequency of deltaic flooding, coastal erosion, and ecosystem loss. Most of the impacts are very common to all deltas (with varying degrees) and some are peculiar to the region. Based on projections from 2001, by the end of the 21st century[1], sea level will rise less than one meter, but the findings of recent reports issued by IPCC suggest that sea level rise will in deed exceed one meter. Deltas in developing countries are more vulnerable because of their lack of financial strength, corruption and mismanagement.

An assessment of 33 deltas showed that, in the past decade, 85% of deltas experienced severe flooding (resulted in temporary submergence of 260,000 km^2) and this will continue to increase by 50% based on the current projection of sea level rise. A large number of population in Asia (more than 10 million people) experience flooding due to storm surges alone every year. Scientific advances in satellite imaging help us to clearly understand the extent of flooding. Flooding can be either caused by river runoff or by coastal storm surges. Natural and accelerated compaction contributes heavily to deltaic flooding. Accelerated compaction supersedes natural compaction by one order of magnitude. The Chao Phraya Delta, for example, has experienced an accelerated compaction of 50 to 150 mm yr-1 due to excessive groundwater withdrawal. Similarly, the Po Delta has subsided 3.7 m in the 20th century. Nearly 81% of this subsidence is attributed to methane mining. More than 100, 000 people lost their lifes because of severe flooding in 2007-08 alone in Ganges, Mekong, Irrawaddy, Chao Phraya, Mahanadi, Krishna and Godavari deltas[2]. At the same time, it has been reported that on the Southeast and East Asian coasts, 40 km^2 of new land was formed annually during the last 2000 years. However, now, the situation is reversed: most of the deltas are sinking because of drastic sediment reduction[3]. Millman et al. estimated that, in the worst-case scenario, habitable land loss in Egypt and Bangladesh between 1989 and 2100 could amount to 24% and 36%, respectively[4]. This makes the situation highly uncertain and calls for integrated and long-term management of deltas[5].

Bangladesh: Home to multiple disasters

In our proposal, we chose Bangladesh as a case study for various reasons. Bangladesh is one of the world's poorest nations and the densest country in the world with a population of 158 million people. The Human Development Index (HDI) of Bangladesh (in 2011) was 0.5 which is below the South Asian average of 0.548. The life expectancy average is 68.9 and GDP per capita and year is only USD 16676. Moreover, Bangladesh is a low-lying deltaic land, and the coastal area represents an area of 47211 km^2. This corresponds to 32% of the country's geographical area, and the coastal areas host 35 million people (i.e. 28% of the country's total population). Bangladesh's geographic location is very unique; the whole area is just a few meters above the sea level. It embraces severe cyclones and storm surges every year. Storms leave no-one immune, and economic, social and environmental losses are inevitable. The population of Bangladesh is already severely affected by storm surges. Catastrophic events in the past have caused damage up to 100 km inland. It is hard to imagine the extent of these catastrophes in the future under accelerated sea-level rise. Since it lies at the foot of the Great Himalayas, and at the convergence point of the south-west and north east monsoons, it receives great precipitation and experiences an accelerated melting of snow during the summer. This combined effect almost every year results in floods of coastal land.

Over 40% of the world's total storm surges take place in Bangladesh. Between 1877 and 1995, Bangladesh embraced 154 cyclones – including 43 severe cyclonic storms and 58 tropical depressions. One severe cyclone hits the country in every three years and causes tremendous damage to the livelihoods of people. Local governments and international aid have helped in protecting livelihoods, but additional steps are necessary to avoid potential damages from existing and future climatic events. Since 1960, Bangladesh invested $10 billion annually on disaster reduction strategies, by constructing engineering structures like polders, cyclone shelters, and warning systems. The major monsoon flood in 1998 inundated two-thirds of Bangladesh and resulted in the loss of over $2 billion (i.e. 4.8% of GDP). The poor are disproportionately affected because their lack of adaptation capacity. Agriculture is the worst affected sector by the continuous storms, which make the local farmers landless and force them to migrate to other villages or urban areas. Global Circulation Models (GCM) predict for Bangladesh that it will be 1.5°C warmer and 4% wetter by 2050. The intensity and frequency of the cyclones are expected to rise because of a rise in temperature in the Bay of Bengal. Most of the models predict that precipitation will increase by 20% during the monsoon season. Flow discharges from the major rivers are expected to increase between 6 and 18 % by 2050. Consistent results are shown by all models that the flooded area is expected to increase by 13% for most of the flood season in 2050. A one meter sea level rise is estimated to impact 13 million people in Bangladesh and cause a 6% loss in rice production. Coastal areas will be badly affected every year, nearly 33,000 km^2 will be inundated. Storm surge heights of 6.5m will reach 5km towards the inland. Based on the baseline scenario, inundation depth would be greater than one meter and cover 20,876 km^2 of land. An area of 10,163km^2 would experience a water depth greater than three meters.

Conceptual Framework: A systems thinking approach to deltas

Deltas are an extended form of land which forms a rich relationship with the sea by acting as a filter, repository and reactor of continental materials. In addition, deltas provide freshwater, sediment, carbon sources and nutrients (for the nourishment of coastal and marine biodiversity) and unintended pollution. As mentioned before, deltas are very vulnerable to climate change and especially deltas in developing countries are in peril. Substantial action is necessary to protect the deltas from shrinking and inundating. A systems thinking approach is essential to curb the threats which deltas are facing. The dynamic nature of deltas can be addressed through the systems approach. This approach is very sustainable in the long run and cost-effective. Solving the problem of deltas in a patchy process will not help. The systems thinking approach is not easy, though, but complex and time consuming. This approach requires 'soft' and 'hard' interventions. Deltas in general are affected by several parameters, each with its own magnitude. Land-use changes are the major causes of vulnerability of deltas. In this proposed study, we take agriculture as the main variable affecting deltas.

Agriculture and Deltas

Ever since the modern human evolution began, agriculture was the biggest discovery of the mankind. From the past 5000+ years, humans practiced agriculture in different geographical landscapes. They mastered the soil, nourished it and used it for their own purpose. Water and arable land were the prime reasons for human settlements. When these resources are not available, they migrate in search of food and water. Agriculture has changed the course of human being. Many ancient civilizations flourished near river beds like the Egyptian Civilization (Nile River), the Mesopotamia Civilization (Tigris and Euphrates), the Indus Civilization (Indus river), etc. Man learned the mastery of utilizing the water in an efficient way, conserved it. Several historical stories remind us how mismanagement of agriculture led to societal decay and collapse of civilizations.

Bangladesh is an agrarian economy, where the majority of the residents are employed in agriculture, aquaculture, and rural production. Despite this, also industrial manufacturing is on the rise because of favourable macroeconomic policies. Ensuring food security is one of the major goals of Bangladesh, since, although it produces sufficient food, most of the population are in hunger and poverty. Nearly half of Bangladesh's children are underweight and severely malnourished. Because of climate change, the agricultural productivity is estimated to reduce by 1% every year[9]. According to recent projections, there will be a surplus of 1.2 mMT of food grains, but an overall deficit of other food items. As the population grows, the food gap will also increase. Especially during severe flooding and cyclonic storms, cultivated lands are inundated, which temporarily increases the food insecurity and hunger. This is expected to get worse because of sea level rise and changes in local weather patterns.

As the population grows, the food demand increases and so does the demand for water to cultivate the crops. Man is always in quest of land and water for sufficient food production. There is a strong interconnection between agriculture and water (water in general; surface, sub-surface, rain-fed etc.) As the demand for water increases, also conflicts between different communities for the access to water occur, and the risk of food insecurity increases, with the consequence of poverty and environmental damage. In order to expand agricultural production, man encroaches wild forests and river beds and thereby changes the fate of whole delta systems. Deltas are often affected by upstream actions, such as by the construction of dams, which reduces the sediment load and access to freshwater. Agriculture and deltas are strongly related and solving the problem of agriculture in a holistic way will ameliorate the deltaic system. Similarly, agriculture and poverty are related. Whenever agriculture is impacted by climatic events this is also reflected in the livelihoods.

Bangladesh's soil is rich and fertile because of the nutrient rich sediments carried by the three great rivers. Bangladesh is a rural agricultural economy, where 61% of the labor is absorbed in agricultural, forestry and other activities. Rice (of different kinds at different periods of monsoon) is the predominant crop cultivated, which accounts for 84% of the total area. In addition, numerous minor crops like potatoes, oil seeds, pulses, vegetables and non-food crops such as jute are cultivated. Food insecurity is high in coastal and drought-prone regions.

Subsistence farmers face several challenges: riverbank erosion, groundwater pollution, frequent floods/cyclones, droughts, sea level rise, etc. These compounding problems will worsen in the future, if sufficient actions are not taken. In this paper, we will limit ourselves to the impact of agriculture on deltas and vice-versa. There is a strong connectivity between the vulnerability of deltas and their agricultural development (or damage). Since deltas offer rich alluvial soil for cultivating crops, river beds are used for agricultural purposes because of the soil fertility and available water resources in surface and ground. During the wet monsoon, water is utilized from the rivers and in some places rain-fed agriculture is practiced, and during the dry season groundwater is extracted. An increase in peak discharges from the three rivers; river siltation, land use changes, etc. also increases the chances for floods. Eventually, this results in loss of livelihoods and agricultural land because of water logging and saltwater intrusion in coastal areas. Mangroves are destroyed for food production which increases the risks of deltas for flooding, erosion, etc. Shrinking agricultural land pushes the farmers to overexploit natural resources by encroaching the forest and riverbeds for food production. Therefore it is very important to improve the resilience of agriculture.

Though sedimentation (or accretion) and erosion processes are seasonal and fluctuate in a long timescale, this has been aggravated by improper agricultural practices. Land degradation in the Barind Tract is caused mainly due to over exploitation of groundwater for agriculture lands and poor cultivation practices.. Degradation of soil quality in the floodplains is mainly due to chemical fertilizers and pesticides to increase agricultural production. This increases in pollution runoff during the monsoon and the flooding season, which pollutes the rivers and the coastal ecosystem. Other natural causes of land degradation in coastal areas are a result of recurring cyclones and storm surges. Increases in shrimp farming in the last 20 years has degraded the land and made it unfit for agriculture, e.g. through increasing the salinity.

Coastal Agriculture

Agriculture is not only practiced in the inland, but also in coastal areas. The types of crops are different, however, because of the varied geography and local atmospheric conditions. Since the 1970s, the population has doubled and agriculture expanded in coastal areas. The coastal region covers almost 29,000 km^2 or about 20% of the country. Again, the coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity.Over 30% of the net cultivable area is in the coastal areas of Bangladesh. The total land area (coastal and offshore) is 2.85 million ha, of which 0.828 million ha is arable land. This covers 64 Upazilas of 13 districts. The majority of the coastal population relies on agriculture and aquaculture. Mangrove lands were destroyed for agriculture and development. Later on, shrimp farming became the 'economic messiah' for the local population which would save them from poverty and create jobs. These two problems had adverse impact on the environment and it will continue until radical measures aren't taken to protect the coastal land from inundation.

Rivers, which are supposed end in the coastline are diverted for agricultural purposes, which in turn, reduces the water flow in those rivers, increases estuary salinity and decreases estuary circulation. This changes the productivity of the fish. Because of extensive fertilizers and pesticides used in agriculture, local estuaries, rivers and inshore waters are being polluted and eutrophied. Extensive cropping or grazing on watersheds leads to erosion, river turbidity, floodplain deposition etc. and coastal areas rely heavily on groundwater for cultivation. The result of this extraction leads to salt-water intrusion into coastal aquifers, increases salinity and contaminates the groundwater. Over-grazing on coastal wetlands and salt-marshes increases coastal subsidence and increases the possibilities for flooding, beach erosion, increased salinity, etc. A recent study shows that there is a growing concern for land degradation: around 30-50% of cultivable land remains fallow in the Rabi and Kharif-I (types of different rice cultivated in Bangladesh) seasons. The soil remains wet for most of the time. The crop's productivity is declining and it is expected to continue declining because of the degradation in soil quality, erratic rainfall, river water diversion upstream, sediment deficiency and riverbank erosion[10].

In addition to man-made problems, climate change has a detrimental impact on the coastal agriculture because of an increase in tides, storms, intense cyclones, sea-level rise, etc. Most of the surface and groundwater is becoming saline because of storm surges and seawater intrusion. There is a significant increase in salt-affected areas, from 750,350 ha in 1973 to 950,748 ha in 2009, which makes a 26.71% overall increase[11]. An interesting study by

Muslemet. al. (Nov, 2010) on various impacts on different crops cultivated in coastal districts because of natural disasters and climate change. Climate vulnerabilities n different crop varieties inBagerhat district is given elsewhere[12].

Factors making Deltas Vulnerable

Global Sea Level rise is directly linked to the rise in temperature. Even the moderate assumption on temperature rise in the coming century would bring great environmental damage to Bangladesh. Since the whole of Bangladesh lies below 10 m above the sea level, any incremental change in the sea level will affect the coastal lands, and bring great damage to the livelihoods and ecosystem. Scientific studies prove that there are two fundamental factors affecting eustatic sea-level rise due to global temperature rise and diversion of fluvial sediment destined for the coastal zone.

In this section, we will highlight the various important factors affecting the Bangladesh deltas. Though there are other visible and invisible factors that are contributing to the vulnerability of deltas, these are out the scope of the study. Like other developing countries, Bangladesh faces several environmental problems, and due to limited size of the paper, we will only highlight each issue threatening food and water security and local livelihoods in snapshots. For more details, there is extensive literature given at the end of paper on each problem.[13-36] Some problems are caused by short-sighted economic gain like shrimp farming. World banks' proposal to shrimp farming was adopted by the Bangladeshi government as an 'economic messiah' to lift the people out of poverty, but the repercussions were severe like an increase in local violence, human rights abuses, loss in arable land, and increased coastal vulnerability.

Threats	Explanations
Sea Level Rise	By 2050, coastal loss could amount to: 18% land loss, 15 % of total nation's population and 13% of total GDP. Nearly, 13 million people will be affected by 2050. But the assumptions are moderate. Barisal and Putaukhali would be inundated 80-100% by the same time.
Sediment Loading	Coastal areas are undergoing a mean annual land subsidence of 15-50 mm. Sediment is reduced from 2.4 to 1.6 billion tons/ year. Only 10-15% of the sediment load reaches the delta plains.
Mangroves Destruction	Nearly, 73% of the original mangroves are lost. In the last 37 years, 170 km^2 of land is eroded.
Saltwater Intrusion	Nearly 52.8% of the cultivable land in coastal area is affected by salinity. The total land loss is 18, 65,000 hectares.
Riverbank Erosion	Displaced 728,000 and 60,000 landless annually.
Inland Flooding	Floods are very common in Bangladesh, every year the country floods, but in some years the magnitude of damage is very high, e.g. floods in 1988, 1998, 2006
Shrimp Farming: Desert in the Delta©	In 1983-84, shrimp farms were occupying just 52,000 ha, but they rapidly expanded to 140,000 ha by 1995. Shrimp farms are replacing agricultural farms, increaseing salinity, and fostering coastal degradation.

Table 1: Snapshot of local problems to the Bangladeshi deltas [13-36]

Part B: Solutions

Protecting Nature through Agriculture: Agroecology and Agroforestry

There is a strong bondage between agriculture, water and livelihoods. Without the former two, there will be no livelihoods, and when the former is at stake, the pursuit of water and food encourages to invade the wild forests and breach the natural boundaries. Natural landscapes were converted to rural and urban landscapes. In the past, many rivers changed their shape because of human intervention which resulted in flooding, siltation, erosion etc.
Fifty years ago, farmers were the stewards of the local landscape, where they maintained the fields cultivated, non-productive farmlands (to be explained later) and polyculture was practiced. Then, the idea of Green Revolution was executed to increase the food supply and to reduce poverty in third-world countries. This fundamentally changed the agricultural practices and been responsible for accelerated soil erosion, declining productivity, land degradation, invasive species, increased frequency of floods and outbreaks of crop pests, to name the few. Intensification of agricultural production led to the neglect of the importance of non-productive farmlands in the rural landscape.

Improving the landscape ecology near the coast and inland is not only expected to provide scientific understanding but also pragmatic and immediate solutions to the threatened rivers, deltas, coast and agricultural areas. Though there are ample benefits of each non-productive farmland for agriculture and the environment, landscape ecology is completely neglected at the farm and community level. Very few resources are available to design multifunctional landscape at the whole-farm scale, and indigenous knowledge is applied wherever needed. Mosaics of spatial multifunctional landscapes are essential to improve agricultural productivity.

Agroforestry, according to The World Agroforestry Center, is ‵‵a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels[37].′′ Practice of agroforestry is not new, it is as old as agriculture. Farmers and peasants in earlier days understood the significance of multifunctional landscape diversity which provides ecological, social, and cultural services. Indigenous knowledge on which trees should be cultivated and how the land should be managed have been underestimated since 1970s. In this paper, we will discuss some of the important benefits of agroforestry, which provides rich diversity and ecological services. At the same time, the farm land is designed to protect from environmental threats[40].

Agroecology is defined as[39]

- The application of ecology to the design and management of sustainable agroecosystems.
- A whole-systems approach to agriculture and food systems development based on traditional knowledge, alternative agriculture, and local food system experiences.
- Linking ecology, culture, economics, and society to sustain agricultural production, healthy environments, and viable food and farming communities.

Tackling agricultural problems through the systems level will provide a rich scientific platform to understand the cause-effect relationship of different variables. There is a growing research interest on agroecology and new research areas are emerging to scientifically design, understand and manage agroecosystems build upon the traditional and cultural values. It is a holistic study of agroecosystems including all environmental and human elements[41, 42, 43]. Findings of Tilman et al, show that, diverse natural communities are productive and more efficient than simple systems. The diversity increases the stability, resiliency, productivity and sustainability of agriculture systems[9]. A recent survey by FAO, shows the dramatic increase in yield by adopting agroecological practices in agriculture without losing profit.

Transition from monoculture to polyculture[38, 42,43]

The grain output has doubled in the last 40 years. This was a remarkable achievement of green revolution. For the intensification of agriculture machineries, chemical pesticides, fertilizers, etc. were developed and commercialized at larger scale. Another great modification in this revolution were high-yield variety seeds and genetically modified seeds. Monoculture came as a panacea for the growing food shortages. There was tremendous support from scientific and political committees, who pushed the subsistence farmers to forcibly convert to monoculture in the early 60s. But the repercussion of this energy-intensive, fertilizer reliant, single-cropping agriculture is witnessed now. Large-scale monoculture food production systems are no longer sustainable. Because of their poor natural defense mechanisms, they lead to soil erosion and, moreover, monoculture farming draws extensive water. Drying of groundwater and surface water in the Asian countries are alarming and push the local farmers further into poverty. Though a lot of scholarly work has been done in the past about the ecological and socio-cultural impacts of monocultural farming.

Polyculture is a traditional method of growing food along with other crops, varying year-round and with multifunctional non-productive landscapes, based on traditional knowledge. The different varieties of crops that produce overall higher yield are carefully selected. This intercropping method requires less fertilizer input, because of the greater resistance to pests, allows for an increased water retention, and enhanced productivity of the soil because of the constant exchange of nutrients. Some studies suggest that diverse plant communities are more resistant and resilient to environmental threats like droughts. When compared with monoculture, polyculture productivity is higher during drought. Characteristics of agroecosystems are productivity, stability, sustainability and autonomy.

There is a renewed interest in polyculture and many studies in laboratories and on field level have proven the significance of polyculture farming systems. Here are some of the benefits of polyculture which can be seen elsewhere[43].

Riverine wetlands[38, 47-52]

“Riparian areas are three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems, that extend down to the groundwater, up above the canopy, outward across the floodplain, up the near slopes that drain to the water, laterally into the terrestrial ecosystem and along the water course at a variable width”. (Ilhard et al., 2000)

The importance of riverine wetlands is enormous, especially for altering the biogeochemical fluxes. They function as metabolic gateways of nutrient and sediment loading to recipient waters. They buffer the effects of surface water runoff on rivers and they buffer the effects of river flooding on adjacent uplands. This completely depends upon the variation of the water flow. These wetlands are dynamic agents for transporting the nutrients, they control the water flow and vegetation distribution. Different scales of riparian wetlands are formed: At the smallest scale, these wetlands form near water areas which hosts aquatic plants and animals, at medium scale, they form bands of vegetation and at the largest scale, they occupy extended floodplains of tens of kilometers. During regular flooding, these floods interact with the riparian wetlands and exchange organic matter and infiltration (downwelling) of surface water into the riparian groundwater body is observed.

The function of riparian wetlands is also dependent on the vegetation cover, which determines the degree to shich it strips nutrients from the incoming water, provides raw material for the organic soils, reduces runoff by evapotranspiration, and buffers water-level fluctuations. Because of the percolation of groundwater, it provides rich space for nearby vegetation. Very importantly, wetlands increase sediment stability. They function not only as sinks but as well as sources of organic nutrients. Riparian wetlands help regulating nitrogen households and this eventually helps the adjacent agricultural landscapes. Riparian vegetation decelerates the kinetic energy of surface flows during sudden overflow. Near agricultural landscapes, the preferred land use alternative is perennial grassland with a combination of forest or bush buffer strip directly on the riverbank or lakeshore.

Bangladesh is perfectly suitable for riverine wetlands because of its floodplains and the heavy precipitation in monsoon periods, as well as the water influx from the GBM rivers. Since Bangladesh, has different land shapes (mountainous, flat, etc.), various types of riparian wetlands can be constructed depending on the geography.

Fencing through Nature: Hedgerows and Shelterbelts[38, 46-52]

Hedgerows are narrow bands of woody vegetation and associated organisms that separate fields. They function as shelterbelts or corridors which provide habitats and different services to the ecosystem.

Hedgerows were typical in old landscapes, but due to urban and rural expansion, most of the hedgerows have been destroyed. Recently, the ecologists realized the importance of hedgerows. Many countries in the North started planting them as natural barriers/corridors for inhibiting soil erosion from forests and fields. Hedgerows interact with neighboring landscapes, such as:

a) fields, including those under cultivation and pastures,
b) natural vegetation, such as woodlots, heaths and streams, or natural corridors,
c) human habitations, such as farmyards and villages.

There is a strong interaction between hedgerows and the neighboring agricultural landscape (though the crop productivity is slightly improved, yet this relationship is still debated). These linkages provide direct economic and ecological benefits for food production. Hedgerows influence the microclimate, particularly the effects of wind and temperature. Subsurface water is absorbed by deep and dense roots of hedgerow plants and this accelerates evapotranspiration during excessive rainfall. It stores water for later use. A 1 ha field with a 50m hedgerow, for instance, can store between 150 and 375 cubic meters of water during rainy periods for slow release down the slope during the dry periods. Hedges reduce the rate of flow of water from the catchments, helping to reduce flooding downstream. Soil erosion on slopes is considerably reduced with hedgerows along the contours. Hedgerows act as tiny reservoirs of storiage of organic matter relative to the fields. They protect soil nutrients in the field, and ameliorate nearby stream attributes such as siltation, flooding and water quality. Groundwater infiltration is greater if the hedgerow is on a slope, where the surface runoff is impeded by the hedgerow. Bangladesh is susceptible to the soil erosion, and planting hedgerows near the areas that are often exposed to soil erosion could contribute in solving the erosion problems.

Shelterbelts (or windbreaks), as the name itself signifies; act as barriers to reduce the wind speed. They are usually comprised of, trees and shrubs or perennial trees or annual crops. Shelterbelts are very useful for protecting wildlife, agriculture and for relieving people suffering from severe climates. Other ecological services provided by shelterbelts are the protection from erosion, improved crop production, filtration of air and water, the mitigation of climatic extremes, and the improvement of other environmental qualities. Densely planted trees near croplands will reduce the severity of cyclonic and storm surges. Shelterbelts can reduce soil evaporation and this improves the soil water availability for the crop later in the dry season. Thus, shelterbeds improve the water-use efficiency of crops. they also lower soil and canopy temperatures and reduces moisture losses. Overall, shelterbelts provide improved growing conditions for crops and improve crop-yield and quality. Well-planned shelterbelts increase the biological diversity which may introduce natural predators to prey on pests and thereby reduces the need to usa of pesticides. Wooden trees near farms help reducing erosion a common phenomenon observed in Bangladesh.

Coastal Agriculture

Crops covered by cover crops, and planted using intercropping and agroforestry suffer less damage from hurricanes. Through constructing wetlands, riparian buffers, or other landscapes in mosaics,valuable space is occupied in space-constrained Bangladesh. But this, in-turn, offers valuable ecological services to agriculture, and protects livelihoods and property from floods, hurricanes and cyclones. At the same time,biodiversity is improved and, most importantly, multifunctional landscapes are strongly resistant to any future climatic threats.

Mangroves and coastal vegetation: Biological Shields[38, 50-53]

Deltas interface with coastal vegetation like mangroves, coral reefs, salt marshes and the sea. Coastal vegetation acts as a shield from environmental threats and provides ecological services to the neighboring coastal agriculture/aquaculture. Furthermore, it acts as a carbon sink and protects biodiversity, while providing space for habitats. In the previous discussion, the change of mangrove cover in Bangladesh was discussed, and it was attributed to shrimp farming, port construction, and other economic purposes. This led to severe destruction of local biodiversity and increased the vulnerability of coastal areas against coastal subsidence because of groundwater extraction, reduced sediment loading, natural compaction and sea-level rise. The costs of construction and engineering structures for coastal protection is very high. As mentioned before, the ecosystem-based approach is a cost-effective and efficient solution to a growing problem. It is important to protect existing mangroves and expand afforestation in the coastal areas of Bangladesh. A mixture of swamps, salt marshes and forests will protect the coast from erosion, winds, tides and sea-level rise. Another important factor that is affecting coastal agriculture is salt-water intrusion. Bangladesh is a low-lying coastal land and extremely vulnerable to sea-level rise. Based on the climatic projections, the situation will worsen, if sufficient actions are not taken. In the distant past, mangroves acted as biological shields from cyclones.and provided muddy, brackish soils. Sufficient sediment loading and freshwater influx are essential components for the continuous survival of mangrove forests. Mangrove forests also control and stabilizes the shoreline by trapping sediments during flooding. Dense forests in the coastal lands will reduce the vulnerability of sea level rise.

In field studies, mangroves have shown extraordinary resilience to coastal threats. As the depth of the sea decreases, the intensity of tides increases. The speed of tidal waves decreases lateral to the land because of the resistance by mangrove vegetation. For instance, Rhizophora spp. and Bruguiera spp. have strong, intricate, large prop roots, which curb the intensity of tidal waves. Approximately 86 % of the energy is dissipated by the mangroves. The level of damage depends on the density of the mangroves vegetation. Therefore, in well-grown, densely packed mangroves, the cost of damage on coastal areas is less.

Salt marshes[38, 47-52]

Salt marshes are saline ecosystems with peculiar geomorphology such as the sediment composition, and environmental soil texture, but also with specific vegetation, habitats etc. They usually occur along shores, lagoons, barrier islands and shallow inlands. Vegetation in salt marshes acts as a biogeochemical barrier and traps sediment during high water flow. Appearance and disappearance of salt marshes depends upon sediment flow and tides.

When the sediment accumulation is outweighed by erosion, salt marshes retreat. Salt marsh ecosystems in the USA (Atlantic and Gulf Coasts) are productive: microbial activities are elevated, organic matter is produced, food webs and commercial fisheries are supported. In sediments of tidal marshes a lot og denitrification occurs. As other agroecosystem landscapes, productive salt marshes act as carbon sinks. New roots are formed which decelerate the impact of sea level rise on coastal areas.

Participatory Spatial Planning[38,54,55]

Recently, spatial planning has become a very important tool to mitigate the impacts of climate change. As mentioned before, solving delta challenges in coastal areas alone will not solve the problem. Previously, science was developed outside the political domain and planning was done without consent of the local citizens who are most affected of planning decisions. This top-down planning approach neglects local values, knowledge or priorities of citizens. We propose to implement participatory spatial planning as a tool in landscape planning and multifunctional agriculture. This should involve a gradual change from top-down ecological planning to bottom-up, with active participation of different stakeholders like scientists, policy makers, farmers, planners and local citizens. In this process, indigenous knowledge and scientific advancements will be exchanged to resolve the natural problems and propose ways to conserve the biological system.

Participatory spatial planning (PSP) will play a strong role in society provided that it focuses on ecosystem based management, integrated water resources management, and adaptive management aims to protect ecological resources, while at the same time addressing the local economic, social and cultural dimensions. In order to prevent scientific activities from being inadequate under certain circumstances, they should be coupled with local knowledge. Iterative participatory communication will derive solutions that are robust, politically and economically feasible and scientifically valid. For a sound multifunctional agricultural landscape planning, the methods adopted by the engaging stakeholders are crucial, and the inclusion of diverse groups, group size, incorporation of local knowledge and expertise and the time available for the process to develop are important factors. Another important characteristic of PSP is that it reduces conflicts between different groups. Collaborative effort is required in collecting the spatial data and disseminating them to those who are affected and, potentially, to influence policy makers.

In the previous paragraphs, we explained the importance of landscape ecology in agricultural systems and we introduce the concept of landscape planning. Multifunctional ecological mosaics can be planned with spatial planning tools. Previously, spatial planning tools understood the ecological system as independent, but many ecologists challenged this approach. Since the ecosystem as a whole is integrated, we can use these tools to construct efficient landscapes. Understanding the complexity of integrated ecosystems is a challenge, yet it provides multiple functions. GIS modeling should integrate qualitative and quantitative information across spatial and temporal scales of coastal and inland agricultural fields of Bangladesh. A sustainable ecological landscape design should not only focus on physical landscape resources, but also aim to ensure economic and social sustainability.

Local farmers, for instance, generally have a profound understanding of the agroecological zones, local environmental problems and the kind of trees that need to be grown and the habitats to be established that can support both the ecosystem and agricultural activities. This knowledge should not be ignored in planning. Careful selection of different species and biodiversity goals is a key for successful agricultural practices. Key questions should be answered, by using participatory spatial planning. The questions can be categorized as follows: area of the habitat type, average patch size on each farm, ecological values from the mosaics, place selection for the construction of wetlands, riparian buffer zones, hedgerows in adjacent fields, conflict resolution, mangroves distribution, forest plantation in coastal, areas etc.

This shows that integrated spatial planning is required to employ multifunctional landscapes in the coastal and inland agricultural zones of Bangladesh. Socio-economic data should be integrated in every level of planning. Extreme climate events should also be included as well as information on how these will impact agricultural practices. For instance, in next 50 years, most of the coast of Bangladesh will be submerged. Indigenous knowledge and natural resources management is of equivalent importance as scientific knowledge, because it integrates the knowledge from decades of generations. For most of the Bangladeshis, subsistence agricultural farming is the way to earn their livelihood. Therefore, the locals will be empowered in participating and promoting agroecological practices, and new practices will be developed through active participation in combating soil erosion, riverbank erosion, salinity intrusion, improved agricultural productivity etc. Participatory spatial planning can be a powerful tool in agroforestry and agroecology. Well-designed agricultural landscapes will increase the productivity and functioning of downstream deltas.

Bangladesh has a vibrant civil society organization and active NGO network across the nation. There are many NGOs working on promoting sustainable agricultural practices and improving the resilience of farms together with local farmers. The government of Bangladesh, international organizations like FAO, WFP, and development organizations should participate with local farmers in spatial planning exercises. Learning from previous successful strategies of stakeholder management can be help to promote the replication of the concept of agroforestry and agroecology.

Recommendations

There are some key challenges in transforming the 'now-existing-agriculture' to a multifunctional agricultural system, such as space constraints and the development of a policy system to support multifunctional mosaics. The current market forces will prevent the land from being used for non-productive types of landscapes. Most of the farmers will not agree to non-agricultural landscapes because of the scarcity of space. However, there is a growing tendency in rural communities to value non-productive landscapes which will bring wider social and environmental benefit. This integrated approach of multifunctional agriculture offers multiple benefits, compared to conventional approaches as it addresses, economic and cultural aesthetics.

A district-oriented, coalition-based approach involving partnerships and bottom-up governance mechanisms, which operates over a range of scales, can bring sustainable solutions to the local communities. District-wide spatial planning processes will be more convenient than nation-wide planning because of the comparatively limited bureaucracy, coordination and resources involved. We propose a 5-step process to implement multifunctional landscapes and agriculture in Bangladesh (this process is slightly modified form of the one Ling et al [56] propose). The entire process mentioned in this proposal is inclusive and participatory.

Step A: Increasing the awareness

Two generations ago, farmers were well aware of non-productive landscapes, but the current agricultural practices are endangering local habitats and increasing the vulnerability of livelihoods. Therefore, it is essential to increase awareness through local and international NGOS and development programs.

Step B: Planning

Planning of landscapes can be done through a process of mapping and classification. Spatial mapping and other satellite imagery techniques will be of great help. It is also important to identify various functionalities, such as historical, ecological, communitarian, economic and aesthetic functions.

Step C: Evaluation

Once the attributes were identified, it is important to assess each functionality. Assessment should be based on quantitative and qualitative approaches and it should not be guided by mere neoclassical economic evaluation. The historic functionality of a particular landscape, for instance, can possibly not be justified only in economic terms.

Step D: Management

Continuous support from national and local governments will help to execute the plan appropriately. Setting up district-wide planning processes will reduce the burden of bureaucracy in national planning. Furthermore, if the pilot models will be successful, governments should come forward in building a common strategic planning framework for multifunctional landscapes.

Step E: Monitoring

The monitoring is an ongoing process after the implementation. Local farmers are the stewards of their communities. Though the ecological services cannot be easily quantified, the qualitative change could be visualized and the local authorities should encourage the farmers for further improvement.

Conclusion

Climate Change exacerbates the current economic growth and imperils the society. It is essential to curb the impacts of climate change. Some solutions to this dilemma are already known, though political will and mutual support from rich and poor countries is lacking. In the present study, we have shown how deltas are vulnerable to climate change and how they are affected by land-use. Protecting agriculture through an ecosystem-based approach will also protect deltas in long-run. At this point, the authors would like to stress that 'soft' processes are not a panacea, but a combination of 'hard' and 'soft' processes will be necessary to increase the resilience of coastal areas. Bangladesh is vulnerable to all climatic changes, and every major climatic event will create disastrous impact on the economy and society. Since Bangladesh is prone to natural disasters, the government of Bangladesh and with its international partners have established new mitigation and adaptation policies. This includes engineering structures like the construction of polders, cyclone shelters, and cyclone-resistant infrastructure, early warning dissemination systems, education, and conferences for raising awareness among residents and stakeholders. Currently there are 123 polders formed by 5017 km of embankments, which protect 1.5 million ha of land (mainly agricultural). There are currently 2591 shelters which serve 2.8 million people i.e. 7.3 % of the coastal population.

Nature is the best engineer we have and her solutions are optimal. We believen that a combination of the ecosystem based approach, engineering solutions and participatory management is the best solution to mitigate the growing environmental threats. Agriculture is the main source of employment and living in Bangladesh. When the present arable land is reduced by coastal storm damages, riverbank erosion or inland flooding, farmers will either seek new land or move to urban areas in search of a job. As the latter option is not sustainable, heavy migration from rural to urban areas will eventually create conflicts and exacerbate the precarious economic situation of farmers. Multifunctional landscapes which support agriculture by offering ecological services that will help protecting fields from river erosion, coastal and inland flooding, soil erosion, droughts, etc could help in providing a more sustainable basis for future agriculture in Bangladesh. Natural landscapes should be integrated with agriculture that enhances biodiversity and resilience of the farming system as a whole. Mosaics of multifunctional landscapes at the same time increase crop productivity because of moisture retention, nutrient cycling, integrated pest management and a reduced necessity of fertilizers, an increased soil productivity, reduced salinity in the soil, etc. Shifting from monoculture to polyculture will ensure food security, and a strengthening of local communities. Protecting the river system starting from the source will eventually result in protection of deltas. The demand for water to cultivate in polyculture and the here proposed agroecosystems is reduced considerably, because meadows, and salt marshes are formed near the agricultural landscapes, which can act as riparian buffers,. Participatory planning is an essential tool to design agroecosystems well embedded in the districts. Planting trees and hedgerows in the coastal areas will reduce the impact of flooding on coastal residents and agriculture. Windbreakers will reduce the intensity of wind entering inland. Riparian buffers and salt marshes will reduce the salinity of groundwater and help protecting the soil from waterlogging. These multifunctional landscapes also provide economic and aesthetic services. The proposed solutions are cost-effective and together form an efficient system. Landscape ecology is a pragmatic approach to solve the growing problem of deltas, rivers, agriculture, and other ecological systems around the worls. Thus, we can conclude that ntegrating agricultural production with environmental protection is a sustainable solution for both minor and major ecological problems.

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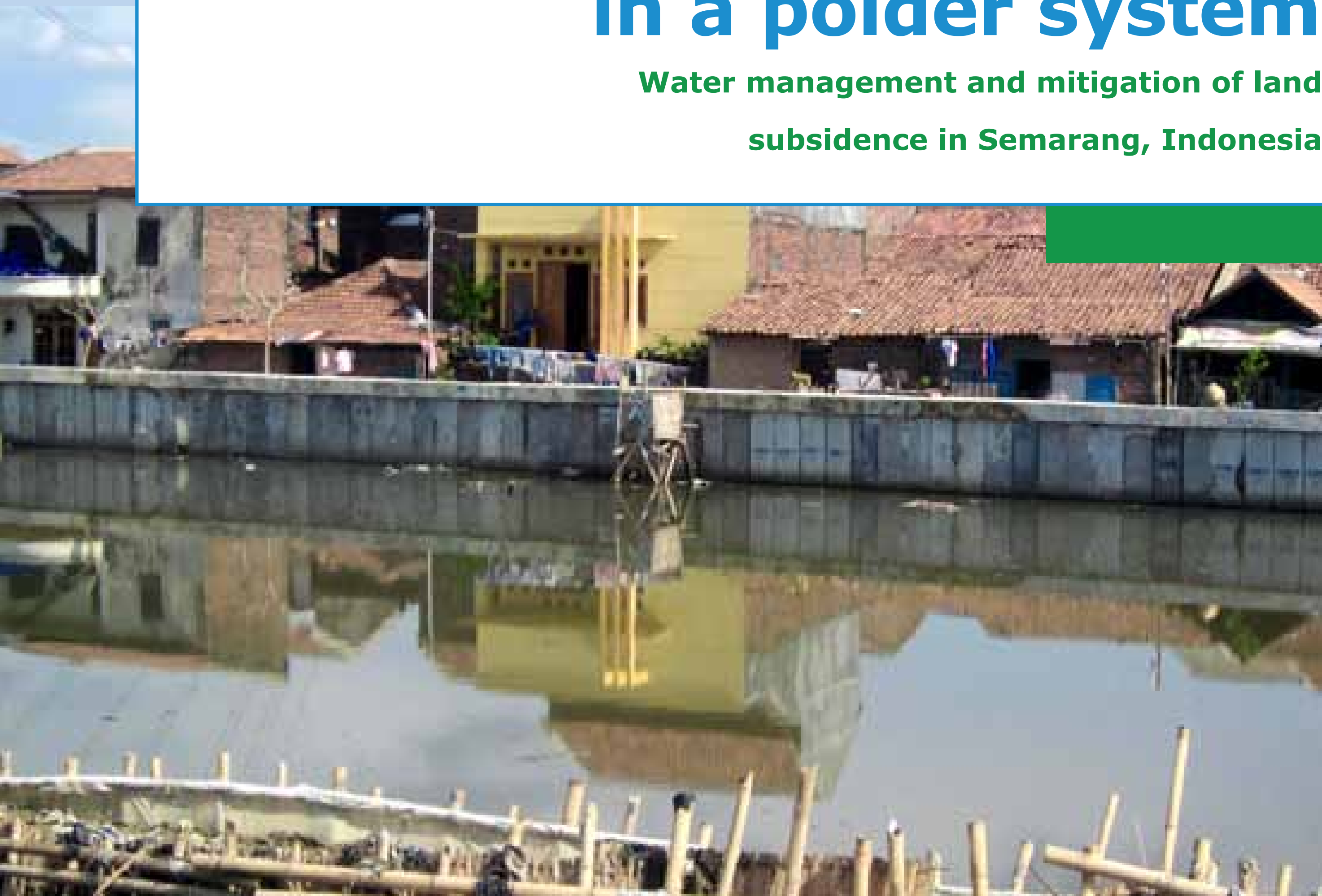
Demak
Kaligawe
Semarang Utara
Gemuk
Semarang Timur
Soegiyopranoto
Padanaran
Semarang Selatan
Pendurungan

G

Integrated artificial recharge in a polder system

Water management and mitigation of land subsidence in Semarang, Indonesia



Andung Bayu Sekaranom[1] | Widya Alwarritzi[1] | Sepviana Rahmawati[1]

Abstract

Semarang city in central Java-Indonesia is located in a coastal lowland area which has developed as an industrial city. This area has experienced several environmental problems due to rapid population growth, coupled with intense economic activities and a rising fresh water demand. Excessive groundwater withdrawal as a by- product of the human effort to meet the increasing water demand is the primary cause of such environmental problems, particularly of land subsidence. Land subsidence, combined with increasing coastal flooding due to climate change, has a highly devastating impact on coastal environment. The aim of this paper is to present an alternative solution to address land subsidence by recovering the decreased water table in Semarang and thereby promoting sustainable water management. The present solution is focused on improving water management, by building an artificial recharge well to raise the groundwater table and integrating it with the existing polder system. The integration of an artificial recharge well with a polder system has a high potential to solve common environmental problems in Semarang, such as land subsidence, fresh water scarcity, sea water intrusion, and tidal floods, under which the area is periodically suffering.

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Integrated artificial recharge in a polder system:

Water management and mitigation of land subsidence in Semarang, Indonesia

Introduction

Semarang, as one of the coastal cities in Indonesia and the capital city of Central Java Province, has gained importance as an industrial area. This development generated rapid growth of the population, which is resulting in high groundwater exploitation (Apridar, 2011). The dynamic growth of the coastal city of Semarang resulted in a change of the natural conditions. Land subsidence in Semarang, which is experienced as a downward movement of the land surface, is mostly triggered by a decreasing water table due to groundwater over-exploitation (Abidin, 2005). Moreover, groundwater exploitation causes an intrusion of sea water, which is affecting the ground water system. In Semarang, land subsidence in combination with sea level rise due to climate change, is predicted to exacerbate tidal flooding. According to projections, this will produce higher damages of buildings, infrastructure, industrial estates and also result in a deterioration of social and economic factors.

In order to address this land subsidence rate and its impact, mitigation measures are necessary to be developed. This research focuses on an innovative solution to the problem of land subsidence corresponding with groundwater over-exploitation. The main concept of this mitigation measure is based on refilling over- abstracted aquifer systems through artificial recharge. Artificial recharge requires large amounts of water supplies, which need to be extracted from specific water recharge sources. With this paper, we show that it is possible to integrate existing polder systems, built by local governments, as potential water recharge sources to overcome tidal flooding problems,. Through linking them, integrated artificial recharge wells and existing polder systems can be more efficient, and thereby, water management measures can be applied optimally to mitigate and reduce land subsidence.

Conceptual framework

Artificial recharge well

Artificial recharge is an anthropogenic effort to refill water into the groundwater system, and is mostly applied for increasing fresh water supply (Todd, 1976). According to Todd (1976), media for aquifer recharge with surface water can be pits, wells, and possible measured pumping, and water spreading. Refilling groundwater through a well is the method chosen for the solution proposed. Considering the extent of land subsidence in the study area, application of artificial recharge can address the problems of groundwater overabstraction in Semarang, which in turn is one of the main causes of land subsidence. The artificial recharge well is utilized to replace water losses from groundwater pumping, by adding a new source of fresh water originating from the surface. The basic principle of the calculations made is whether, when water is recharged into the aquifer, the cone of recharge well will have the same shape as the cone of the pumping well. This would mean that the discharge flow which will be recharged into the well has the same volume as discharge flow which is being pumped

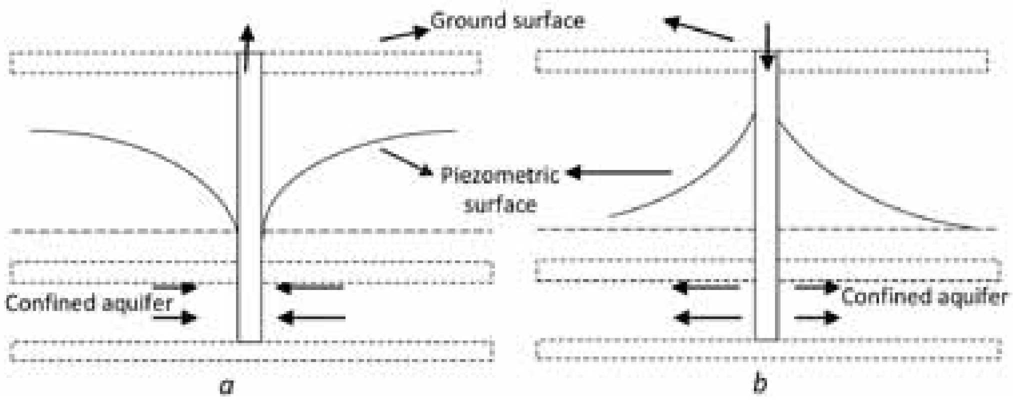

Figure 1:
a) Condition of confined aquifer after pumping
b) Condition of confined aquifer after recharge is applied

of the well (Figure 1). Figure 1a represents the condition in which groundwater is pumped, Figure 1b represents the condition after an artificial well has been applied. The figure shows that the condition as depicted in Figure 1b will restrain the land subsidence rate.

The polder system

Physically, a polder is a complex building with the purpose to restrain floods, which has the function to move excessive water from lowlying land to the sea. Polder systems were recently introduced by the local government authorities of Semarang as an effort to improve water management. The purpose of this initiative was to address the impact of inundations caused by river flooding and coastal floods. The degree of inundation of Semarang is increasing every year because of land subsidence. Therefore, polder systems are one of the structural mitigation measures taken by the local government of Semarang to reduce the impact of floodings.

Sustainable water management

Groundwater overabstraction occurs due to the high pressure of the fresh water demand from various human activities, which causes sinking water tables, and impacts land subsidence. On the other hand, the climate change phenomenon causes the sea level to rise. The impact of land subsidence coupled with sea level rise exacerbates periodic tidal flooding. Polder systems were built to protect the land from tidal- and river flooding. By integrating these polder systems with artificial recharge wells, the polder system will not only constitute part of a mitigation strategy to defend the land against floodings, but will also provide water as the main source of artificial recharge wells. Artificial recharge is a system in which water is recycled; water from the polder system usually discharged to the sea can be used to re-fill the aquifer system (Kodoatie, 2008). The integration of artificial recharge and polder systems can promote sustainable water management, by aiming to achieve the main goal to restrict land subsidence, by recovering the groundwater table in coastal cities. In addition, it mitigates water scarcity and increases fresh water availability (Figure 2).

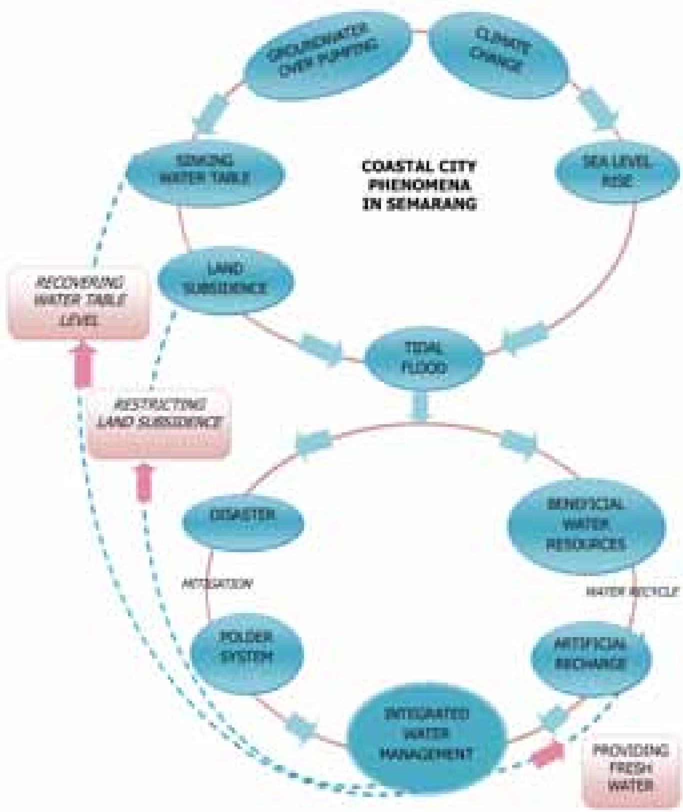

Figure 2: Scheme of sustainable water management

Research methodology

In order to assess the volume of water which must be infiltrated via the artificial recharge well in Semarang, spatial analysis based on Geographic Information System (GIS) technology was applied. The detailed method applied in this research consists of

1. an analysis of the volume of water which must be infiltrated to reduce groundwater level decrease, and
2. an analysis of the necessary recharge rate for the artificial recharge well.

Analysis of the volume of water which must be infiltrated to reduce groundwater level decrease

Vector based GIS has been applied in this analysis. This analysis is calculated based on the decrease of groundwater levels, using per year data as a basis. Temporal groundwater level data in a confined aquifer has been utilized with a time interval of 12 years. Using calculation in GIS software, the current groundwater level is compared to the previous groundwater level. The equation applied to calculate the volume that must be infiltrated is expressed as follows:

$$V = \frac{GWt1 - GWt2}{t1 - t2} \times A \ldots\ldots(1)$$

V is the volume of water that must be infiltrated, GW is groundwater level, t1 and t2 are the time (in year), and A is the area of coverage.

Analysis of recharge rate of the artificial recharge well

The calculation of the recharge rate of the artificial well is based on the data of groundwater level which form the cone of depression in Semarang. The recharge cone can be modeled based on the assumption that the recharge cone has the same shape as the cone of depression, although in the opposite direction. The equation, according to Todd (1976), is as follows:

$$Qr = \frac{2\pi.Kb.\ (ho - hw)}{\ln(ro/rw)} \ldots\ldots\ldots(2)$$

Qr is the recharge rate of water which can be infiltrated, Kb is the hydraulic conductivity, ho is the depth between normal water level and the surface of the confined aquifer, hw is the depth between the groundwater level inside the recharge well and the surface of the confined aquifer, ro is the radius of the area affected, and rw is the radius of the recharge well. The analysis of the number of recharge wells required is calculated based on volume of the water which must be infiltrated, divided by the artificial well recharge rate.

Description of Study Area

Geological and hydrogeological setting

Based on geological condition, the coastal city of Semarang is formed by alluvial sediments which have been deposited on the beach. It comprises clay and sand aged holocene and the average of its thickness is about 80 meter (Marfai and King, 2007). This geological formation determines the aquifer type in Semarang City. According to Soedarsono (2011), those types of aquifer which have experienced land subsidence in Semarang are generally semi confined and confined aquifers, with a thickness of about 30-70 meter.

Groundwater overabstraction in Semarang

Groundwater overpumping in Semarang is mainly caused by the rise of urban population, especially due to the increasing fresh water demand for drinking and business activities. Overexploitation of groundwater in the city resulted in a decrease of the water table. Groundwater taken from confined aquifers has affected land subsidence most strongly in the coastal area of Semarang (Soedarsono, 2011). The decrease of the groundwater level has been classified and mapped as shown in Figure 3.

Figure 3: Map of Groundwater Level Decrease in Semarang
source: result of the analysis, satellite imagery taken by maps.google.com

According to Figure 3, the spatial distribution of the decreasing groundwater level of the confined aquifer system in Semarang is divided into three zones, including zones of high, medium, and low rates. The groudwater level decrease, according to Soedarsono (2011) correlates with the land subsidence rate. Zone A has a high rate of goundwater overpumping, which is followed by a land subsidence rate of more than 0.20 meter/year. Previously, the main form of land use in this area were fishponds. This has been changed into dense settlements and an expansion of the Tanjung Mas Harbour. Zone B, as the zone of medium groundwater level decrease, has a land subsidence rate of 0.10-0.20 meter/year. The previous main land use in this location were also fishponds, which has been changed to industrial estates. Zone C, which is covered by dense settlements, experienced a land subsidence rate of 0-0.10 meter/year.

According to Sudarsono (2011), decreasing water tables due to groundwater overpumping have caused severe land subsidence in Semarang. This condition also generated problems such as groundwater salinization, sea water intrusion to inland areas, and increasing tidal flooding. Furthermore, it affected fresh water availability in the groundwater supply, which has become more and more scarce. Increasing coastal inundation induced by land subsidence and sea level rise also affect urban coastal areas in Semarang. In addition, the longest inundation periods occured in densely populated areas, which caused public health problems such as diarhea, dysentry, dengue fever, etc. These problems are most suffered by low income inhabitants living in the flood-prone coastal area. Land subsidence also has severe impacts on and damages public infrastructure. In Tanjung Mas Harbor and the center of the industrial estates surrounding the harbor area, damages of public infrastructure such as roads, have become worse because of land subsidence combined with heavy transportation loads which frequently pass through the road. As a result, this condition has affected the productivity and the mobility of industrial activities (Soedarsono, 2011).

Result and Discussion

The integrated polder and artificial recharge system proposed in this paper will structurally consist of a polder, canals, water treatment installations, channels, and artificial recharge wells as illustrated in Figure 4. Two canals, the east and the west canal, are the water source flowing within polder system, which is to be discharged into the artificial recharge wells. The channels are proposed to connect the polder system with the artificial recharge well. Before the water flowing in the polder is extracted and flows through the channels, water treatment is undertaken in an installation for water treatment. Thereby, the water quality can be increased before the water is recharged into the aquifer.

In the present paper, the volume of fresh water which must be infiltrated has been calculated, considering the volume of groundwater extracted from the aquifer (Table 1). The highest volume of water must be infiltrated in zone C, followed by zone B and A, respectively. Although zone C has the lowest rate of water table decrease, the area coverage is the largest. Therefore it requires infiltration with the largest amount of water to be stabilized. The opposite condition occurs in zone A which has the highest rate of groundwater level decrease, but the smallest area coverage. Assuming a uniform geological condition over the area, the discharge rate on a single artificial well is calculated to be about 557 m^3 per day.

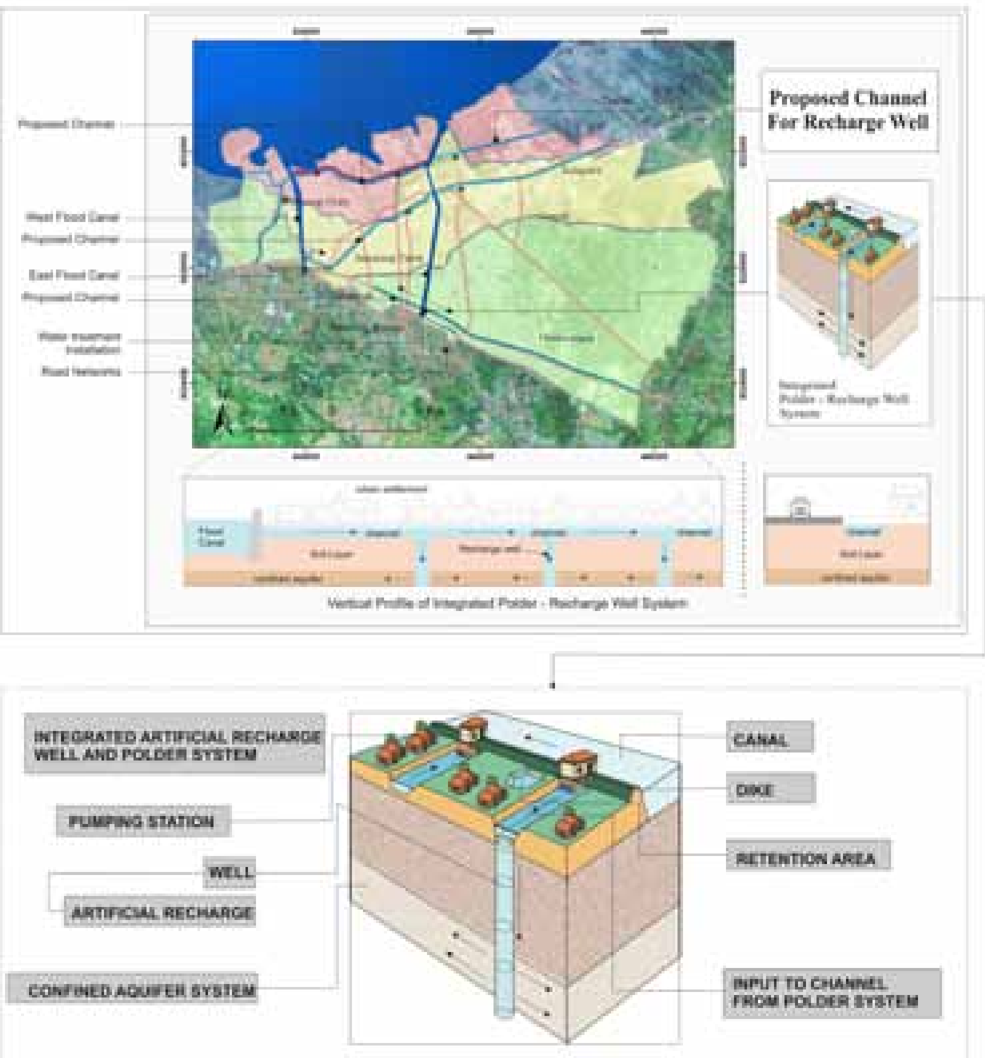

Figure 4: Integrated artificial recharge in a polder system
source: adapted from Sudarsono (2011) and SIMA (2011), satellite imagery taken from maps.google.com

By dividing the volume of water which must be infiltrated by the discharge rate of a single recharge well, the number of necessary artificial wells can be calculated. The analysis has shown that zone A requires 169 recharge wells, zone B requires 218 recharge wells, and zone C requires 169 recharge wells.

Assuming that the discharge rate of the water flowing in the polder has an average of 740 m^3/s (BPDAS Pemali Jratun, 2007) and the amount of water that can be infiltrated into a single artificial well is 557m^3/day, about 0.54% of the total amount of water flowing in the polder is taken into the recharge wells per day. This condition is based on the assumption that the system works on a 24 hour basis, and about 0.022% of the water is taken in per hour. Therefore, if the system works for only 12 hours, about 0.045% of the total amount of water flowing in the polder has to be taken per hour. This is required to fulfill the volume of water that must be recharged into the wells.

Artificial recharge is very essential in providing fresh water for community living, both for domestic and drinkingwater purposes. An observation of present alternatives of water sources and uses, estimates that around 50 percent of the households use deep wells for domestic purposes, including drinking water (SIMA, 2011). Shallow wells are still in use by a minority of households, but these wells are contaminated and not suitable for drinking water purposes. As a consequence, every household buys fresh water from water vendors. In addition, the majority of households use water from installed pipes from the regional water company. Recently, pumped groundwater was categorized as uncontaminated water.

Table 1: Proposed artificial recharge wells for different zones in the polder system, including proposed pumping volume, infiltration and discharge rates to reach targeted water table decrease rates

Classification of groundwater decrease rate	Zone	Area (m^2)	Decrease rate of water table (m/year)	Volume of pumped Ground-water per year (m^3/year)	Rate at which water must be infiltrated (m^3/year)	Discharge rate of artificial well (m^3/day)	Annual Discharge rate (m^3/year)	Number of recharge Wells
High	A	20,618,749	1.667	34,371,454.806	34,371,454.806	557	203,305	169
Medium	B	35,424,797	1.250	44,280,996.466	44,280,996.466	557	203,305	218
Low	C	55,860,364	0.833	46,531,683.764	46,531,683.764	557	203,305	229

In order not to pollute aquifers, water recharged into the aquifer system should meet the requirements for household purposes. Good treatment is needed to ensure the quality of water introduced into the system; so that the recharged water will not change or contaminate groundwater quality.

Conclusion

The integrated artificial recharge in a polder system proposed in this paper is a sustainable water management strategy to address land subsidence. In addition, it can solve common environmental problems in Semarang, such as fresh water scarcity, sea water intrusion, and tidal flooding, from which the area suffers periodically. Last but not least, this innovation will promote sustainable development and prosperity.

G

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.006 LEAGUES UNDER

Rethinking the American Way of Death

Rachel Baudler[1] | Jonathan Blaseg[1]

Abstract

This project examines the possibility of creating a memorial landscape by reclaiming a decommissioned oil rig and repurposing it for coral reef burial. To construct the reef, cremated remains would be combined with concrete and attached to the rig structure below water, providing a memorial landscape as well as new habitat and a potential economic generator.

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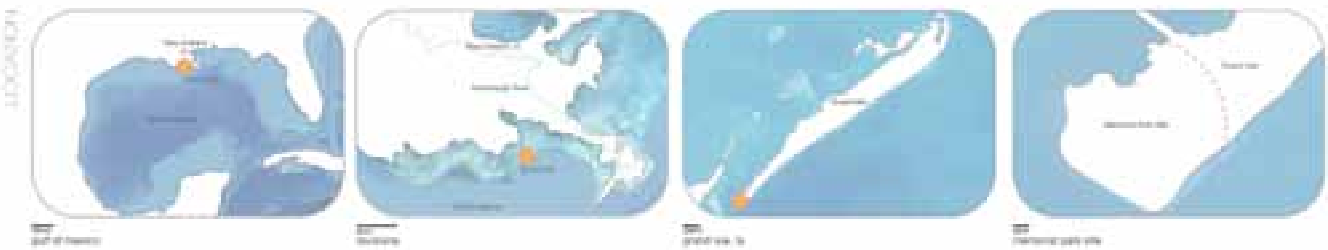
.006 LEAGUES UNDER:
Rethinking the American Way of Death

Introduction

Grand Isle is a barrier island located approximately 95 miles south of New Orleans, Louisiana, just west of where the Mississippi River outputs into the Gulf of Mexico (Figure 1). It is located within Jefferson Parrish in Louisiana, which consists of 70 percent marshland. This area is a victim of coastal erosion from the destruction from the oil and gas industry and the levees on the Mississippi River. Sediment no longer replenishes the wetlands with erosion washing a football-sized chunk of Louisiana land out to sea every half hour. Due to this erosion, the island, and larger region, are exposed to massive flooding and loss of habitat.

There are more than 4,000 oil rigs in the Mississippi River Delta and the Gulf of Mexico varying in size, depth, and mobility that will be decommissioned within the next century (Figure 2). Because a deck on one of these rigs is approximately 20,000 square feet, then there is potentially 80 million square feet of programmable space just off the coast of the United States. The current method for rig removal is explosion, which costs millions and destroys massive amounts of aquatic life. It costs three times more to completely remove a disused platform than it does to re-implement the same reef as an artificial reef.

Figure 1: *The project is located off of Grand Isle, Louisiana, a barrier island 95 miles south of New Orleans.*



There is a delicate balance of river, delta, and Gulf of Mexico processes that must work together to benefit the incredible 'ecosystem services' the Mississippi River Delta region provides to the United States. This project examines the possibility of creating a memorial landscape by reclaiming a decommissioned oil rig and repurposing it for coral reef burial. To construct the reef, cremated remains would be combined with concrete and attached to the rig structure below water, providing a memorial landscape as well as new habitat and a potential economic generator.

A ceremonial boat trip will take the remains from a memorial park on Grand Isle to the rig. A memorial park will be created on the west end of Grand Isle with the revenue from the first memorial reef. This memorial park will also be the staging ground for coastal restoration utilizing concrete reef balls and mangrove plantings to prevent erosion.

Could aging oil and gas infrastructure be a new burial alternative for our aging population and the rig the artificial island on which to build it? This project examines the possibilities of creating a self-sufficient, eco-friendly memorial experience in the United States' backyard – the Mississippi River Delta and Gulf of Mexico.

Marine Life and Migrating Birds

The project provides necessary marine habitat. The region relies on fishing, hunting, and tourism to survive. However, due to over-fishing and the most recent oil spill, the fishing stock of Mississippi River Delta and Gulf has dissipated in recent years. Oysters, fish, and other marine habitat thrive on artificial reefs, established on shallow artificial reefs, rehabilitated mangrove forests, as well as artificial reefs created by oil platforms.

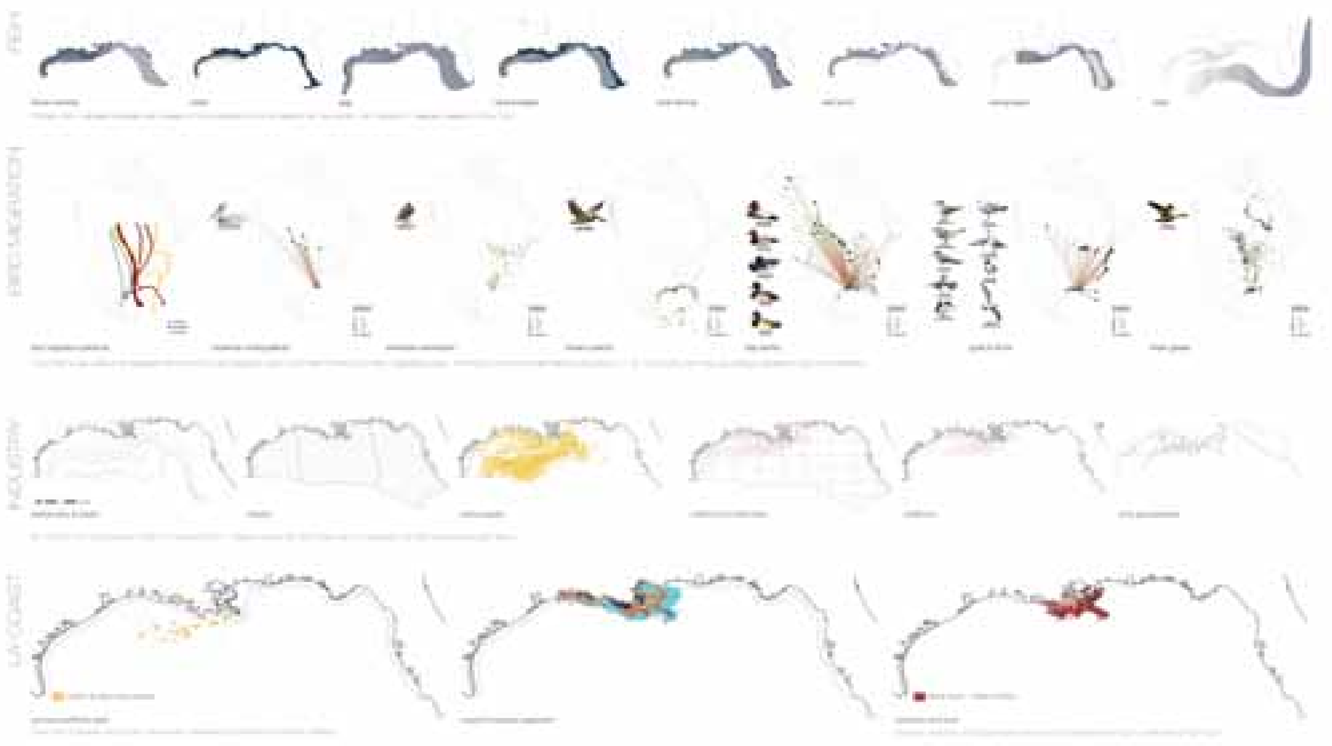
The area is a major flyway for migrating birds. The trip to cross the gulf takes birds from 11 to 18 hours. The more than 4,000 rigs in the Gulf and oil and gas infrastructure in the Mississippi River Delta are important stop-over places on a bird's migrating journey (Figure 2). Restoring habitat, such as mangrove forests and providing coral reef infrastructure will directly benefit these fish and bird species that are important ecologically and economically to the region.

Off-shore Drilling

Drilling off-shore in the Gulf Coast is relatively recent, as the high costs of drilling keep commercial rigs close to the shore; however, with shrinking reserves and climbing oil prices, there has been increased drilling in the Gulf. Technology has not kept up with the pace of drilling. As an example, the Deepwater Horizon oil spill in 2010 became the largest accidental spill into the ocean in history, larger even than the Ixtoc I blowout in Mexico's Bay of Campeche in 1979. The impact of the more recent spill is not entirely known; however, many of the reefs in the area have still not recovered.

There are 12,355 square miles of wetlands where land meets the sea in the Mississippi River Delta, down at the bottom of the Louisiana boot. One-third of the United States oyster and shrimp crop comes out of the waters along the Louisiana coast. Within a month of the explosion, water reached the wetland areas.

Figure 2: Analysis of the important marine and bird habitat in the region as well as an overview of the oil and gas industry in the Mississippi River Delta and Gulf of Mexico



Providing increased coastal restoration and protection on barrier islands is essential in the Mississippi River Delta. This project provides necessary restoration in the form of artificial reef balls along the northern shore of the island and can be utilized as a model for other barrier islands.

Alternative Burial

Cremation continues to grow as an accepted form of respectful memorialization. This is due to many reasons including the cost. Cremation is an affordable option compared with traditional service. Traditional burial is most costly of all burial types at an average of more than $12,000. This memorial reef would range between 4 to 5,000 dollars, which includes the casting, viewing, and placement (Figure 3).

Burial in the Louisiana delta region is above ground due to both cultural reasons, as well as the high water table. Because the only cemetery on Grand Isle is currently at capacity, above-ground burial was included at the memorial park. Burial was designed to be culturally sensitive as well as provide additional ecological infrastructure.

Figure 3: Cremation continues to grow as an accepted form of respectful memorialization

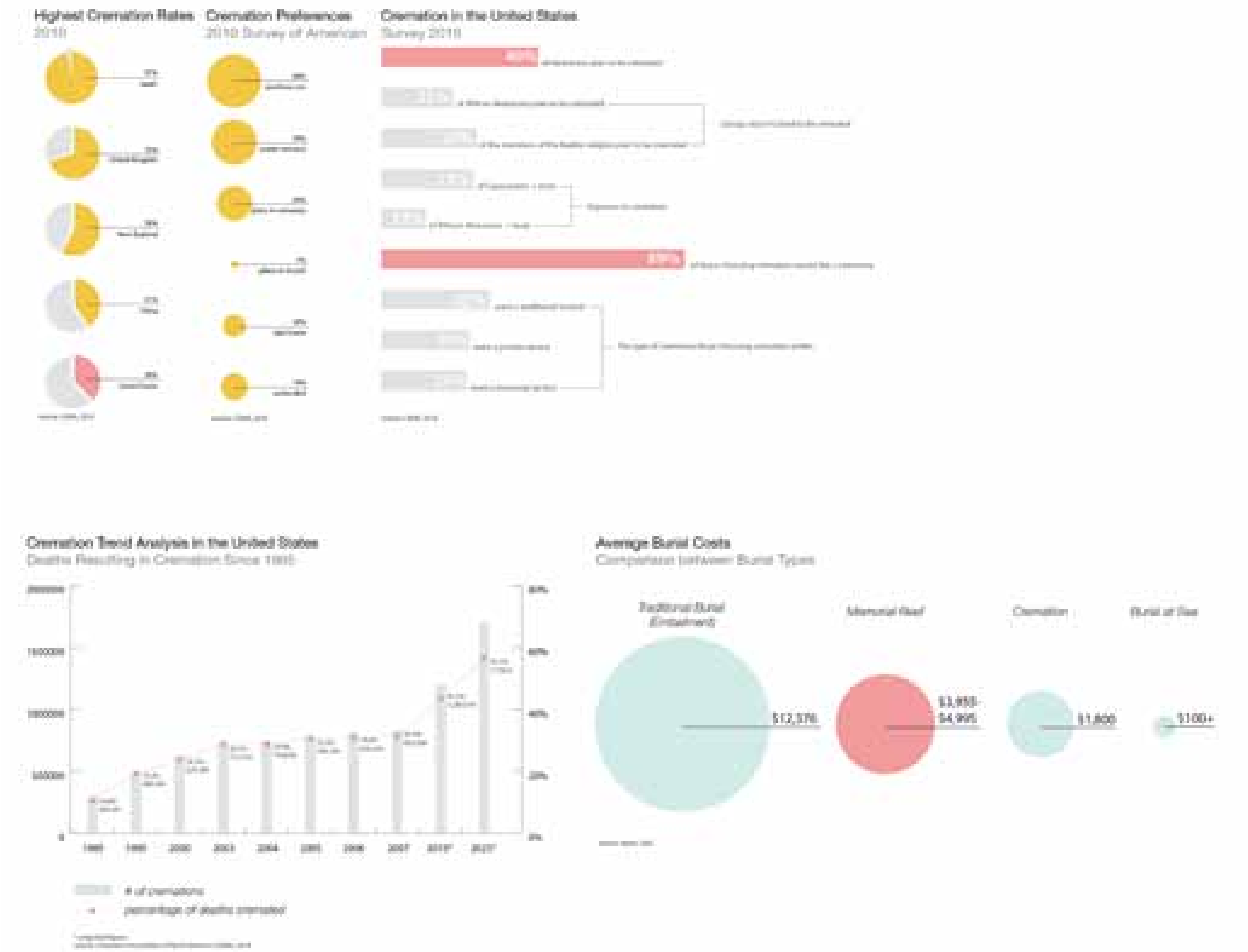


Figure 4: A view on Grand Isle down one of the shallow canals lined with mausoleums

Location

For this project, Grand Isle, Louisiana was selected because it is located in an ecologically and economically critical area in Louisiana's delta. Establishing a memorial reef near a vacation destination, such as Grand Isle with its beautiful beaches and fishing attractions was important to provide a family every reason to come back and visit. With more families moving away from their hometowns, fewer relatives return to their ancestral cemetery.

The Memorial Park

The design for the island and rig is to provide a multifunctional landscape, providing a balance between cemetery, public space, and ecological restoration, allowing both passive recreation and sanctuary to co-exist (Figure 6). The project is designed to aid in rehabilitating the Mississippi River Delta and Gulf of Mexico in a unique and sustaining way.

The cemetery program starts at the transfer area where the service facilities and the launching point are situated. The dedication ceremony, where the cremated remains are combined with a concrete slurry, will happen on the deck in this area. The mixture is poured over a dome-shaped fiberglass form and allowed to harden for a month. Plaques, handprints, and other mementos are then added to personalize each reef module. Family and friends

Figure 5: Site plan of the memorial park on Grand Isle

then return one month later for the deployment of the modules. At the rig, the reef modules will be placed from the rig platform, with friends and families watching from the rig deck.

From the transfer area on the site, a boat will take the remains through the grand canal toward the rig (Figure 4). Mausoleums align the canal, built into the land with tall grasses peaking on top. The smaller canals off the main channel are shallower, demonstrating the island's tidal flux and high water events. Inside the canals, the light and water reveal the passing of the hours. At low tides, the canals have little to no water; however, at high tide, the shallow canals are flooded and become unwalkable, visually communicating the temporal qualities of the island that are sometimes lost with construction of the levees. When the tide is high, the casket can be brought by boat out to the tomb for burial (Figure 5).

The entire cemetery area is submerged, creating a division from the surrounding park. There are many places for contemplation, with the larger being the mausoleum area and the columbarium wall built into the levee. The levee creates a sanctuary, with the visitor's eyes directed up towards the graves on the walls, accented by the lush, vertical grasses that are planted in mass (Figure 6).

The large, curved pathway that divides the park is lined by a grove of mangrove trees. The trees roots are covered with water twice a day with the tidal flux, with smaller paths cutting into the grove. When looking down these paths, the viewer is directed towards the rig, with runnels leading the visitor onward in the direction of the sea. At night, the view is further directed with buoyed lights leading the eyes to the memorial reef location (Figure 7).

Figure 6: Cross sections of the memorial park and a view of one of the columbarium walls

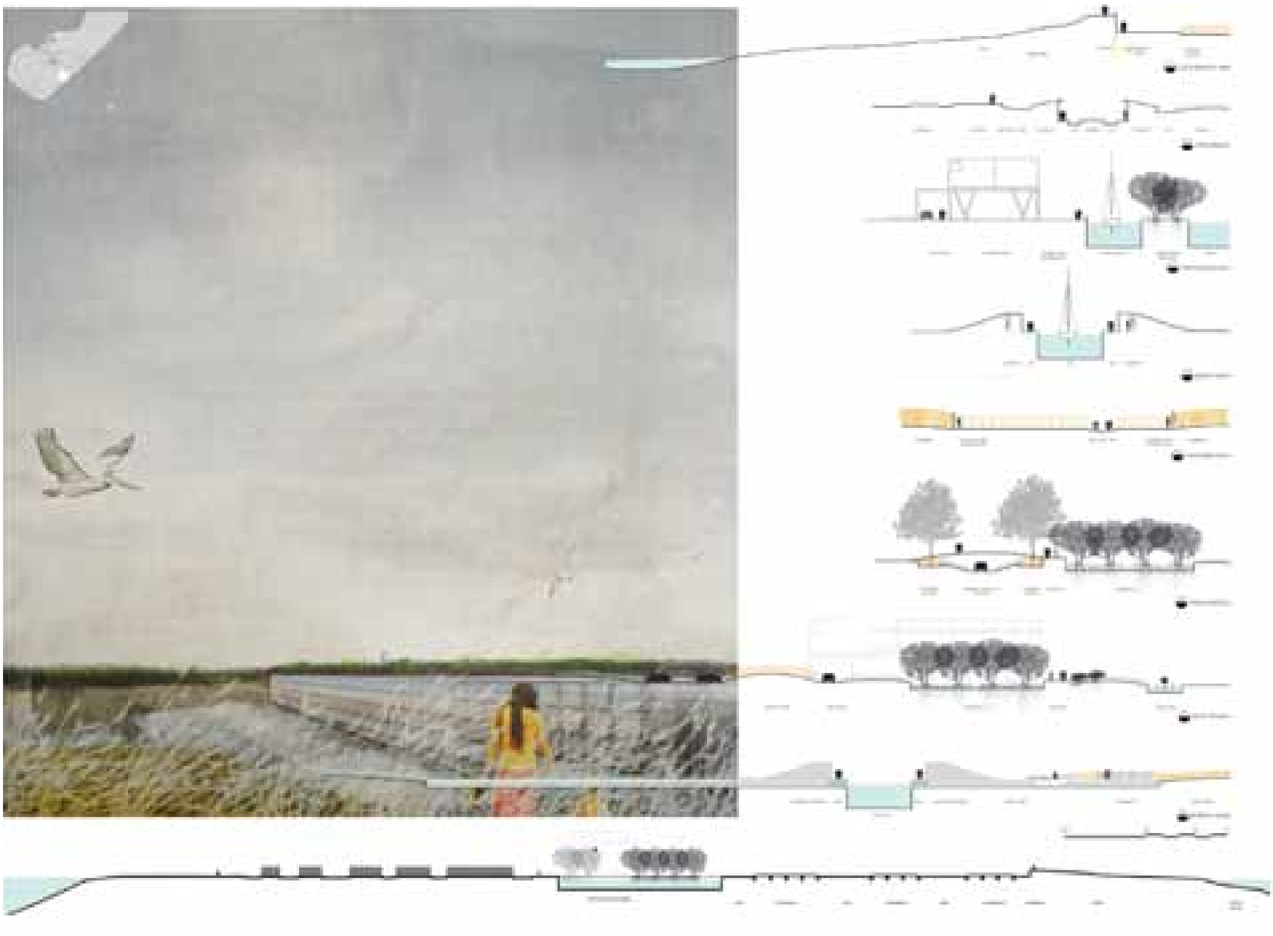


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Figure 7: At night, views from the park are directed to the memorial reef location with buoyed lights and lighting ceremonies

Restoration

Vegetation will be restored to include a saline marsh and mangrove swamp. In the initial phase of planting, black mangroves will be planted into reef modules on the northern edge of the site, as the concrete ball allows the tree to grow within a supported structure. As the forest matures, the coast will be stabilized with the new ecological habitat emerging. The roots restrict soil from washing out to sea and brown pelicans, royal terns, and other migrating birds perch safely in this habitat, while young sport fish, including gray snapper and red drum, find that tangled mangrove roots make great hideouts (Figure 8).

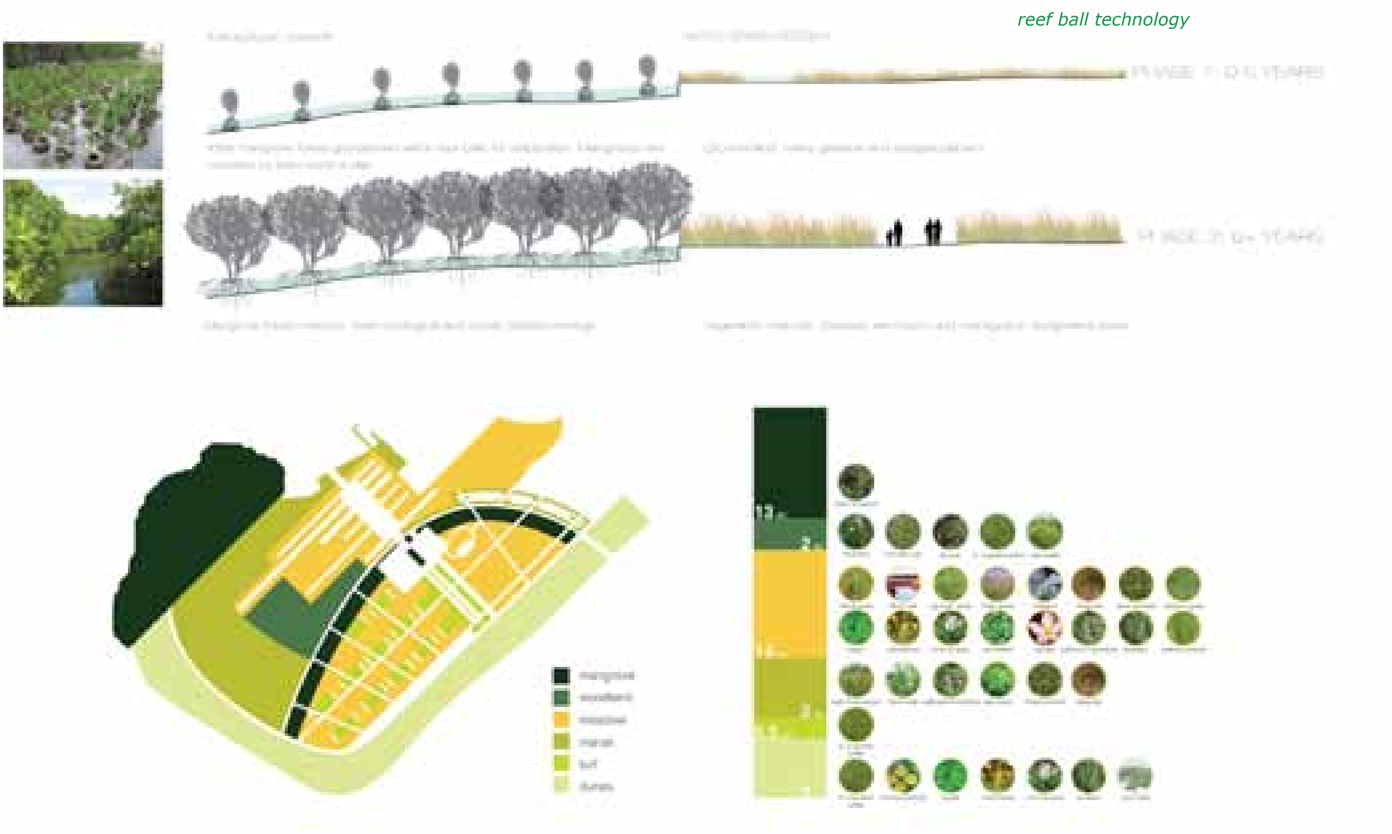


Figure 8: Vegetation will be restored to include a saline marsh and mangrove swamp by using the reef ball technology

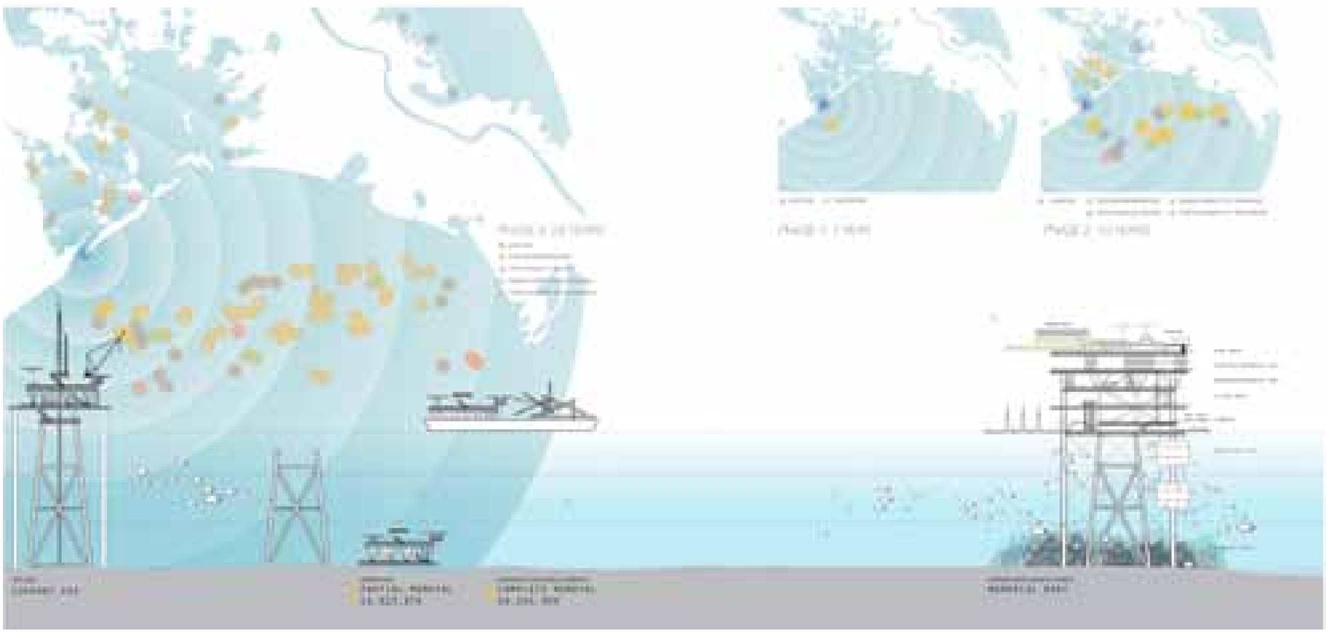
Figure 9: A view of the memorial reef (the reef balls) providing habitat in the delta ecology

Further inland, a meadow will be planted with vast native grasses and sedges that shelter ducks, snipes, cranes, doves, and other animals. The grasses vary in heights, with many taller than six feet in height. After establishing, such grasses will be mown and maintained to create outdoor rooms for the cemetery.

Reef Balls

Over 5,000 reef balls have been deployed in more than 3,500 projects worldwide. Only a fraction of these have contained human remains, but these numbers continues to rise. Reef modules have had huge success in building artificial reefs. Within five years of their deployment, reef balls attract about 80 percent of the diversity as natural forming reefs. Reef balls can be deployed in varying water depths, providing habitat in delta ecologies as well as deeper, coral reef applications (Figure 9).

Figure 10: In future phases, additional platforms and infrastructure on and offshore of Louisiana will be repurposed for memorial and artificial reefs, as well as other uses, including alternative energy such as wind turbines, research stations, recreation, and hospitality services



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Reef Building

Many rigs and other oil and gas infrastructure are located within a few miles of shore in the delta and Gulf, many with high visibility from the shoreline (Figure 10). By 2020, Mississippi River Delta and the Gulf of Mexico will lose 95 percent of the platforms and other oil and gas infrastructure in depths less than 600 feet due to depletion of offshore oil and gas fields.

Phase I repurposes a rig two miles off the coast of Grand Isle for the memorial reef. This rig is envisioned as a place for memorial, ecological research, and tourism to overlap and integrate (Figure 11). In future phases, additional platforms and infrastructure on and offshore of Louisiana will be repurposed for memorial and artificial reefs, as well as other uses, including alternative energy such as wind turbines, research stations, recreation, and hospitality services. Phasing of the reuse of the platforms and infrastructure in the delta and gulf is based on the amount of oil and gas wells and the rate at which those reserves are depleting.

Figure 11: A view from the rig looking down as a reef ball is being deployed into the water

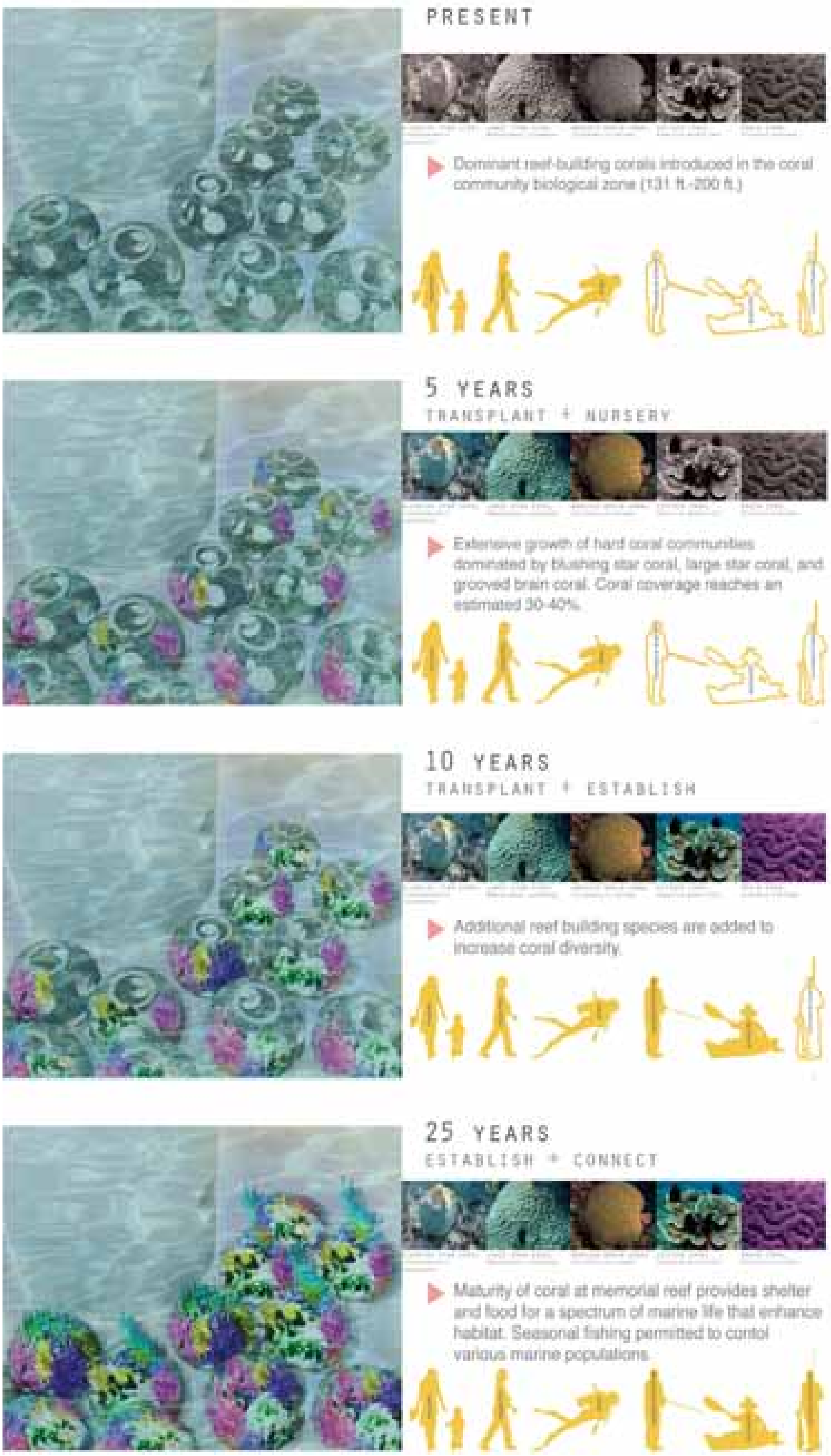

***Figure 12:** The memorial reef and its users will be phased over a 25-year period*

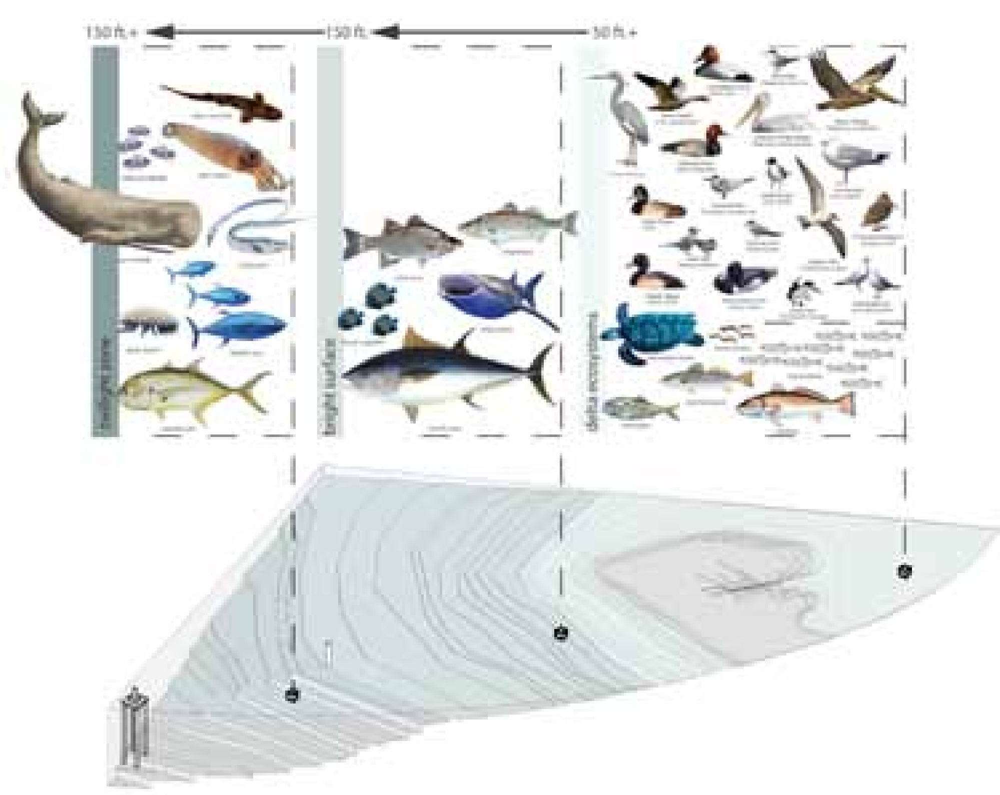

Figure 13: Marine species in the region

Reef Phasing

The memorial reef in Phase I and its users will be phased over a 25-year period (Figure 12). Within the first five years, dominant reef building corals will be introduced at the reef. Coral coverage is expected to reach approximately 30 to 40 percent in this phase. During these years, mourners, researchers, and divers will be allowed access to the rig and memorial reef. At ten years, more reef species will be added to diversify the coral habitat. In addition to the other users just mentioned, recreational fishermen and ecotourists will also be encouraged to visit the reef. At 25 years, the reef will be fully mature. Seasonal commercial fishing will also be permitted to control various populations (Figure 13).

The money generated from this memorial reef in Phase I will help fund the park and burial on the island, as well as future rig and structure repurposing. Explosion is the current method for rig removal, at an estimated cost of 45 million US dollars. In recent years, a reef program has been established by the state of Louisiana to create and sustain reefs at decommissioned rigs and other oil and gas infrastructure sites both in the delta and Gulf. Comparatively, this only costs approximately 15 million US dollars, a savings of about 30 million US dollars. The oil and gas companies are required to pay the cost to establish and maintain the reefs. Currently, over 60 reefs exist on and offshore of Louisiana.

Conclusion

In summary, this project examines the possibility of creating a self-sufficient, eco-friendly memorial experience in the United States' backyard - the Mississippi River Delta and Gulf of Mexico, while also providing necessary marine habitat and coastal restoration. As John F. Kennedy mused: "I really don't know why it is that all of us are so committed to the sea… We are tied to the ocean, and when we go back to the sea – whether it is to sail or to watch it – we are going back from whence we came."

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Burial

Coral Reef Burial Companies

Great Burial Reef: www.greatburialreef.com

Eternal Reefs: www.eternalreefs.com/resources/links.html

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NEW ORLEANS
Missisipi River Delta
ROTTERDAM
Rihne-Meuse
HO CHI MINH CITY
Mekong
SHANGHAI
Yangtze
SAN FRANCISCO
California Bay Delta
TULCEA
Danube
DHAKA
Ganges-Brahmaputra-
Meghna
CAIRO
Nile
JAKARTA
Ciliwung
BUENOS AIRES
Parana
MAPUTO
Incomati
SAMARINDA
Mahakam Delta

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Cyclicity

A new direction to protect deltas and preserve marine ecosystems

K.M. Czapiewska[1] | B. Roeffen[1] | R.E. de Graaf[1,2]

Abstract

Delta areas all over the world face multiple interconnected problems. They are increasingly threatened by flood damage, land subsidence, sea level rise, and extreme weather events. This article shows that these trends can be divided into two main components; food issues and space issues. The main challenge is how to accommodate a huge increase in population while at the same time reducing the pressure of delta areas on the environment. This article uses the concept of productive urbanization based on cyclic resource flows. Current modern cities produce hardly anything else than waste. At the same time, cities extract all resources from rural areas and ecological systems. This parasitic behaviour should be reversed and cities should be built that have a positive impact on their environment and create pleasant living conditions for involved and resilient communities. This article introduces the concept of the Cyclicity. The Cyclicity is a spatial intervention for delta areas that is based on cyclic patterns of resource flows. It establishes a symbiotic relation with an existing delta where it is plugged in. Cyclicity represents a "productive" floating urban development, in contrast with the traditional "consuming" city. Conventional urbanized areas consume large amounts of food, fuel and other goods, often transported over long distances, and produce waste and emission. Because it is a floating city, the Cyclicity will adapt to any future water level and will not suffer flood damage due to extreme weather events. The floating city can also

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function as wave breaker, protecting vulnerable delta areas. The article presents some key elements for the governance of a Cyclicity. Sufficient attention should be paid to stakeholder receptivity, improving innovations, creating a commercial market, a new task for designers and institutional mechanisms. These are important elements to realize a Cyclicity as a new direction to protect deltas and preserver marine ecosystems.

Introduction

Delta areas all over the world face multiple interconnected problems. They are increasingly threatened by flood damage, land subsidence, sea level rise, and extreme weather events. This article shows that these trends can be divided into two main components: food issues and space issues. This chapter provides an outline of some urgent delta problems and challenges.

Spatial issues

Land subsidence

Over-exploitation of groundwater resources in delta areas has led to land subsidence and saltwater intrusion in many delta cities such as Jakarta, Bangkok, Shanghai and Venice. In Jakarta, Indonesia, land subsidence of 20 cm to 200 cm has been reported in various locations and land subsidence rates of more than 10 cm a year are not uncommon (Abidin et al. 2007). As a result, large parts of the cities have subsided below the sea level. Due to the construction of dams upstream in the river and dikes along the rivers, the natural sedimentation process in deltas no longer takes place. This makes it impossible for the land to keep up with rising water levels in the river. The problem of land subsidence is aggravated by the expected impacts of sea level rise (IPCC, 2011). Groundwater extraction and land subsidence are not limited to delta cities only. The centre of Mexico City, for instance, has experienced land subsidence of 7.5 meters due to decades of groundwater extraction (Ortega-Guerrero et al, 1993).

Land scarcity

With the continuing growth of urbanization, cities in delta areas face land scarcity. It is expected that in 2050, 75% of the world's population will be living in cities (Arup, 2011) and the urban population will increase from 3.5 billion to 6 billion (FAO, 2011). This urbanization mainly takes place in areas that are located in coastal areas and river plains. It is estimated that in 2030, about 50% of the world's population is expected to be living within 100 kilometers of the coast (Adger et al, 2005). Continuing urbanization will lead to an increase of the number of people who are exposed to hazards in vulnerable areas (World Bank, 2009). Land scarcity usually leads to an increase in land value and property value. Poor city dwellers are forced to live in vulnerable areas near cities where land prices are still low. As a consequence, slums emerge that are often located on the most vulnerable places such as flood plains of rivers and coastal plains.

Flood damage

Over the past decades there has been a steady increase in the number of natural catastrophes from around 400 a year in the early 1980's to almost a 1000 a year in the late 2000's. Due to the rising number of extreme weather events and continuing urbanization in vulnerable areas, global flood damage in urban areas has increased up to more than 100 billion US$ a year (Munich Re, 2010). The IPCC (2011) predicts that climate change is likely to further increase the number of extreme weather events. Moreover it is very likely that sea level rise will contribute to an increasing frequency of extreme coastal high waters such as storm surges. This will further increase flood damage.

Degradation of ecosystems

River basins are polluted by agricultural and urban activity. As a result, pesticides, fertilizers, organic pollutants, pharmaceuticals, heavy metals, plastics and other pollutants end up in marine coastal ecosystems due to unsustainable human activities. This is problematic because coastal areas play a key role in marine ecosystems that both have a huge intrinsic value but also support other ecosystems and human food supply. Most biodiversity is concentrated on the land-water interface. This means that delta areas have a key position for the ecological preservation of migratory birds and fish. Coastal ecosystems such as wetlands, mangroves and coral reefs also protect cities from coastal flooding. In New Orleans, human activities caused the deterioration of the Mississipi Deltaic Plain. This increased the vulnerability during the severe flooding during the Katrina Hurricane in 2005 (Day et al, 2007). Removal and destruction of these ecosystems increases the flood vulnerability of many delta areas. Degradation of ecosystem in delta areas has accelerated over the last decades. Coastal ecosystems are under strain because of land cultivation, reclamation, destruction of habitat and pollution. Around 50% to 70% of all coral reefs are under threat of human activities such as overexploitation, pollution, human induced climate change and tourism (Hoegh-Guldberg, 1999).

Food issues

Food availability

Due to urbanization and population growth, the land area available for food production is continuously decreasing while the demand for food is continuously increasing. This has led to rising food prices over the past years which endangers the food availability for many poor people.

From the 18th century up to now agriculture has changed dramatically. Several developments resulted in unprecedented crop yields that could sustain a much larger world population. The most important are the invention of artificial fertilizer and pesticides, genetic seed development and mechanization. These developments each have huge risks that are increasingly becoming apparent. Excessive use of artificial fertilizer and pesticides leads to soil degradation. The Guardian reports that in 2007 approximately 40% of the world's agricultural land is seriously degraded (Sample, 2007).

The earth's total available surface is 510 million km^2. About 100 million km^2 of biologically productive land is available and in use. More than two third of the total area of the world is covered by of water. Mostly the expansion of agricultural land decreases the amount of forests. An example of this is the extensive deforestation in Brazil, for the sake of soybean production, mainly used as food for livestock farming (Wallace, 2009).

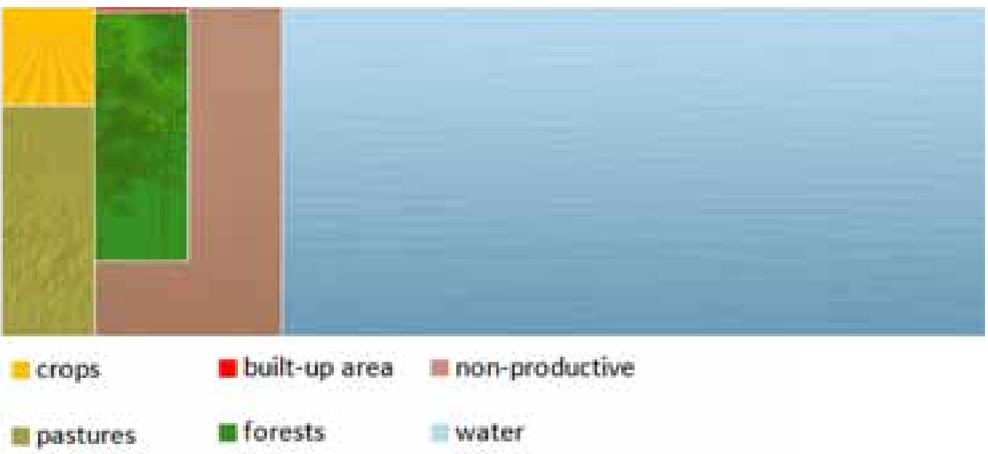


Figure 1: Representation of land use on earth. Categories are crops, livestock, build up area, forests, non-productive and water.

Livestock is the largest user of land in the world, utilizing 3.9 billion hectares in total. This is about 78% of all agricultural areas and amounting to one third of all the land on our planet (FAO, 2006). Livestock farming is significantly less sustainable than crop farming. In comparison with grain, meat production requires up to 80 times as much land to produce the same amount of food energy (MNP, 2007). With the consumption of meat and fish increasing, especially in the developing countries as Asia, Latin America and the Caribbean (FAO, 2000), (McMicheal et al, 2007), land scarcity will become more and more a pressing problem for delta areas.

Dependency on fossil fuels

Modern industrialized food supply is highly dependent on fossil fuels. An amount of 10 kJ of fossil fuels is needed to produce and deliver 1 kJ of food to a consumer in the US (Pfeiffer, 2006). Research shows that in total 30% (about a third) of the global GHG emissions can be attributed to agriculture and meat production. Moreover 95% of the fertilizer is produced using natural gas (Smil, 2001). In 2009, only 3% of the world energy supply was from renewable resources (excluding hydro power) (IEA, 2011). Almost half of the increased energy demand in the past decade was met by coal, a non-renewable energy source that produces more pollution than other fuels. The known gas- and oil reserves will decline with 40% to 60% in 2035 (IEA, 2011). At the same time, with economic development and population growth the energy demand will increase. Cambridge University professor David Mackay (2009) elaborates in his book that switching to 100% renewable mergy for a developed country such as the UK, is only possible if almost the whole country is used for energy production including significant parts of the coasts. On the other hand, if the world succeeds in reducing the energy demand by 15% in 2050 compared to 2005, it is possible to switch to 100% renewable (Ecofys et al, 2011).

Nutrient depletion and eutrophication

Another problem related to food availability is the depletion of nutrients, in particular phosphate. Nutrients such as phosphate and nitrate are critical to food supply. Currently, the global food supply depends on artificial fertilizers. The production of most fertilizers is based on mining of finite reserves of rock phosphate. Proven phosphate reserves are sufficient for 100 years of economic use (Driver et al, 1999; Isherwood, 2000). Local urban sources such as local wastewater streams are hardly used. According to scientists with the Global Phosphorus Research Initiative, the world is not going to have enough phosphorous to meet agricultural demand in just 30 to 40 years.

On the other hand delta areas suffer an excess of nutrients (nitrogen and phosphorus) dissolved in river water. These nutrients, resulting from intensive agricultural practices, industrial activities and urban runoff, are ending up in the environment. The over-enrichment of water by nutrients such as nitrogen and phosphorus causes eutrophication (excessive growth of phytoplankton, micro- and macroalgae), which leads to hypoxia (oxygen depletion) and algal blooms, destroying aquatic life in affected areas.

Over exploitation of water resources

Water resources are overexploited in most river basins (Smakhtin et al. 2004). Water accounts for the largest material inputs to cities in terms of mass (Kennedy et al., 2007). The amount of imported virtual water to cities is even larger. Virtual water is the water needed to produce agricultural commodities (Allen, 2001). It requires about 1,000 cubic meters of water to produce a ton of grain. If a city imports a ton of grain it also imports 1,000 cubic meters of virtual water. This means water is not imported literally, however the amount of water had to be extracted in a rural area to be able to produce the grain that was imported by the city. This makes the city very dependant on the surroundings. Harvesting of rainfall in cities only takes place at a relatively small scale. In the future, cities should make better use of local rainfall. It is estimated that China and India will need all runoff that is generated to meet urban and agricultural water demand in the next 20 years (Jury and Vaux, 2005). According to the World Bank, an equivalent of 130 million people in China and 175 million people in India are being fed with grain irrigated with water that is being pumped out of aquifers faster than it can be replaced (George, 2011).

Due to overexploitation of water resources, some rivers no longer reach the sea anymore because all water is extracted for irrigation and drinking water production. Examples are the Colorado River and Rio Grande in the United States and the Yellow River in China. In other rivers such as the Nile in Egypt and the Indus in Pakistan, the discharge has considerably dropped (Pearce, 2006). Because river flow is severely reduced or even eliminated, salt water intrusion threatens several coastal areas. The productivity of these areas decreases, further putting food production under strain. Many cities face water scarcity. While desalination is often seen as solution for the water scarcity of cities, this technology requires much energy and leads to a high emission of CO_2 if fossil fuels are applied.

Depletion of fish stocks

The majority of all the world's major commercial fish stocks are threatened and overexploited. A study of fisheries data in 2006 concluded that if the current trend in marine species population declines continues, all such populations will have collapsed by 2048 (Cohen, 2012). Overall, 80 percent of the world fish stocks are reported as fully exploited or overexploited and (FAO, 2008). This is an indication that the boundary of maximum fish yield has been reached or even exceeded. Increasingly efficient fishing technology, lacking management systems, insufficient enforcement and a lack of awareness among consumers have led to depletion of many fish species.

Aquaculture becomes increasingly important and accounts for almost half of the total fish supply. Intensive aquaculture in open seas often has an industrial character and requires a high amount of antibiotics and fish feed. The result is a low quality product that pollutes waterways and degrades the coastal ecosystem even more. According to a study published by Bioscience (Duarte et al, 2009) aquaculture can cause health hazards to humans. Organic pollutants and heavy metals are found in fishmeal and oil that may accumulate in aquaculture products. Fish food is subsequently enriched with nutrient supplements, antibiotics and hormones what can lead to resistant pathogens that may affect humans. Also the escaping of fish could have a negative impact on native species. For this reason, the global spread of aquaculture could have negative effects on biodiversity and ecosystems.

Another large environmental impact is the use of fish food and fish oil containing wild caught feed. The production of fish oil is a large scale environmental hazard of its own. An example of this unsustainable fish farming is salmon farming. The biggest issue here is that much of the fishmeal and oil produced in Peru from anchovy fish stocks is the principal ingredient of feed used in salmon farming. Therefore, aquaculture can also cause a decline in natural fish stocks that are used for the production of fish meal and fish oil. Furthermore, the production of fish food often is connected with poor labour conditions for the production workers and detrimental environmental impacts (Wasley, 2008).

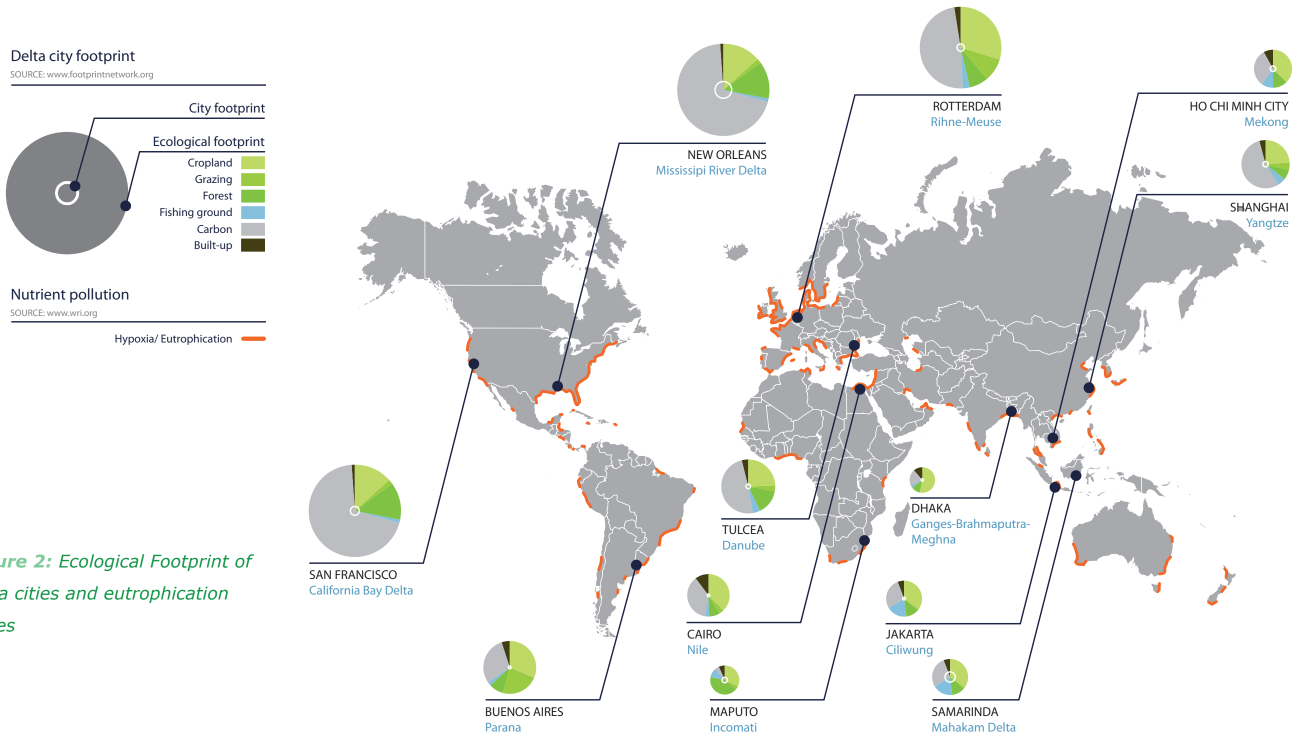


Figure 2: Ecological Footprint of delta cities and eutrophication zones

River deltas worldwide struggling with sustainability

With the mission of improving the resilience of the world's deltas, coping with the issues elaborated in the previous paragraphs, the international Delta Alliance has been established. For the Alliance, a comparative assessment was made on the vulnerability and resilience of 10 deltas (Bucx et al, 2010). This analysis showed that in most deltas the sustainability was not satisfactory due to an imbalance between supply and demand for water and land, an inadequate or ageing infrastructure, disruption of natural delta processes, inadequate governance to address problems and implement solutions. In figure 2 relations between the city footprint and the ecological footprint are visualized. An ecological footprint measures the total amount of land and resources used by a person, organization or country (Bestfootworward, 2011). Based on the calculations from the living planet report (WWF, 2010) the global hectares that are needed per inhabitant per year are compared to the area of the city divided by the number of inhabitants. This analysis shows that food is a large part in the footprint of all the cities. Also the excess of nutrients are shown which are largely concentrated around coastal areas, especially where rivers mouth into the sea.

To reduce the existing negative effects, a mode of urbanization is needed that reduces the current footprint, eliminates nutrient problems and does not need the already scarce and overexploited space.

Problem analysis

This paragraph analyzes the connections between the problems that were presented in chapter Solution Strategies. The principle of circular metabolism, the accumulation effect and the trophic level form the basis of the solution that will be presented in the first chapter about Spatial Issues.

Delta cities are almost entirely dependent on surrounding areas. They use resources (land, water, energy, food, materials) as input and have waste and emissions as output. In such urban systems, resources are used without much concern about their origin. Neither is there much awareness about the destination of waste. A linear metabolism leads to depletion of resources at the beginning of the resource flow and accumulation of waste at the end. Therefore, linear flows are finite. To be sustainable, cities have to close their cycles, in a way that waste of one component of the system becomes a resource for another.

A systems perspective is applied to analyse the problems in delta areas. This approach is needed because the spatial and food related problems occurring in delta areas are inextricably linked. When one problem occurs it can influence other problem areas. These connections have been divided in three categories and applied on the issues previously presented:

- Post - Linear: When development 1 occurs it can lead to the occurrence of development 2.
- Pre - Linear: The occurrence of development 2 causes development 1 to occur.
- Cyclic: Development 1 leads to occurrence in development 2 which on the other hand again enlarges the effect of development 1.

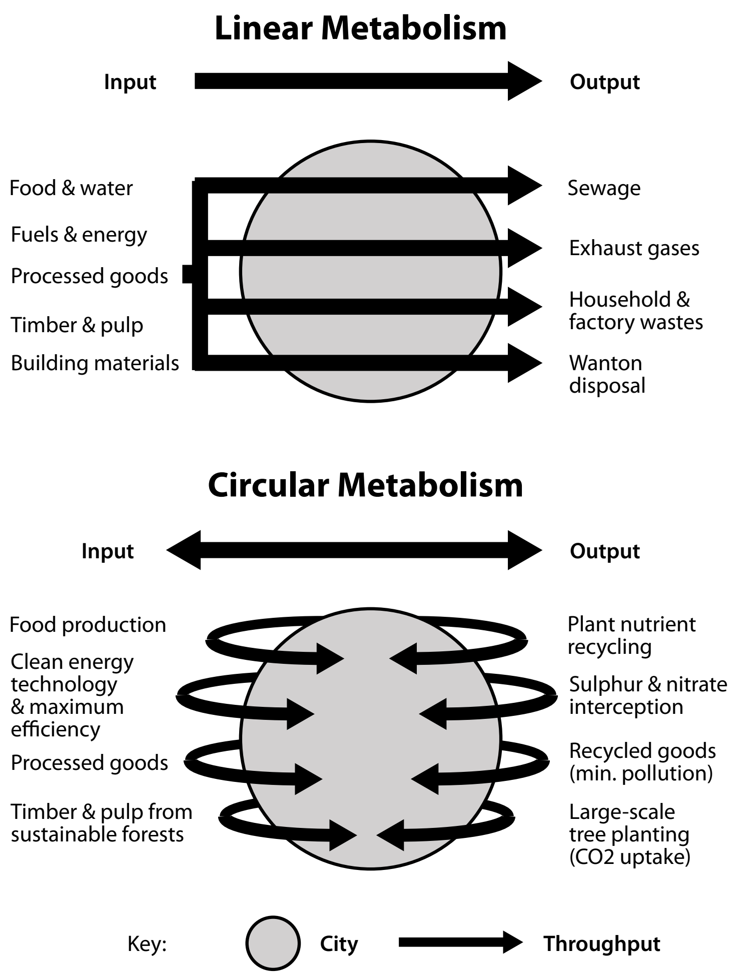


Figure 3: Linear and circular metabolism

Source: Blogspot, 2007

Figure 4 shows the connections between the problem areas. What can be concluded is that some of the themes are interlinked far more than others. The graph shows that food availability is the central theme with most connections to other issues, followed by flood damage. The problem areas are outlined below.

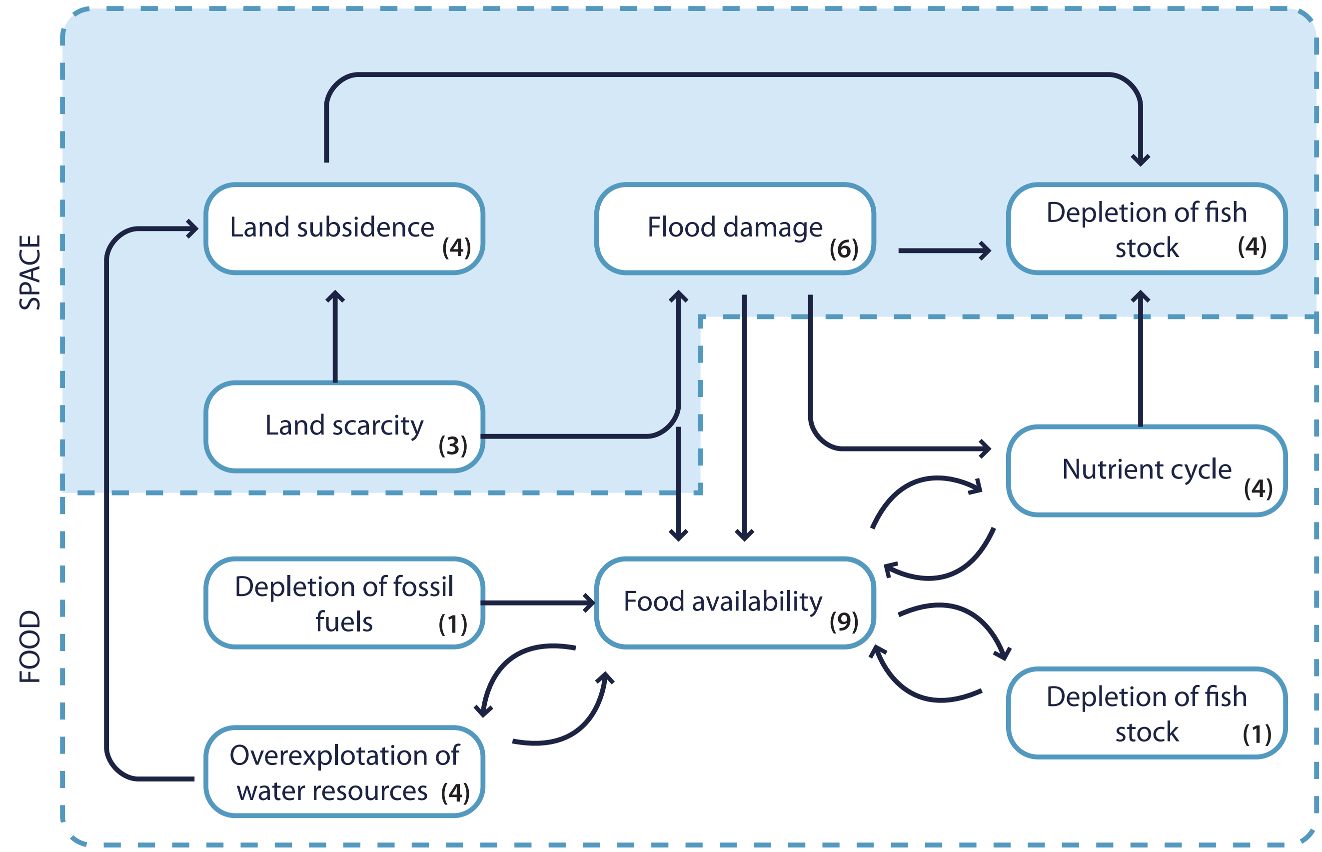
Land subsidence

Land subsidence is caused by overexploitation of ground water resources. Water is often applied for the irrigation of crops or for animal farming. Land subsidence is also caused by lowering groundwater level for growing crops (WMD, 2012), when suitable land for agriculture is not available because of land scarcity. When land subsidence occurs, flood damage increases.

Flood damage

When floods occur, often food availability decreases due to the overload of the water and possible crop diseases (UMass, 2012). Flood damage can also cause a wash out of nutrients from the soil. Land subsidence leads to more flood damage. Flood damage can also lead to the degradation of ecosystems. At the same time, degradation of ecosystems such as wetlands, that protect areas during floods, increases the flood damage.

Figure 4: Connections between problems in delta areas from a systems perspective. The numbers in the boxes indicate the level of interconnectedness to other problems.



Land scarcity
Because of land scarcity people start to inhabit more vulnerable areas such as flood plains of rivers and coastal plains. This causes an increase in flood damage. Cropland is scarce, especially in highly populated areas. The scarcity of land also influences the availability of food because agriculture has to compete with urbanization.

Degradation of ecosystems
Flooding can cause eutrophication of ecosystems, the wash out of nutrients from the soil, drowning of life stock and crops, and the release of chemicals from industrial areas (KIWA, 2007). Wetlands for example play a vital role in controlling floods (Maine.Gov, 1996): if they degrade, flood damage increases.

Food availability
Food availability has several connections to other issues. Important is the dependency on fossil fuels for a variety of stages of the food process; from the manufacturing of fertilizer to the transportation of the food. The supply of fossil fuel is finite and for this reason, alternatives as biofuels are examined. Biofuel is a type of fuel whose energy is derived from biological carbon fixation.

Land previously used for food production is now used for biofuel crops. This creates a potential competition for land between food production and biofuels that could cause food prices to rise up to 75% (Chakrabortty A., 2008) (Walsh B., 2011). Overexploitation of land leads to land degradation. This influences food availability. The overexploitation of water resources is mainly caused by agriculture. At the same time, food availability is threatened when water resources are under strain. Also the depletion of the fish stock influences food availability.

Dependency on fossil fuels
Food and fossil fuels are interconnected in several ways. Fertilizer is produced using natural gas, the operation of field machinery, transportation, irrigation and pesticide production all need excessive amounts fossil fuels.

Nutrient cycle
Nutrients such as phosphate and nitrate are critical to food supply. Currently, the global food supply depends on artificial fertilizers. The production of most fertilizers is based on mining of finite reserves of rock phosphate. The availability of food is therefore influenced when nutrients deplete. Also floods can cause nutrients to wash out causing ecosystems to degrade.

Over exploitation of water resources
Overexploitation of water resources is mainly caused by extracting water for agricultural use. The total amount of water needed highly depends on the type of product. For example potatoes and tomatoes need relatively little water; 105 – 130 m^3/ton of food. For meat products the numbers are higher. Poultry needs 4,100 m^3/ton and other meats up to 11,350 m^3/ton (FAO, 2002). Over exploitation of water resources can lead to the decrease in water level which in its turn can lead to land subsidence.

Depletion of fish stocks
Because of the growing consumption, fish stocks are depleted in a high rate. This influences the availability of food for many coastal populations, who depend on fish as their main source of protein.

Solution strategy

Based on the problem description and analysis in the previous paragraphs the characteristics of sustainable urbanization in delta areas can be outlined. The main challenge is how to accommodate a huge increase in population while at the same time reducing the pressure of delta areas on the environment. This article introduces the concept of productive urbanization based on cyclic resource flows. Current modern cities produce hardly anything else than waste. At the same time, cities extract all resources from rural areas and ecological systems. This parasitic behaviour should be reversed and cities should be built that have a positive impact on their environment and create pleasant living conditions for involved and resilient communities. The solution, space for a productive city, consists of the following key elements.

Use of space on water

Delta areas are lacking space for both urbanization and food production. On the other hand all delta areas are close to the water. This is also the reason they often suffer from floods. By applying floating urbanization and floating food production these problems are prevented. The effect grows even larger because new agricultural land on the water does not have to compete with nature for the scarce land. Instead the abundant water surface is used. Vulnerable delta eco systems will have the chance to recover because excessive nutrients are extracted from the water for the production of food and energy. Because production of food is close to the city, the use of fossil fuels for transportation is reduced.

Aquaponics and integrated multi trophic aquaculture

To use the benefits of aquaculture in a sustainable way, creating a closed cycle according to the circular metabolism strategy, the method of aquaponics can be applied. Aquaponics is the combination of aquaculture and hydroponics. Hydroponics is a method to grow plants in a liquid solution consisting of water and the required nutrients for a particular plant (NorthernAquaFarms.com, 2010). Aquaponics combines plant growing with fish farming in a self contained eco system. Plants and bacteria use the nutrients that fish create and purify the water. The water use for crops can be reduced up to one tenth of regular vegetable growing and reduces the water needed for single usage fish farming by 95% or greater. The system will be applied in fresh water growing; tomatoes, bell peppers, cucumbers, herbs, lettuce, spinach, chives, basis and watercress can be grown in combination with tilapia, trout, perch, arctic char and bass (Diver, 2006).

For salt water fish, another type of aquaculture that can be framed into the idea of circular metabolism is integrated multi-trophic aquaculture. In this system a simplified ecosystem is recreated. The current existing system consists of three components (salmon, kelps and mussels) but other components like sea cucumbers will soon come into the picture (Chopin, 2006).

Trophic level

The trophic level is the position an organism occupies in the food chain. Wildlife biologists often call it a natural "economy of energy" that is based upon solar energy".

Organisms can be organized in three categories; producers, consumers or decomposers. Producers, like plants and algae use nutrients and photosynthesis to supply in their own nutrition. Consumers are organisms eating other consumers (omnivore and carnivore) or producers (herbivores). Decomposers, like bacteria and fungi, break down remains of the two other categories (Wikipedia, 2012).

The trophic pyramid consists of five levels where at the top there are the predators which have no predators and at the bottom the primary producers. Considering the estimated energy efficiency of only 10% per level in the pyramid, consuming fish from the highest levels in the pyramid requires the most energy. Focussing on the two lowest levels for food production of a productive city is therefore the most energy efficient choice.

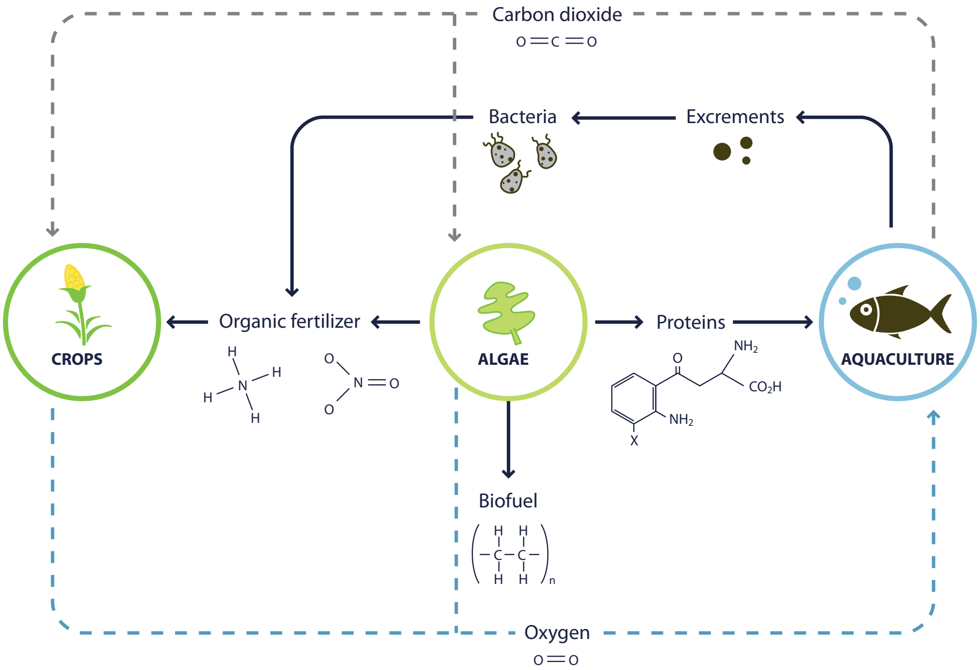


Figure 5: How pollutants can turn into essential nutrients

Nutrient cycle

To enable the delta city to become more sustainable the concept of circular metabolism including the nutrient cycle is an important element. Large amounts of nutrients especially exist in delta areas. Seafood viruses often originate from human sources like sewage inputs to coastal waters (Duarte et al, 2009). These nutrients can increase algae growth and have a negative impact on their surroundings. However, under well controlled circumstances algae can have many beneficial applications. Algae are made up of proteins, carbohydrates, fats and nucleic acids, which vary in percentage according to the type of algae. For this reason algae can be used for:

- bio fuel production
- food production
- organic fertilizers

The negative characteristics of this byproduct of nutrient effluent will be turned into organic fertilizer used for fish farming and crop farming on the mainland. Combining this organic fertilizer with the artificial fertilizer can lead to higher crop yields while it causes less deterioration of the soil. A second application is biofuel. Algae yield the highest quantity of oil, compared to other biofuels (Leong, et al, 2012). Two main systems are used to produce energy from algae; photobioreactors and open ponds. A photobioreactor (also known as PBR) is a piece of equipment that provides a contained environment to cultivate algae. It is better than cultivating it in a small pond as it allows all the requirements of algae growth to be introduced into the system in a very controlled manner. For example, parameters such as carbon dioxide, water, temperature, exposure to light, mixing regime, etc. can be controlled very accurately. However, the cost of cultivation using photobioreactors is very high, preventing the photobioreactor from being used that much.

Algae are grown in natural waters (lakes, lagoons, ponds) and artificial ponds or containers. The most commonly used systems include shallow big ponds and tanks. The ponds have to be shallow and wide as this maximizes the sunlight taken in by the algae. The biggest advantage of open ponds is their simplicity and convenience. They are easier to construct and operate, resulting in low production and operating costs. This results in maximum production most of the time. However, uneven light intensity and distribution within the pond would have negative effects on the algae's growth (Leong et al, 2012).

The Cyclicity

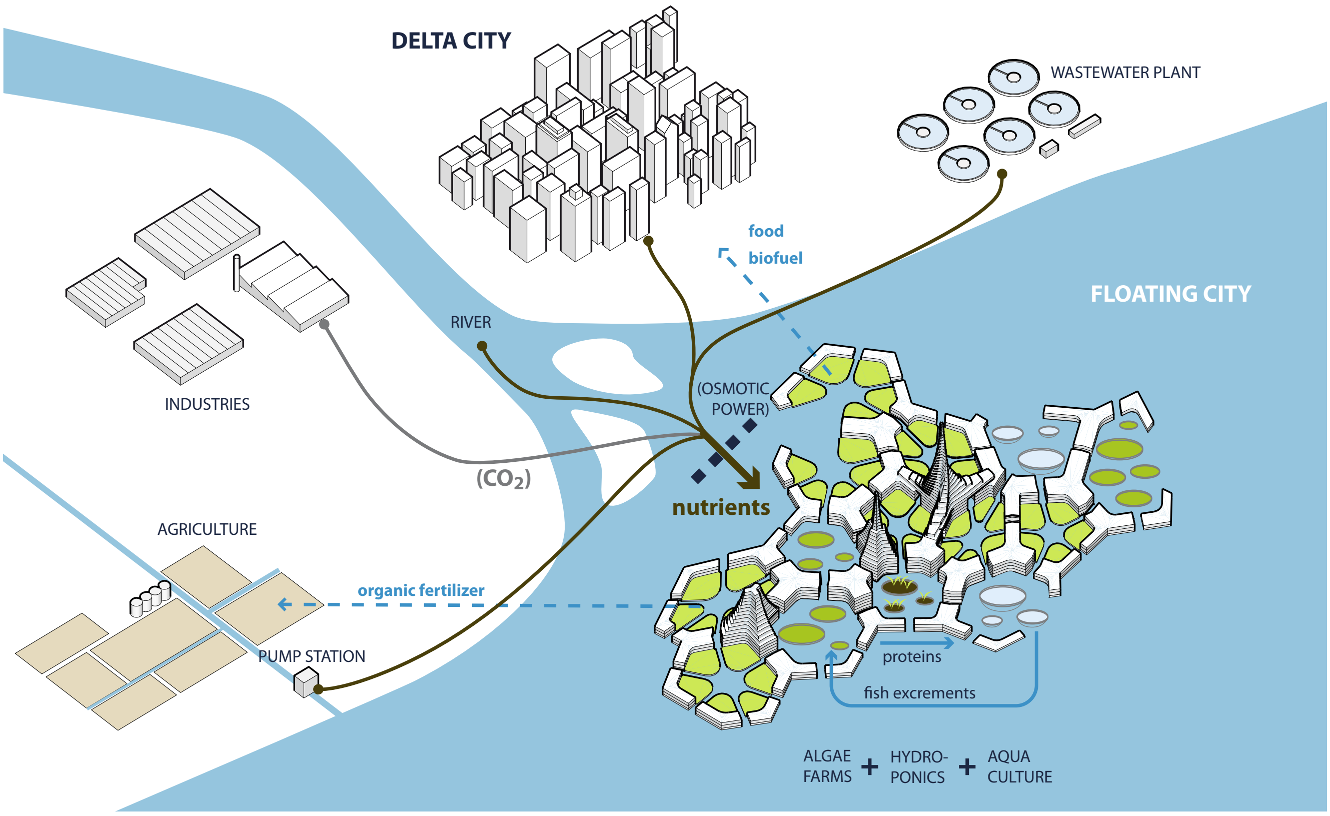
The Cyclicity is a spatial intervention for delta areas that is based on cyclic patterns of resource flows. It establishes a symbiotic relation with an existing delta to which it is plugged in. Cyclicity represents a "productive" floating urban development, in contrast with the traditional "consuming" city. Because it is a floating city, the city will adapt to any future water level and will not suffer flood damage due to extreme weather events. The floating city can also function as wave breaker, protecting vulnerable delta areas.

Based on the theory of circular metabolism, the Cyclicity will plug into a delta area to enable to close these cycles and can use waste of this delta area (CO_2 and nutrients) as inputs to produce energy and food. The main focus will be on solving food and space issues. Many other problem areas are interlinked with one or both of these issues. Consequently, a solution in one area will positively influence other issues. For example, producing local food on the water will save fuel for transport and recycling nutrients will save fuel for the production of artificial fertilizer.

Urban waste as a resource

In many urbanized delta areas large quantities of nutrients from agriculture fertilizers, industrial waste water and sewage plants are introduced into the ecosystem. According to recent study, waste water is an efficient fertilizer for algae farming (Yang et al, 2010). Nitrogen and phosphorus dissolved in the water are used to cultivate algae, which will find application as biofuel, fish feed or fertilizer for agriculture. On a yearly basis, a city the size of Los Angeles flushes an estimated 15,000 tons of nutrients to the sea. This amount would produce enough algae for some 8000 tons of biodiesel and would allow 4000 people to run their cars on biofuel. Urban waste water is likely to make up almost a half of the effluent

Figure 6: Scheme of the Cyclicity. Waste from delta areas is used for production of food en energy.



nutrients that are used in the Cyclicity. Additional nutrients from agriculture and industrial facilities will substantially increase this number. More importantly, high eutrophication and hypoxy levels, will be lowered and nutrients will be regained for use in food production. In the Los Angeles example, the production of 15,000 tons of artificial fertilizer would normally require about 20,000 tons of oil. This can be saved by creating organic fertilizer from algae. Taking into account nutrients from agriculture and industry, it would be reasonable to conclude that 60,000 ton fossil fuels can be saved each year by closing the nutrient cycle.
For delta cities that have sanitation, catching waste water effluent will be easy. Agricultural effluent will be more challenging. High nutrient concentrations are likely to be found at places where excess irrigation water is sent to. In many low-lying delta areas pump houses are being used to get rid of excess water in agriculture areas. The Cyclicity will plug in to such systems and, if possible, make use of the existing pumps to transport the nutrient-rich water to the algae farms on the sea.

Aquaponics

An aquaponic system will be applied to cultivate crops for the inhabitants of the Cyclicity and the delta area where the city is located. Producing local sources of food will decrease the ecological footprint of food consumption. This will take the concept of Aquaponics a step further, then the current conventions in which fish feed is often from external sources. For example, when farming Tilapia, a typical farm fish, it will feed on floating aquatic plants, such as duckweed (Lemna sp.), submerged plants, and many forms of algae. Tilapia thrives in temperatures between 26 to 30 degrees, which is found in several of the Delta Alliance delta areas.

Blue energy

Since most of the surface area of the Cyclicity that receives sunlight will be used for photosynthesis, solar energy will not be the main method of energy production. The transportation of large quantities of dissolved nutrients into the floating cities, does however create interesting opportunities to harvest energy from the osmotic pressure between fresh and saline water. Delta areas and estuaries form a transitional zone between the river and ocean environment. Because of the different concentrations of electrically charged particles in fresh and saline water, the fluids will mix to restore balance. By introducing a membrane that acts as a particle filter, a chemical reaction can be induced that creates an electrical current. At the Dutch Afsluitdijk, a 32 km long barrier, an osmotic energy pilot project was built. The system takes up about the size of several shipping containers and produces 500 kW of osmotic energy, enough for about 1250 homes, producing about 4 million kWh per year (IPO, 2011).

Food production as green space

Many city-dwellers are pleased to enjoy the quiet countryside, even though it is mostly made up of agricultural areas instead of natural landscape. Moreover urban developments with a view of crops or farms, will often have a higher value. In the Cyclicity, integrating food production in the urban context may increase the living quality of the city by creating green floating spaces. In addition, local food production uses less energy on transport benefit from urban waste, but there is also a social issue that may be solved. While there is more and more awareness and attention for a sustainable food production, well-being of livestock, cut-down on antibiotics, and other issues, many people still feel powerless to intervene in the global food industry. Local food production will increase awareness, enable monitoring and educational opportunities and stimulate sustainable operation. At the same time it will improve the urban environment. The Cyclicity uses energy and fertilizers and extracts from the ecosystem a large quantity of nutrients that originated from land based agriculture. These nutrients can be directly collected from their source using plug-in elements connected with the floating delta city, where algae and fish farms are situated. Nitrogen and phosphorus dissolved in the water are used in algae farms. Algae can find application as biofuel, food or organic fertilizer.

Cyclicity governance

To be able to move from the current vulnerable and parasitic deltas towards implementation of the Cyclicity requires system innovation rather than system optimization. This means a fundamental new way of working is needed that will be anchored in the mainstream practice of professionals and citizens in the deltas of the Delta Alliance. Some essential elements for the transformation of current deltas and the realization of Cyclicities are outlined below.

Stakeholder receptivity
A crucial factor for the implementation of a Cycliclity in the deltas in the world, is the receptivity of urban planners, decision makers and other stakeholders to the new approaches, new policies and new technologies that have been outlined in this article. For the full receptivity to be addressed it is necessary that stakeholders

1. are aware of innovations,
2. want to apply these innovations,
3. have the required capabilities, and
4. have sufficient incentives to change their way of working (Jeffrey and Seaton, 2003).

In the Delta Alliance an awareness program could be started to inform stakeholders on the possibilities of Cyclicities and use the stakeholder feedback to further improve the concept. Next, capacity building to develop the skills and knowledge to realize and maintain the innovative solutions should be executed. These measures will accelerate the implementation process.

Improving innovations
Many innovations in the Cyclicity are relatively new and require a new way of working, new skills and new knowledge. They should be further tested and developed. Therefore, the Cyclicity will be constructed in a modular way. It will start with small scale demonstration projects that will be extensively tested working together with research institutes, local government organizations, ngo's and education institutes. The experience will be used to further improve the effectiveness and efficiency of innovations to make them competitive to mainstream technologies.

Creating a commercial market
Most governments will not be able to accumulate the needed investments to build a Cyclicity. Therefore it is important to attract investments from the private sector. However there should be coherent incentives and binding legislation to secure that the Cyclicity is developed according to the philosophy that was outlined in this article. Only investors that comply with strict rules on positive environmental impact and innovations should receive permits to join the development process of the Cyclicity.

The task of designers
In a spatial development process of the Cyclicity there can be a more important role for citizens. The role of the designer will change from a determining role to a facilitating and inspiring role. Co-design with citizens becomes an important approach to develop solutions that are feasible from a societal point of view. The role of design is not to produce a blueprint for a future situation, but to inspire stakeholders to develop unique solutions within the concept of the Cyclicity. Additionally, the role of design is to provide input for discussions and stakeholder involvement.

Institutional mechanisms
Organizations in delta areas should not be rewarded based on effective execution of their fragmented statutory tasks, short term targets and costs minimisation. Instead, they should be judged on their contribution to the total system performance and long term targets. This creates room for stakeholders to be involved in long term collaborative projects such as the

development of the Cyclicity. To secure public interests, selection of urban development partnerships should be based on costs, quality and positive system impacts rather than costs only. This should be supported by a management culture that is leadership driven rather than responsibility driven. These changes will increase the chance of the Cyclicity to be implemented.

Conclusion

Delta areas all over the world are threatened by a large number of developments such as land subsidence, flood damage, ecosystem degradation, and land scarcity. This article categorizes these problems in food issues and spatial issues. A systems perspective shows that food availability is the issue that is most connected to other issues. The article introduces the concept of the Cyclicity. The Cyclicity is a spatial intervention for delta areas that is based on cyclic patterns of resource flows. It establishes a symbiotic relation with an existing delta to which it is plugged in. Cyclicity represents a "productive" floating urban development, in contrast with the traditional "consuming" city. Because it is a floating city, the Cyclicity will adapt to any future water level and will not suffer flood damage due to extreme weather events. The floating city can also function as wave breaker, protecting vulnerable delta areas.

Based on the theory of circular metabolism, the Cyclicity will plug into a delta area to enable to close these cycles by using waste of this delta area (CO_2, nutrients) as inputs to produce energy and food. The Cyclicity uses energy and fertilizers and extracts a large quantity of nutrients from agriculture fertilizers, industrial waste waters and sewage plants. These nutrients can be directly collected from their source using plug-in elements connected with the floating delta city, where algae farms and fish farms are situated. Algae can find application as biofuel, food or organic fertilizer. Aquaponics and sustainable aquaculture are applied in the Cyclicity to alleviate the food shortage in many delta areas. The proposed solution does not further increase water consumption for irrigation because mainly salt water is used. Moreover, no more land is used for this mode of urbanization. Instead the water surface is used to build on. At the same time nutrients from delta areas are captured by the Cyclicity, which is a new direction to protect deltas and preserve marine ecosystems.

Figure 7: Artist impression of the Cyclicity.

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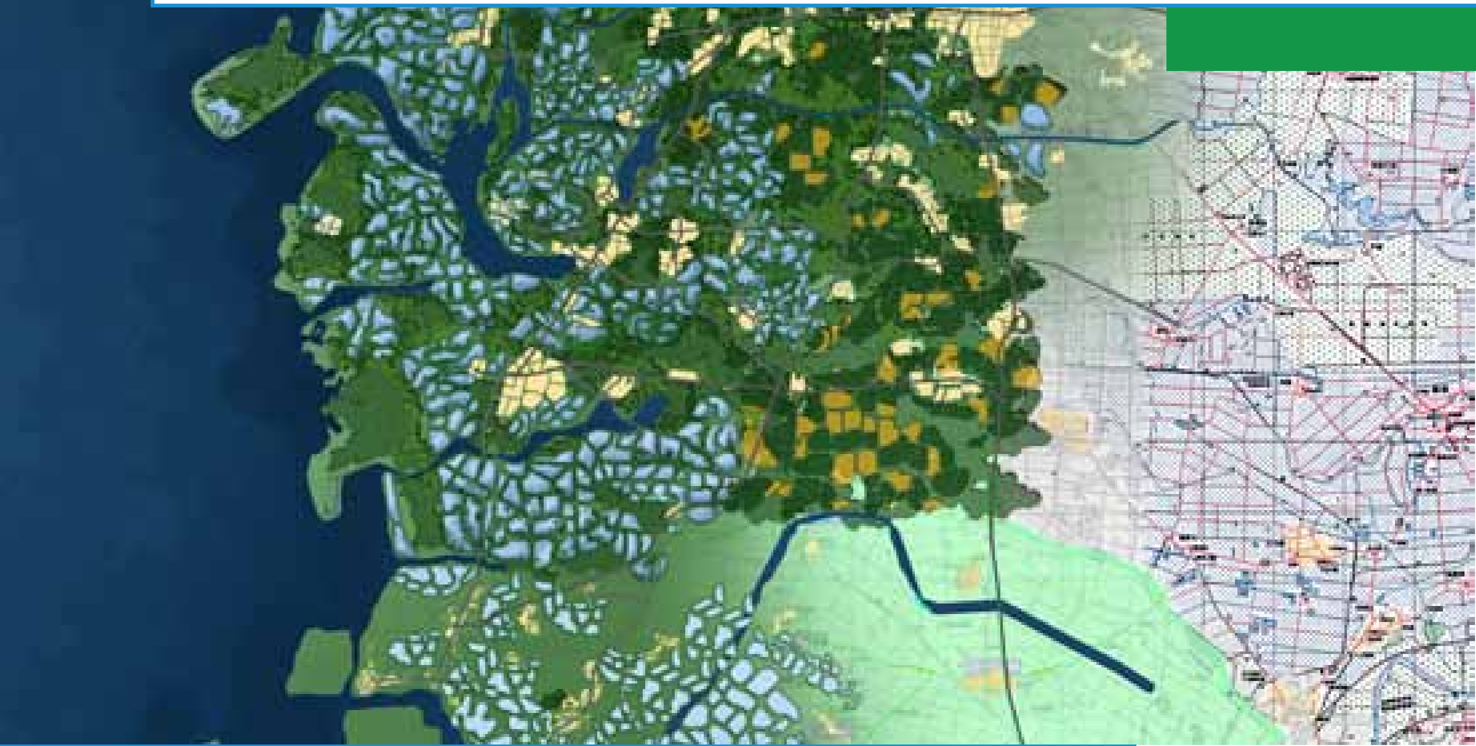
Amphibious Living

Revitalizing a lowland delta area



Sandra M.Y. Lee[1] | Y.J. Chiu[2]

Abstract

Natural disasters or anthropogenic hazards have become the most influential factors in the security of local settlements in delta areas. Delta areas, especially, have been confronted with many environmental issues. The limitation of topography and waterways, the dramatic climate change, and anthropogenic activities, can cause the delta region to enter into a negative circulation. In this study, the conceptual comprehensive design approach is proposed as an idea to address and solve the aforementioned issues. The idea is to combine the methodologies of "Restoration", "Relief", and "Renewal". This comprehensive sustainable planning idea is named "SWITCH" in the present paper. "SWITCH" is an idea for diverse transformation. The delta area and local villages both need to switch to change site, living conditions and the environment. The strategies are as follows:

a) to change existing land texture to multiple land-uses,
b) to change unsafe houses into floating houses,
c) to enhance landscape and ecological diversity, and
d) to live with safety.

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The comprehensive planning concept called "SWITCH" was applied to a coastal delta region as a case study. The study area, Chia-yi, is a lowland delta which is located in the western part of Taiwan. The main idea is to combine characteristic sites by using a sustainable ecological conservation methodology, in order to enhance environmental quality and safety for local villagers, and to make them live with nature.

"SWITCH" was shown to help rehabilitate aquatic delta environment, increase delta-land use value, to revitalize the lowland delta area and to lead to prosperity for local villages in western Taiwan.

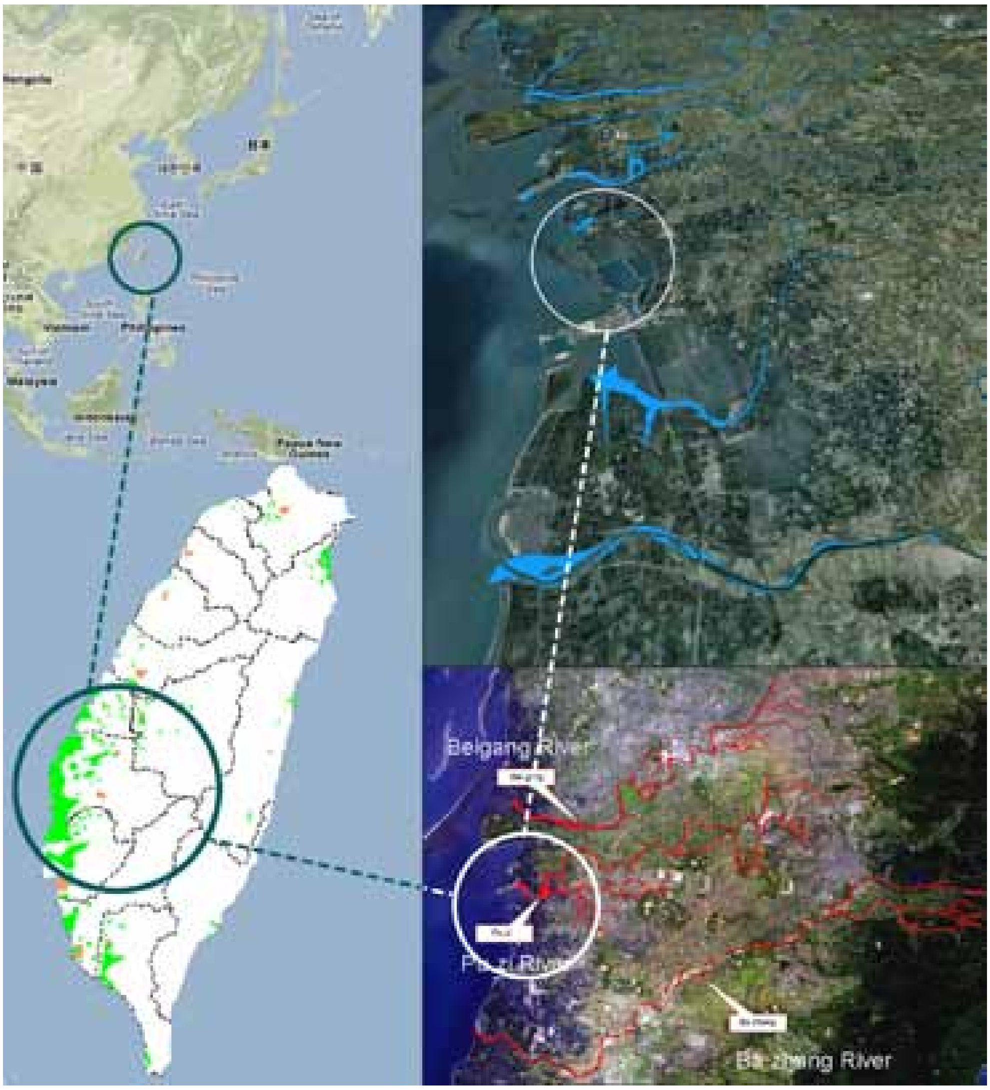


***Figure 1:** The location of study delta*
Source: Google earth image, 2006 and 2012, adapted by author

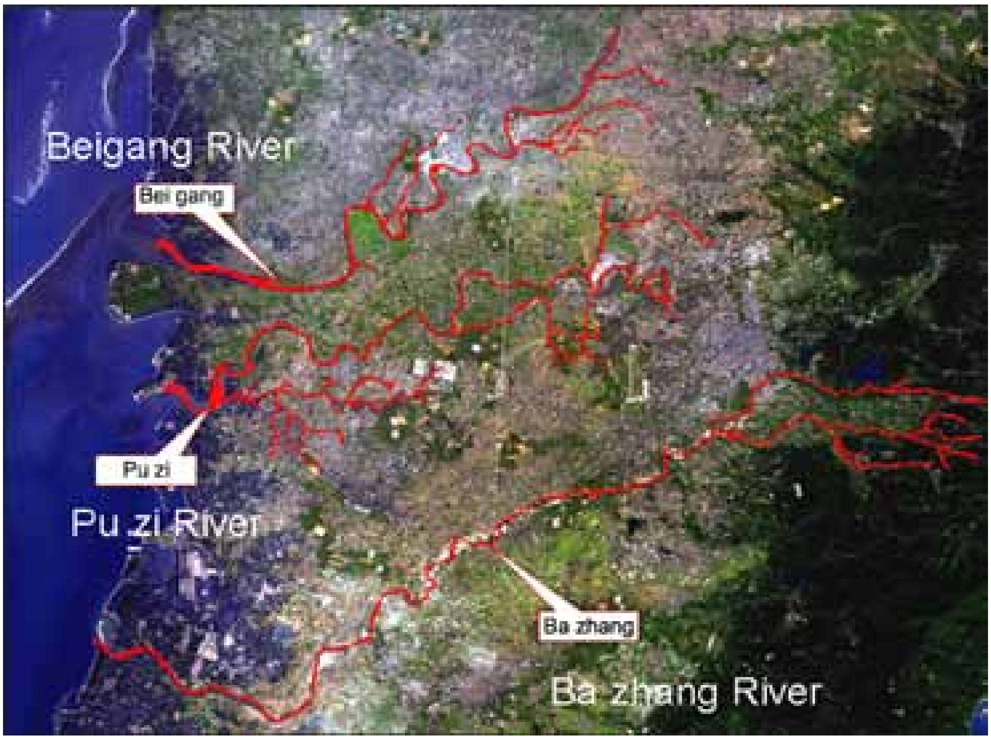


Figure 2: Topographic map.
Source: Google earth image, 2006

Study area

The study area is located in a lowland deltaic region on the west coast of Taiwan (see Figure 1). With the Bei-gang, Put-zi and Ba-chang, three rivers compose the main surface water body (Figure 2). As far as the natural environment is concerned, all of the major rivers originate in the mountains at an elevation of 1,000 meters. With their steep slopes and swift currents, the upper reaches have no capacity to store water, while in the lower reaches, the terrain is smooth, the flow speed is slow, and many accretions of soil and sand occur, as well as frequent natural disasters. The ratio of high flow and low flow is 9:1 (Figure 3).

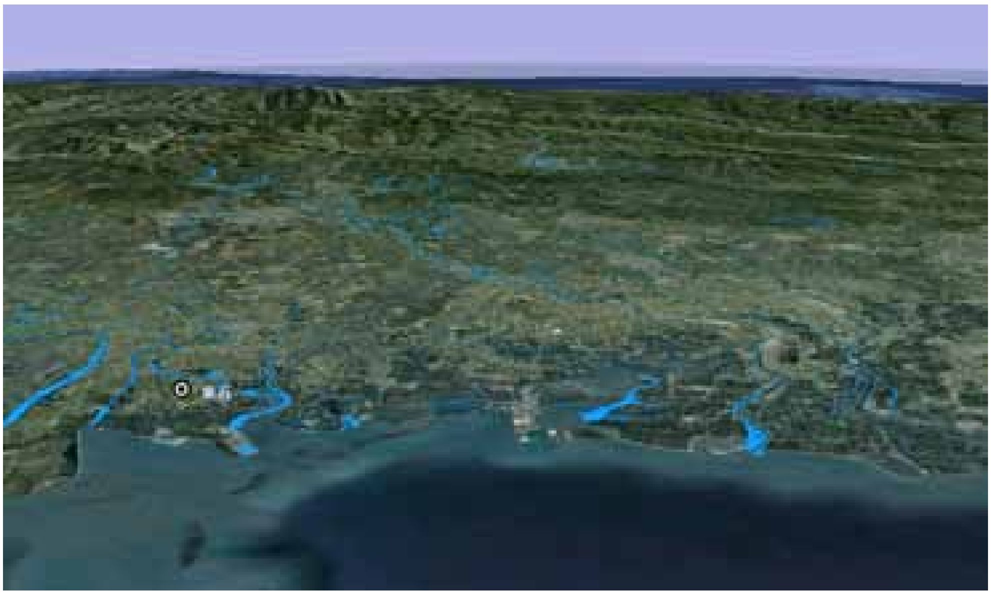


Figure 3: A 3D image of topography, Delta area in western Taiwan
Source: Google earth image, 2012

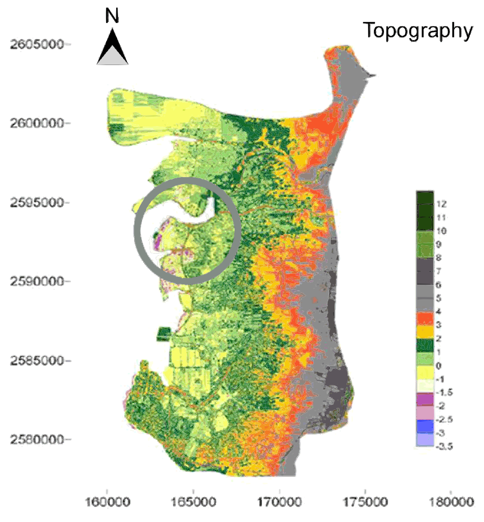
The challenges of the delta area in western Taiwan:

Global climate change

Global climate changes causes some unpredictable weather changes, such as sea level rise, typhoons, heavy rainfall, and dry periods. The changing climate has affected the human settlements in the western coastal delta of Taiwan, and the community needs to be well prepared to face all kinds of coupled human-environment challenges in this 21st century. Taiwan, as a pacific island, should take action corresponding to the "Pacific Islands Climate Change Action Plan", in its efforts for mitigation and preparation.

Topography

The case study delta is located in a coastal area in Taiwan with severe subsidence; it is about 1901.67km^2 big. The approximate area of the plain delta covering an elevation below 100 meters is 790.36 km^2. It is about 40% of the study region and there are large mountains, which emerge prominently behind the delta. (Figure 4)



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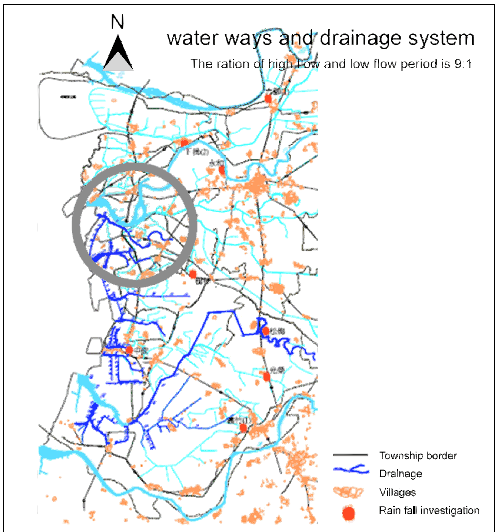

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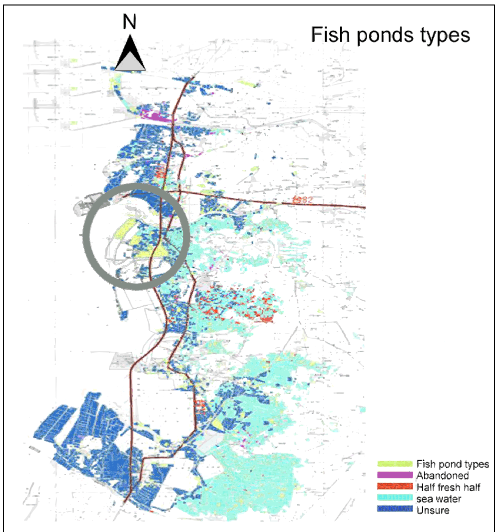

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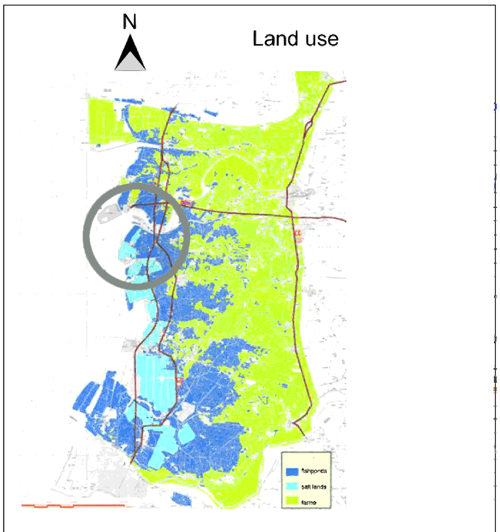


Figure 7

Figure 4-7:
left to right:

- *Topographic map*
- *Map of waterways and drainage system*
- *Map showing Fishpond types*
- *Land use map*

Source: Taiwan International Institute for Water Education, 2006

Waterways

There are three main river basins covered by the study region. The rivers originate from mountains with a height of approximately 900m to 1200m. The water from the mountain oftentimes inundates the township and blocks the access to the Taiwan Strait. Due to the short river length and the sharp variation of rainfall amounts between dry and wet seasons, villagers in the coastal area suffer severe flooding events in the raining season (see Figure 5).

Flooding

During the raining and typhoon season, a considerable amount of rainfall- induced flooding occurs in the Delta. The inundation of the delta generally occurs most intensively between the periods of April to September each year.

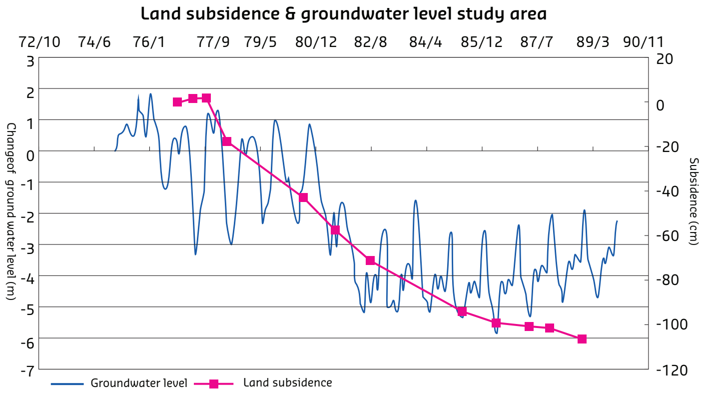


Figure 8: Land subsidence & groundwater level of study area
Source: Industrial Technology Research Institute, 2002

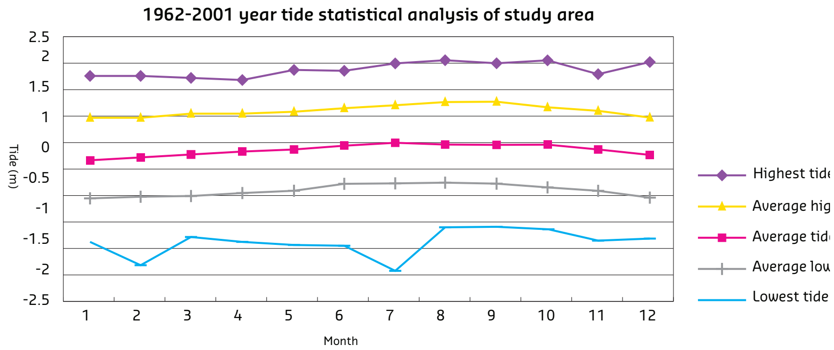


Figure 9: 1962-2001 year tide statistical analysis of study area
Source: Taiwan Central Weather Bureau

Subsidence

Chia-yi County belongs to the Chia-nan plain groundwater areas. The large-scale development and usage of groundwater in the delta region began as early as 1958. In Chia-yi County, the availability of surface water resources is quite limited, and currently, half of the water supply of 250,000 tons per day for consumption is being pumped from the groundwater reservoir. The demand of water resources has rapidly increased due to the development of agriculture and agricultural industries, and the severity of the groundwater over-extraction was enhanced.

According to the register of groundwater wells and pumping capacity, the water demand for irrigation and aquaculture purposes accounts for the biggest proportion, and the excessive pumping of groundwater has made Chia-yi County to become the region with the most serious subsidence hazard in Taiwan.

Many years of improper land-use and management practices resulted in land subsidence of 211km^2 in an areas, which include large numbers of abandoned salt farms, and deserted fish farms. The location of the study area offers no alternatives for the management at land for anthropogenic purposes; only flooding and sinking are taking place.

Land salinization

Seawater intrusion occurs due to over-pumping and excessive withdrawal of groundwater. As the result of this practice, seawater flows inland and coastal land is salting (Figure 6).

Drainage

The region's poor drainage systems cannot afford the frequent flooding, which occurs during high tide hours and storm seasons. The study area does not have the natural ability to discharge the excessive water, and pumping is one of the most critical mitigation practices in combatting flooding events.

Land-use

The lands were mainly used for salt-water fish farms, and regular agricultural farms, which required large amounts of groundwater supply for irrigation purposes. Over-pumping and withdrawal of groundwater have resulted in serious land subsidence hazards in the coastal areas (Figure 7).

Safety

The embankment sea wall along the coast is not high enough to prevent high tides from flowing inland. Especially, as global climate change induces sea level rise, this is in turn expected to increase the frequency of seawater to flow inland.

The locations of Chia-yi region under subsidence hazard are concentrated in the coastal delta region covering the Dong-shi, Bu-dai and Yij-hu Township. Although the recent deterioration rate of the subsidence hazard has slowed down slightly, subsidence-prone areas still have to continuously face a variety of extreme events, such as flooding, typhoons and saltwater intrusion, all of which negatively affect people's livelihood, socio-economic activities and their ecological environment.

Figure 10: *Pictures of inundation situations in the delta area, west part of Taiwan*
Source: TIIWE, 2006

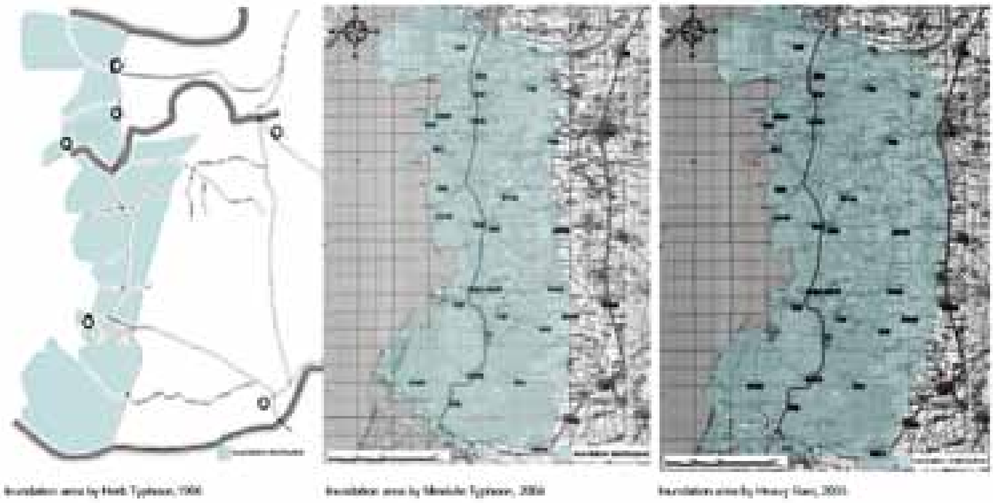


Figure 11: Inundation distribution 1996-2004-2005
Source: Water resources planning institute, 2007

Decline of population and industry

The population growth of Chia-yi County showed negative growth of a non-linear relationship, especially in townships along the coastal delta areas. The average annual growth has declined seriously in the region, as the population growth rate is about -1% (Water resources planning institute, 2007).

The industries in Chia-yi delta area are agriculture, aquaculture and salt industry, while salt industry has been abandoned already for a long period of time. The aquatic industries include freshwater- and, marine-culture, as well as brackish water aquacultures. Due to natural disasters and social reasons, a big amount of the aquaculture lands is abandoned.

The impacts from social and natural influences exert a pressure to change on the Delta area. We have been confronted with a dilemma: to strictly protect the delta by artificial constructions, or to make proper use of the existing environmental resources within the delta region.

Figure 12: Local landscape elements
Source: Author, 2005

Figure 13: *The image of local abandoned fish ponds*

Source: Author,2005

The previously presented analysis suggests a balanced approach, a "Comprehensive Plan" towards sustainability; a plan which deals with different problems and challenges at the same time, moreover, a plan which provides security to human settlements in the delta area and which is also able to guide local people to other possibilities for creating a prosperous livelihood.

Therefore, our aim in this research is to establish a comprehensive planning and design system, which rehabilitates the ecology, and renews and regenerates the environment of the lowland delta, so that the research area in this location can develop sustainably. The primary goals in the proposed plan of revitalizing lowland delta areas are:

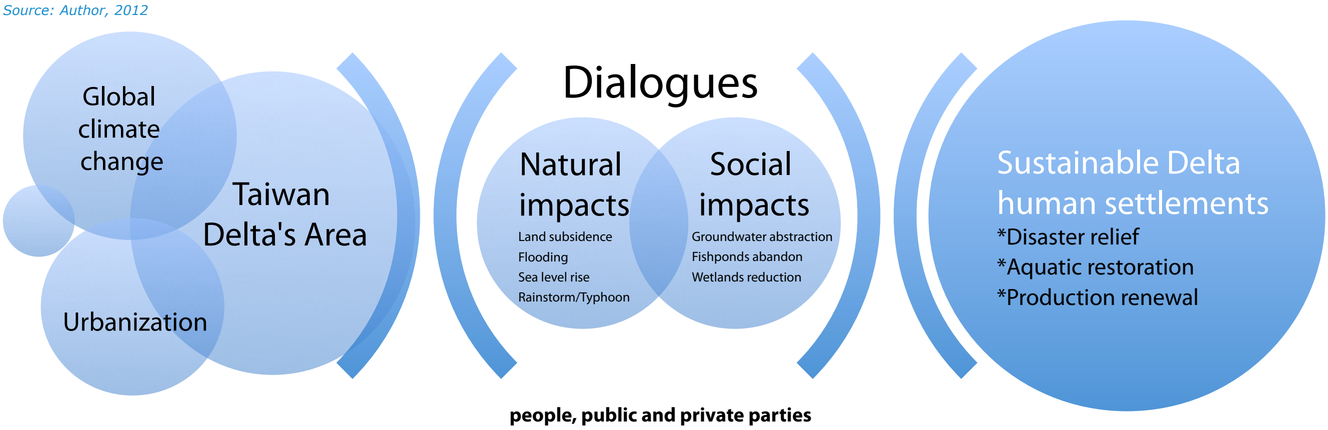
1. To live with nature by applying an ecological conservation method.
2. To co-exist with the nature by means of eco-conservation.
3. To combine site-characteristics in order to provide a sustainable and fundamental infrastructure, while respecting the local natural texture, and designing a sustainable basic landscape structure.
4. To use available water resources effectively.
5. To enhance the quality of the environment.
6. To satisfy the basic needs of regional safety and the basic demand of the security for local residents.

The main priority is to protect villagers and to relief damages from natural disasters in the lowland delta area. This will be done by changing local social behavior and industries in order to switch the negative circulation into a sustainable one.

By designing a comprehensive plan, we hope to fulfill the goal of living in harmony with nature in the lowland delta area in Taiwan.

Figure14: *Planning concept*

Source: Author, 2012



Strategy

At the status quo, natural wetlands and artificial fishponds are in a mosaic-like distribution, bordered by the land-ocean fringe, river channels and, fresh- and seawater fringes. The region is full of abundant wetland landscapes and ecological systems. Due to the natural and artificial impact on the delta environment, coupled with a lack of systematic management, the wetland in the natural delta has been subject to damages. As artificial measures cannot efficiently and successfully prevent disasters, the region is vulnerable to frequent flood and drought disasters. Therefore, a flexible conversion of artificial fishponds and Salinas into artificial wetlands, combined with the natural wetland resources in the delta region, could be able to transform the hazardous region to become an abundant ecotone enriched with ecological diversity. In this way, the purpose of protection can be achieved.

Concerning the case under discussion, the emphasis of our research design is on preventive measures. Responses to disasters can be structured into two main aspects: firstly, disaster control through engineering measures, such as water control, wetland transformation and environmental rehabilitation; and secondly, disaster adjustment through non-engineering measures, such as the regulation of human activities, including the transformation of their lifestyle; industrial adaptation and adjustment; systematic management and/or the development of tourism.

Finally, the proposed major designing strategy is in line with the conceptual approach of **"Restoration, Relief and Renewal "**, which is based on the involvement of interdisciplinary considerations and methodologies, including:

1. Sustainable ecological rehabilitation of the environment;
2. Artificial wetland development, combined with flood retarding lakes;
3. Reutilization of the water resources processed by the wetland;
4. Recovery of the ecological environment of the wetland;
5. Mitigation of inundation;
6. Systematic integral management;
7. Development of non-engineering measures;
8. Flood-preventing designs with specific purposes;
9. The reform of the industrial sector;
10. The development of a plan for landscape and tourism recreation.

Objectives of the "Restoration, Relief and Renewal" approach

- Restoration of sustainable environment by:
  - Construction of wetlands combined with water detention/water treatment
  - Reuse of water resources from the wetland
  - Plan the wetland ecological restoration

- Relief from flooding by:
  - Integrated management, including flood detention, flood relief, etc.
  - Nonstructural measures
  - Flood-preventing design with the aim to protect against 50-100 years flood[3].

- Renewal of Production
  - Planning of landscape and leisure development

3 According to Taiwan's rivers governance rules, the main rivers have to comply with a 100 year flood protection standard; minor rivers have to comply with that for 50 years

Discussion

In order to successfully integrate the plan of "Restoration, Relief and Renewal" within the hazard-prone region, it is critical to engage with **P-P-P** (people, public and private sectors)[4] in an open communication, which involves exchange of information between a diverse mix of stakeholders, including central government, local governments, counties, bureaus, villages management offices, villagers, enterprises, private sectors, etc. The SWITCH program relies on large numbers of dialogues "horizontally and vertically", to communicate with all kinds of involved members, in order to form consensus and to inform about agreements and disagreements concerning the comprehensive integral master plan.

In order to create consent and support from local villagers, we held plenty of public hearings, forums, and discussions in many local villages. By inviting central governors, civil servants, scholars, NGOs, companies, etc., we hope that our plans can raise dialogues between villagers and all participating sectors. Ultimately, we hope our plan will lead to a P-P-P-like cooperation. We have designed various topics for these dialogues to be integrated into different phases of the SWITCH program, in order to fit to the various interest groups within the stakeholders. These topics include:

A. Water management and land restoration.
B. Water utilization and industry.
C. Ecology and leisure.
D. Livelihood and environment.
E. Policy and land.

4 The author would like to emphasize the importance of the participation of local stakeholders/people in the planning and design process

***Figure 15:** Dialogues with local villagers, Public and Private sectors*
Source: Author, 2005

The conceptual framework: Harmony with Nature

The lowland delta in western Taiwan is mostly located within a region prone to subsidence. Therefore, it is crucial for the comprehensive planning to be adaptive and to first assess the current condition, considering the stresses induced by climate- and environmental change within not only the environmental system but also within the man-made physical system. Our research approach not only aims to minimize the impact of hazardous events, but also to promote the enrichment of biodiversity, landscape scenery, eco-tourism and water resources conservation practices within the delta region. Our goal is to achieve an equilibrium of energy exchange between anthropogenic and natural influences on the landscape and its development; and hence to create an equilibrium of co-existence with nature, which will be one of the crucial aspects of our scenario within the SWITCH model.

This conceptual approach will mainly concentrate on the low elevation region, the system of tributaries and adjacent land within the watershed region. Adjacent land-use and land-cover will be further classified and assessed and can vary between the following types: public land, brown fields and abandoned fishponds. Furthermore, we will consider the spatial dimension of each category of land-cover. This will be combined with urban planning, rezoning of agricultural land, and an adjustment of land-use and land-cover, as well as a transformation of abandoned fishponds into flood storage areas, which is the core measurement in this SWITCH model.

This lowland delta revitalization project will be based on the concept of harmony with nature and will be coupled with land-use adjustment and water resources utilization changes, while incorporating physical changes into management practice and regulation planning and collaborating with local residents. Local residents and industries can benefit from the externalities generated from eco-industry and tourism in a long-term adjustment and transformation process from a hazard prone location into a bio-diversified wetland system.

The main strategies of the SWITCH program are disaster relief, aquatic restoration and production renewal. The description of each strategy is outlined in the following paragraph.

The strategy of disaster relief for the lowland community

It is important to help relocate local residents and industry in order to relieve them from disasters, to promote changing land use characteristics and adjust land use management and practice. The surrounding environments of the most vulnerable lowland communities need to SWITCH to a more flexible, adaptive way of living. To choose a suitable demonstration location, a long-term dialogue between People, Public and Private sectors is needed. Therefore, it is suggested to make use of state owned land, cooperated private land, abandoned fishponds, abandoned farmland and brown field as a first priority, for initiating a pilot SWITCH demonstration.

The first priority of pilot locations is their location within the hazard-prone location. The original land use will be transformed into environmental restoration projects, such as eco-parks, natural reserves and community parks, combined with eco-tourism functions.

The strategy of local industry renewal

The current local industries are mainly fish farming, aquaculture, seafood and salt firms or other related businesses and industries. Therefore, in order to successfully revitalize and mitigate the current condition, it is proposed in SWITCH that the land-cover of the surrounding wetland region, through a legislative process, will be adapted and transformed into eco-tourism and eco-industrial demonstration areas. This will be done for the purpose of stimulating transformation of local industries, and to provide diversity in the land use for local villagers and businesses owners in the lowland delta region.

The strategy of environmental aquatic restoration

The SWITCH restoration strategy aims at rehabilitating water quality in the delta region, to maintain and provide sufficient water supply to meet the demand, to increase water quality, to promote groundwater reservoir revitalization, water recirculation and re-use practices.

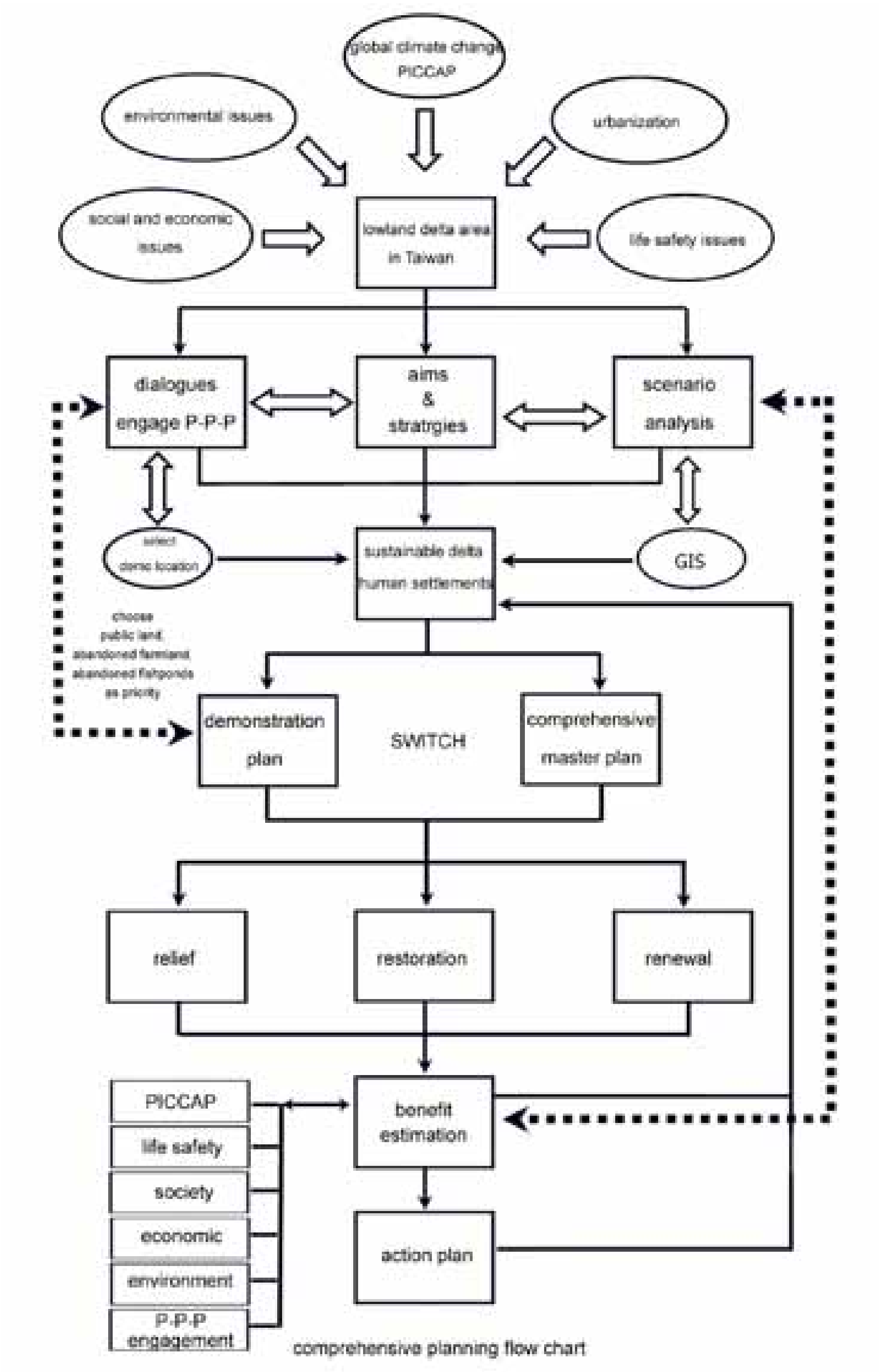


Figure 16: The SWITCH framework

Comprehensive Planning: "SWITCH" design model and its paths to sustainability

Traditionally, problems related to flood and drought disasters in the lowland delta area involved a three-fold strategy: firstly, the adaptation of engineering measures, mainly to change the water regime by reinforcing artificial embankments; secondly, to increase the local resilience to cope with disasters and their impacts on life and property through planning, adjustment and forecasting and other non-engineering measures; and thirdly, to change the post disaster effect of damage distribution through insurance and rescuing measures the Biesbroek R, 2007). All these are passive responses, while our plan also aims to take active measures under possible circumstances, which can be summarized into five main strategies: the "SWITCH" design model.

Switch 1: Transformation and utilization of multiple land-uses

Transformation and utilization of land-use, to convert the texture and characteristics of land features into multi-functional and efficient land-use purposes. The methods of ecological conservation and coexistence with the nature are able to convert phased out salines and fishponds into valuable wetland resources. SWITCH respects the structure and texture of the landscape as well as the local history, culture and wetland ecology. Moreover, SWTICH can obtain a sustainable objective by designing a circular utilization of water resources, using current ecological structures. The main applications of SWITCH 1 are as follows:

- Transforming abandoned salt farms and fish farms for wetland restoration and ecological conservation purposes.
- To co-exist with nature by respecting the existing land textures as the memory of past local activities and landscape: salt farms, fish farms, and fishing villages…etc.
- To utilize wetland functions, flood detention, and flood relief as the basis for sustainable and fundamental infrastructure.
- Efficient water resources circulations for water reuse.

Switch 2: Transforming unsafe houses into floating villages

Here we propose to convert flood-prone residential buildings into amphibious floating structures, so that the local residences can coexist with water and nature. The amphibious lifestyle makes it possible for the inhabitants in villages to adapt to changes of various water levels. The amphibious design in local villages is a typical corresponding to the changes of land-use practice and management allowing the continuation of the current lifestyle of the local fishing village.

- Amphibious living allows living with water and living with nature (Figure 20).
- Floating amphibious villages can adjust to three phases of water levels: dry, normal, and flood periods (Figure 18-19).
- The original living style of fisherman villages is preserved.

***Figure 18:** Floating villages with low water level*

Source: Author, 2012

Figure 19: Floating villages with high water level

Source: Author, 2012

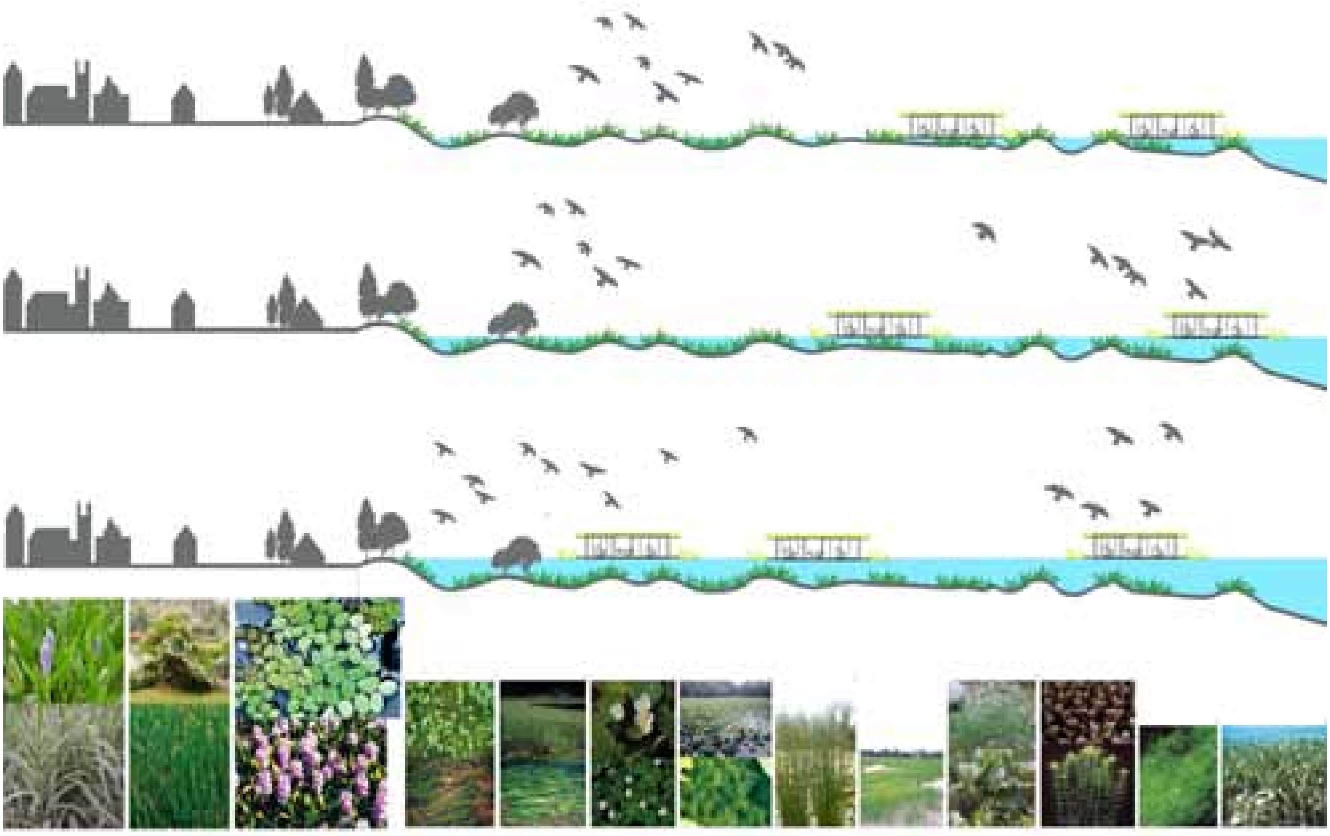


Figure 20: Cross-section of the concept of water level mitigation

Source: Author, 2012

Switch 3: The transformation of landscape

The amphibious design aims to conserve the current landscape and to enhance the security of local residents. The process involves a conversion of the current land-use into a combined landscape with ecological, educational, tourism and recreational values. The landscape and living mode of this amphibious design is subject to the changes of the water levels. Coexistence with water has become the greatest characteristic of the amphibious life, which promotes an improved environmental quality. The goals of the amphibious living style can be summarized as follows:

- Amphibious living is the way to preserve peoples' original living styles but with enhanced safety features.
- To live amphibiously is also a way to preserve the existing landscape regardless of the variation in water levels.
- Changing the local farming practices will promote a more ecological, educational and leisure landscape (Figure 21).
- Both landscape and life style change with different water levels (Figure 22).
- The quality of the environment will be enhanced.

Figure 21: *Landscape with low water level (making use of local landscape elements)*
Source: Author, 2012

Figure 22: *Landscape with high water level (making use of local landscape elements)*
Source: Author, 2012

Switch 4:
The transformation of ecology

The condition of the environment is constantly being improved by the changes in land-use and exploitation and the resulting alteration in land-cover. The condition of the land, which is subsiding, the lowering of underground water tables, drainage problems of surplus water during flooding, and the problem of soil salinization can be gradually improved in the process of implementing environmental and ecological conservation methods. In the future, the wetland within the delta region may become a habitat for seasonal migrating birds. Methods and considerations of ecological conservation include:

- A change of land-use into ecological restoration practices, which will enable and revitalize the environment.
- Land subsidence, ground water withdrawal, rainfall runoff and salinization are gradually relieved and improved as the program progresses.
- It could be one of the flying routes for migrant birds.
- A wetland system can be formed along the coastal lowland area.

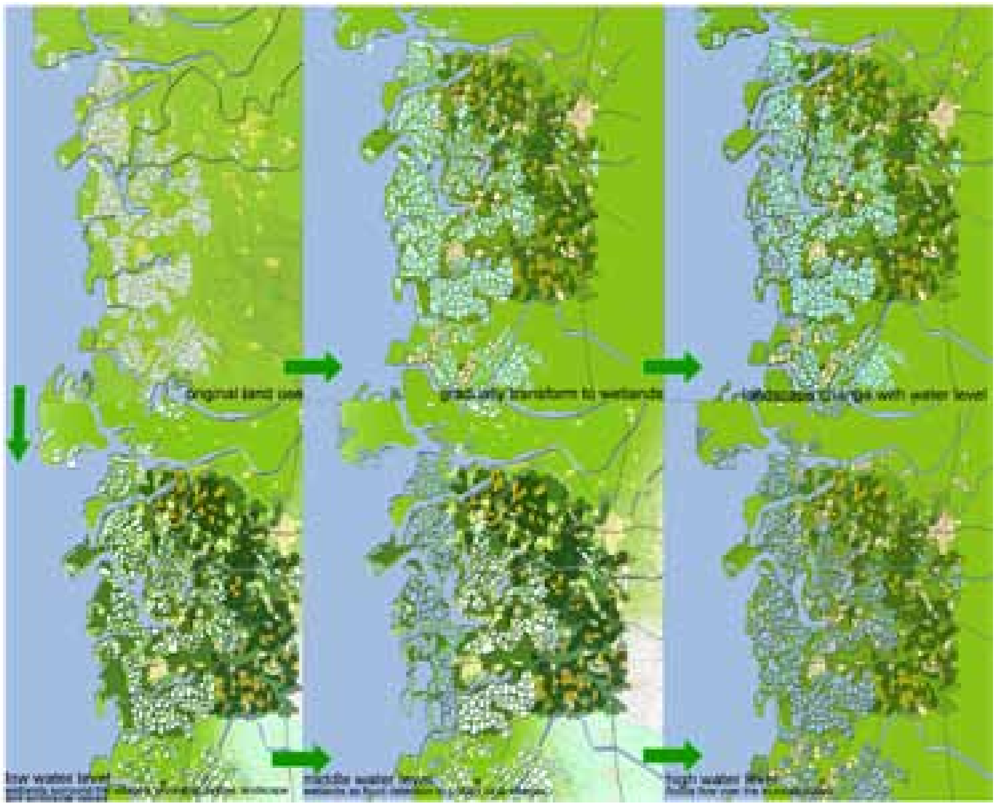


***Figure 23:** Changing land-use into ecological restoration practices*
Source: Author, 2012

More and more evidence has shown that, on the background of global anthropogenic interference, the environment internal and external of the conservation reservations tends to regress. In the design, instead of forming a reserve area to prevent disastrous damages of bio-diversity and to promote habitat renewal and habitat mitigation, we regard the ecological environment as a renewable, alternative and compensable resource, and hence, we employ a more effective approach to solve the problem through space and time.

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Switch 5:

The transformation of lifestyle of local residences

Since the village is surrounded by the wetland, ecological tourism can become a newly emerging industry in village A. The local residents will be guided in the establishment of such a "green industry" by combining the landscape design and recreational plans of the wetland park in their management. "Amphibious life" has a strong appeal, which can stimulate tourists and generate benefits to the communities (Figure 24-25).

The design of the floating houses is targeted to function in the lowland area near the seashore and even within the serious inundation area. The design respects and conserves the livelihood and landscape of local clusters of fishing villages, thereby allowing the local residents to co-exist with nature and water. The design contains the following features:

- Adaptation to the changes of water level and provision of environmental security for local residents within hazard prone regions.
- The multi-dimensional nature of landscapes will be revealed when the houses change with the water level.
- The existing fishponds and saline will be gradually converted into wetlands and combined with the function of flood retardation. Thereby the ecological environment will be able to rehabilitate.
- The floating houses will be combined with renewable energy technology; with emphases that engineering reduction measures are environmental friendly.
- The local residents can still live according to the existing cultural mode in fishing villages, and, more importantly, amphibious living offers a solution to the current insecurity of residences.
- Villagers will be tutored to adjust to the new ecological living by renewing production.

***Figure 24:** local elements design with low water level*

Source: Author, 2012

***Figure 25:** local elements design with high water level*

Source: Author, 2012

Benefit estimation

The benefit, which the SWITCH will provide, is that it contributes to a comprehensive insight into the local implications of global climate change, the security of human livelihood, ecological production, eco-life, environmental restoration and open communication and dialogues between stakeholders and parties of interest within the delta region.
The benefits of comprehensive planning can be separated mainly into six parts: First, SWITCH, through an incentive program will attract open dialogues between people from various public and private sectors. Second, the condition of local security and human livelihood within the hazard-prone area can be improved and enhanced through the SWITCH disaster damage reduction. Third, the damage of public infrastructure and industry is mitigated by reducing the flood hazard. Fourth, the safety of industries is enhanced, while the vulnerability of the agricultural and aquaculture industry for disaster-induced damages and losses are reduced. Fifth, SWITCH will rehabilitate aquatic environment, including its biodiversity, water quality and the status of groundwater reservoirs. Finally, the SWITCH approach contains actions, which correspond to the "Pacific islands climate Change Action Plan", as our research idea is to increase living standards and wellbeing within hazard-prone locations, by using and maintaining ecosystem functioning in an ever-changing environment.

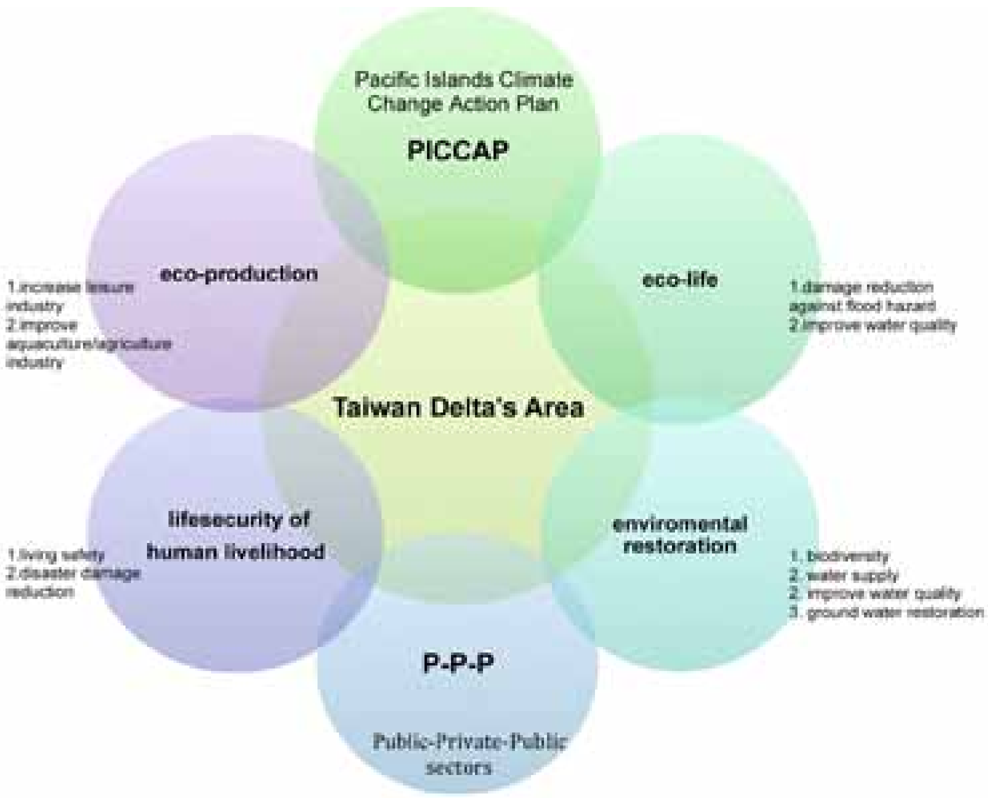

Figure 26: Benefit estimation
Source: Author, 2012

Conclusion

This study of a coastal delta region in western Taiwan intends to address the impacts of global climate change and green house effects from the perspective of disaster mitigation and adaptation; integrated flood relief; strategic planning of sustainability and dialogues between stakeholders.

The authors propose an effective solution and a comprehensive plan in order to accomplish the multi-functional objectives "Restoration, Relief and Renewal" for the studied delta region. Such research is intended to provide a new opportunity for a new life within delta regions, a healthier lifestyle for the local residences, and to form an all-win situation promoting flood relief, aquatic restoration, and production renewal.

In "SWITCH", we try to raise the land use value of the lowland delta region by combining sustainable development of ecology, production and life style, and achieving land and environmental resources utilization targets, by means of designing a system of transformation and an adaptation process.

The "SWITCH" comprehensive plan gives a new definition to the delta area in western Taiwan. The present plan aims to restore the environment in the studied delta region; to relieve pressures or stress from natural disasters and anthropogenic activities and to create a new lifestyle for the local inhabitants. The villages in the delta area are expected to live prosperously and harmoniously with water and nature while applying the SWITCH conceptual logic and approach.

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