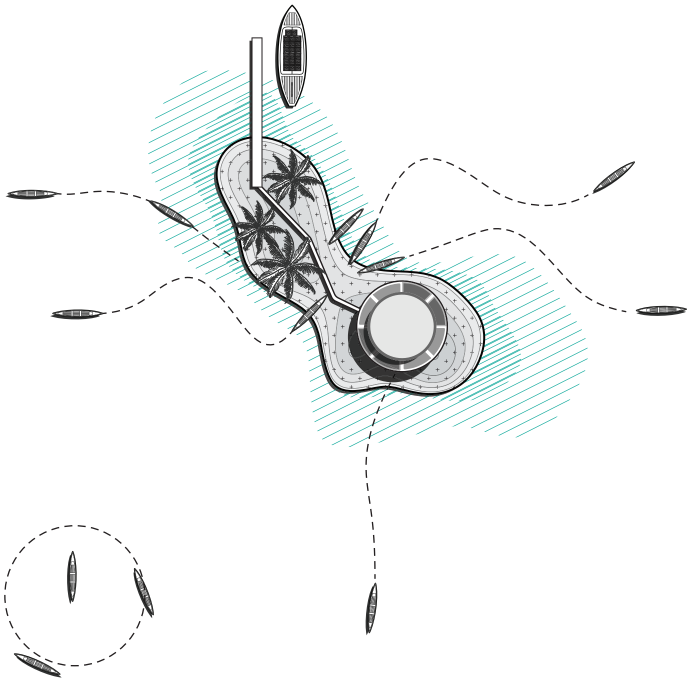

LIVING ON THE EDGE

Reinventing the Amphibiotic Habitat of the Mesopotamian Marshlands

Kurs: AAHM01; Degree Project in Architecture, LTH
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Living on the Edge

- Reinventing the amphibiotic habitat of the Mesopotamian Marshlands

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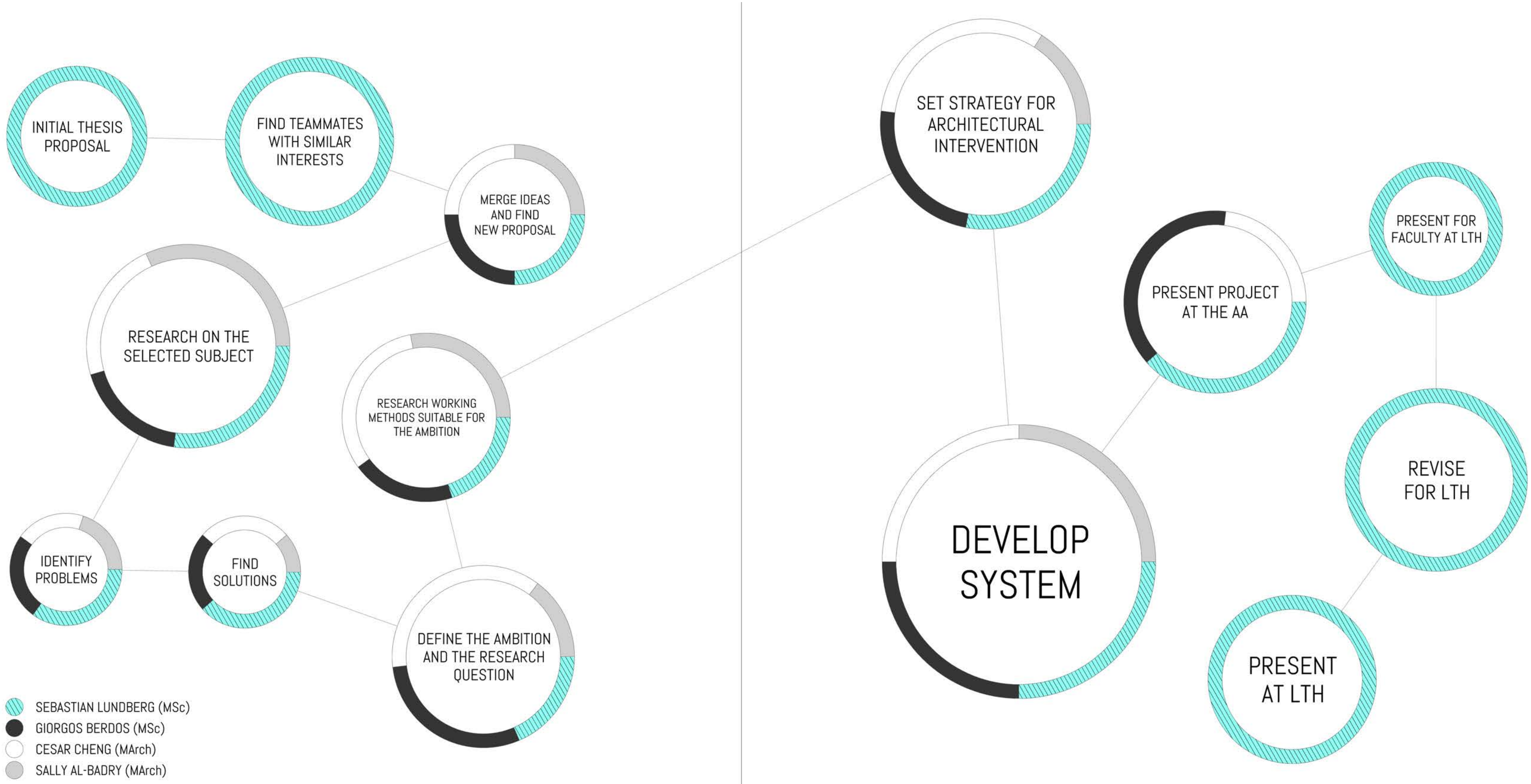


ABSTRACT

The Mesopotamian Marshlands form one of the first landscapes where people started to transform and manipulate the natural environment in order to sustain human habitation. For thousands of years people transformed natural ecosystems into agricultural fields, residential clusters and other agglomerated environments to sustain long term settlement. Moreover, the Mesopotamian Marshlands, located in one of the hottest and most arid areas on the planet, formed a unique wetlands ecosystem, which apart from millions of people, sustained a very high number of wildlife and endemic species. Several historical, political, social and climatic changes, which densely occurred during the past century, completely destroyed the unique civilisation of the area, made all the wild flora and fauna disappear and forced hundreds of thousands people to migrate. During the last decade, many efforts have been made to restore the marshlands. However, these efforts are lacking central planing, coherent goals and deep understanding of the complex current geopolitical situation, making the restoration process an extremely difficult task. This dissertation project aims at providing strategies for recovering the Mesopotamian Marshlands, organising productive functions in order to sustain the local population and design a new inhabitation model, using advanced computational tools while taking into account the extreme climatic conditions and several unique cultural aspects.

0.0 Introduction
***0.1** Background*

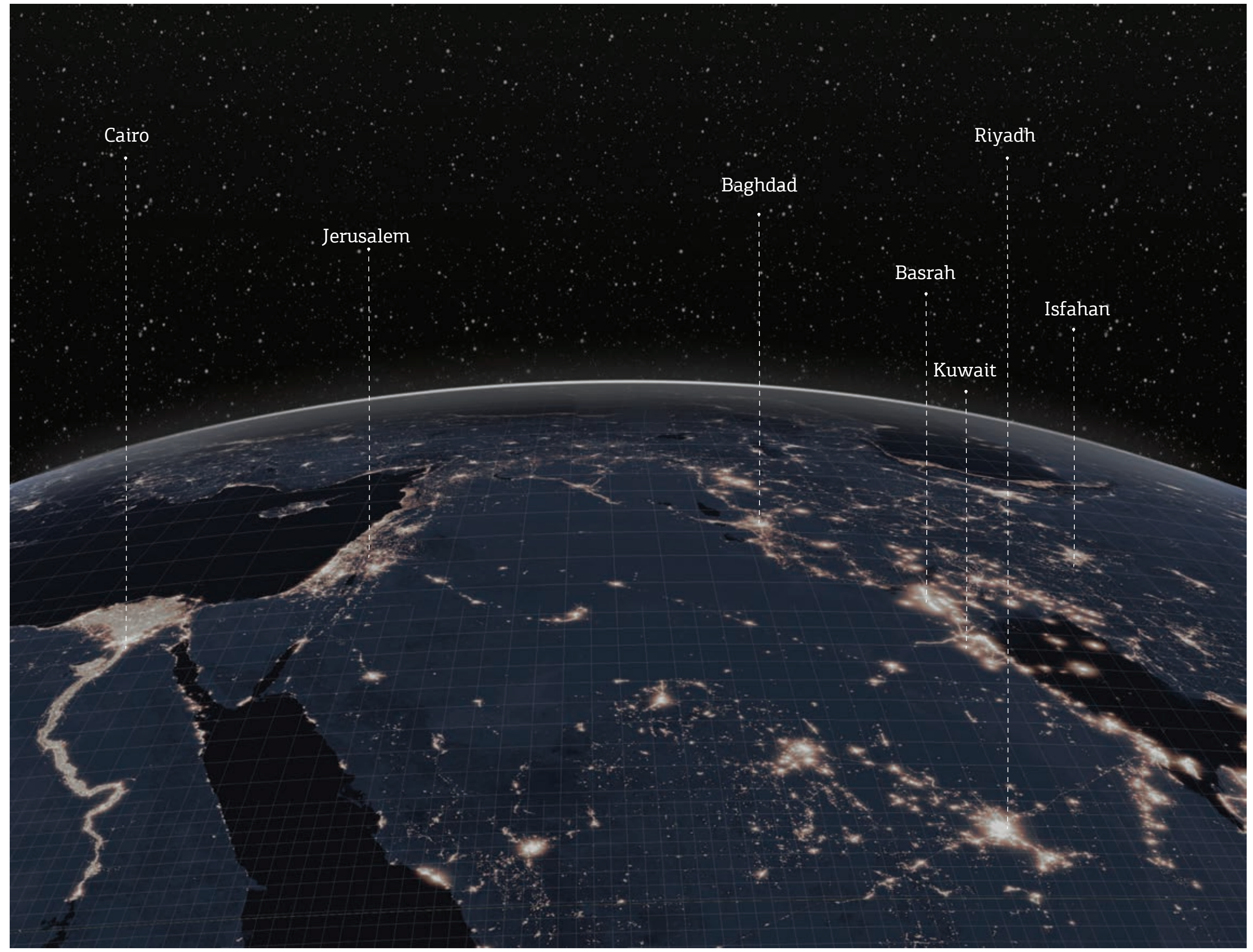
0.1.1 *The Urban Question*

In order to situate this work within the context of urbanisation, it is important to examine a basic and fundamental question that is often taken for granted. What is urbanisation? And what defines the urban condition? This question has been long interrogated both in the design professions and in urban studies. The urban question (La Question Urbaine), was put forward by Manuel Castells in 1972. In his book, Castells elucidates the relativity of the term "urban", showing the difficulties in defining the urban in statistical spatial units. The indicators and thresholds used to define urban areas vary greatly from country to country and are likely to be specific to individual societies. In this sense, defining the urban condition in terms of population growth is inaccurate and inadequate. One nation may measure and define a threshold of 2500 inhabitants as the criterion to define and urban district, while another nation may take 10.000 inhabitants as its criterion. A clear example of this is the Rhur-Rhine conurbation in Germany. Taken as a whole the Rhur-Rhine district would be the largest city in Germany as well as one of the largest cities in Europe both in terms of population and Gross Metropolitan Product. However, the Rhur-Rhine area has no administrative centre and is therefore a conglomerate of many mid-size cities and towns organised in a loose condition between agro-industrial land and urban concentrations. Therefore, according to Castells, "the urban/rural dichotomy loses all meaning, for one might equally well distinguish between urban and metropolitan."(castells 11). While this has been an important question which continues to be subject of debate in urban studies, the fields of urban-design and architecture until very recently paid little attention to this fundamental question forgetting a rich history of architectural theory that understood the intricate dependence between cities and the countryside as inseparable from each other.

Castells, M. (1977). The urban question. Cambridge, Mass.: MIT Press.

For many years urbanisation has been almost uniquely associated with one type of settlement; the city. The city as the ultimate form of urbanisation has become the focus of discussion. Recent work in urban design and urban studies as well as in popular media outlets constantly make reference to the UN proclamation that says that by year 2050, 75% of the world population will live in cities. While it is true that there is major population growth and increase of concentration in cities, the more important question to be examined is how the activity that takes place in these cities is going to be sustained. This, translates into two basic questions, what are the resource requirements of future urbanisation? and where are these resources going to come from?

Activities that belong to the primary sectors of the economy, such as agriculture and resource extraction are land intensive and geographically bound to specific sites. These geographies are described as operational landscapes. Urbanisation is a much broader condition that cannot and should not be limited to the study of the city. The scope of action of the architect and those involved in urban design has been restricted by an incomplete categorisation of urbanism and the city. This project aims at presenting a more comprehensive view of urbanisation that addresses importance of operational landscapes and the transformations that are happening to the countryside.

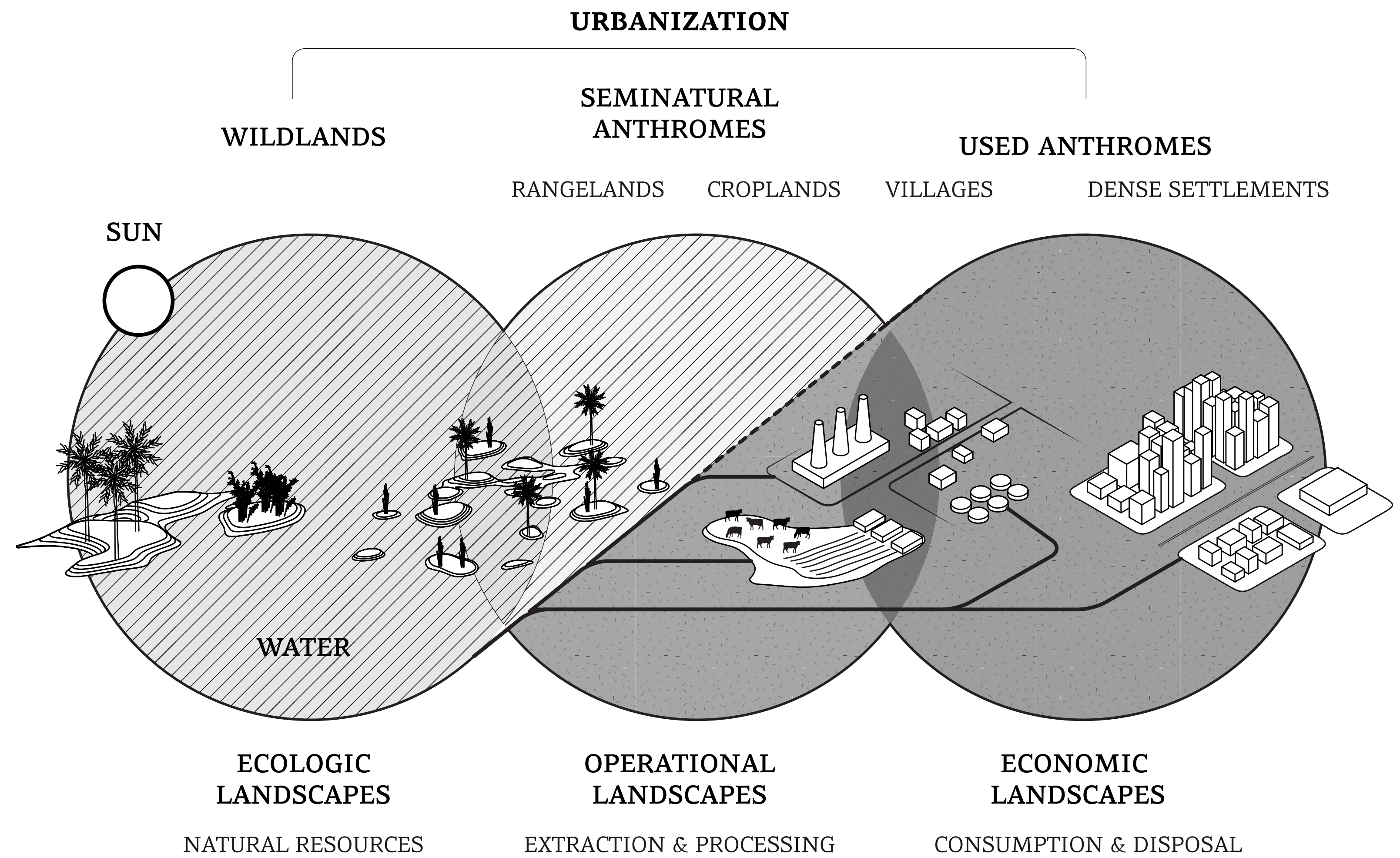


0.1.2 *In-Between States*

Historically human civilisation developed with some connection to natural resources. It is no coincidence that human society developed next to a spring, a river or close to a waterway. It is no coincidence that the great ancient civilisations developed along the Nile River and between the Tigris and Euphrates, where rich silts and fertile soils facilitated agriculture. At the same time technological development occurred as a need to transport and process resources. The Egyptians and Sumerians developed boats made out of reeds in order to take advantage of the river not only as source of food but as infrastructure and transportation arteries that would start to define the logistical frameworks of advanced forms of civilisation. With this in place, the combination of technological development, social organisation and natural advantage allowed cultivators to produce more than they needed to subsist, which lead to a system of labour division and product distribution. "The cities were the residential form adopted by those members of society whose direct presence at the places of agriculture was not necessary. That is to say, these cities could exist only in the basis of the surplus produced by working the land."(castells) For more than 5000 years the land of Mesopotamia has continually been transformed making it one of the most highly engineered environments to be found on earth. It was here were humans began to transform ecosystems into pastures, agricultural land and other engineered environments in support of long term settlements. In this sense, the land of Mesopotamia is intricately linked to the history of urbanisation and city development.

Castells, M. (1977). The urban question. Cambridge, Mass.: MIT Press

In an era of intense urbanisation it is important to examine the relationship between urban centres where activity concentrates and the productive landscapes that make this activity possible. In this regard, this project investigates urbanisation from the perspective of its operational and logistical processes. These processes happen in a space of transition. A space that exist between people and resources. A space between the city and the wild-lands. A space between natural and built environments. The land of Mesopotamia has always been defined by this condition. Etymologically, Mesopotamia refers to the land between two rivers, a space between land and water. Mesopotamia exists in a transitional space, where ecological systems meet human systems. This work presents a new model for human habitation that integrates agro-industrial activity with social functions framed within an ecological setting. Urbanisation is a condition that extends far beyond cities and new forms of settlement are yet to be explored. This work aims at suggesting the possibility of a new form of settlement to re-inhabit the marshlands of Mesopotamia and seeks to reevaluate the role of ecology, infrastructure and architecture in shaping the countryside.



1.0 Domain

1.1 Wetlands.

1.1.1 *The Importance of Wetlands*

Wetlands are the meeting point between terrestrial and aquatic environments, and are among the most productive ecosystems in the world. A wetland can be defined as an area of land that is completely saturated with water throughout the year or partially covered with water periodically. As such, they are transitional zones, which provide unique habitats that sustain a vast number of plant communities and a wide range of animal life. In this sense, they are one of the most biologically diverse ecosystems to be found in nature.

The Economic Value of Wetlands. , WWF, Gland/Amsterdam, January 2004.

The ecological functions of a wetland and the values of these functions to humans shouldn't be underestimated. Instead of being isolated and inaccessible environments, wetlands are vital to the health of other biomes and to many forms of animal and human life. Wetlands are ecosystems that can generate numerous products and services that have economic value, not only to local populations living close to these environments but also to other communities living outside the wetland area.

Natural wetlands perform various functions that are beneficial to both humans and wildlife. Natural wetland systems have often been extolled for their capability to filter pollutants from water that flows through on its way to receiving lakes, streams and oceans. As the water flows through a wetland, it slows down and many of the suspended solids get trapped by vegetation and settle out. Wetland plants also foster the necessary conditions for various microorganisms to live and reproduce there. Through a series of complex chemical processes, these microorganisms also transform and remove pollutants from the water.

Unep.org. (2016). More than a Billion People Depend on Wetlands for Livelihoods, Says Ramsar Convention Secretariat on World Wetlands Day - UNEP. [online] Available at: http://www.unep.org/newscentre/Default.aspx?DocumentID=26862&ArticleID=35883 [Accessed 11 Sep. 2016].

Wetland products range from basic food staples, such as fish and rice for human consumption, to steams and leaves for weaving, timber or reeds for construction material and fodder for various animals. Additionally, wetlands provide important ecological services that benefit humans and wildlife. Wetlands filter, clean, control and store water. Acting like a sponge, wetlands help reduce damage caused by floods by collecting excess water and regulating the level of rivers. During periods of drought, wetlands recharge groundwater supplies and control stream-flow by providing water to streams. Through various mechanisms, wetlands filter and purify water as it flows through the wetland system. Furthermore, plants that grow in wetlands help control water erosion by regulating the flow of water and sediments transport.

A report from the UNEP estimates that more than a billion people around the world depend directly on wetlands for making their living, in activities that include fishing, rice farming and hand-made crafts. Furthermore, wetlands provide recreational opportunities for travel and ecoturism. Despite the great benefit that wetlands represent to sustain life in the planet, around 64 per cent of the world's wetlands have disappeared or have been endangered since 1900; many of these ecosystems are suffering from irresponsible agricultural practices or have been transformed or altered for urban development, putting plant and wildlife at risk. The fast decline of coastal, marine and inland wetlands is estimated to be approximately 40 per cent in just over 40 years and this decline is continuing at an accelerated rate of 1.5 per cent annually.

DISTRIBUTION OF WETLANDS

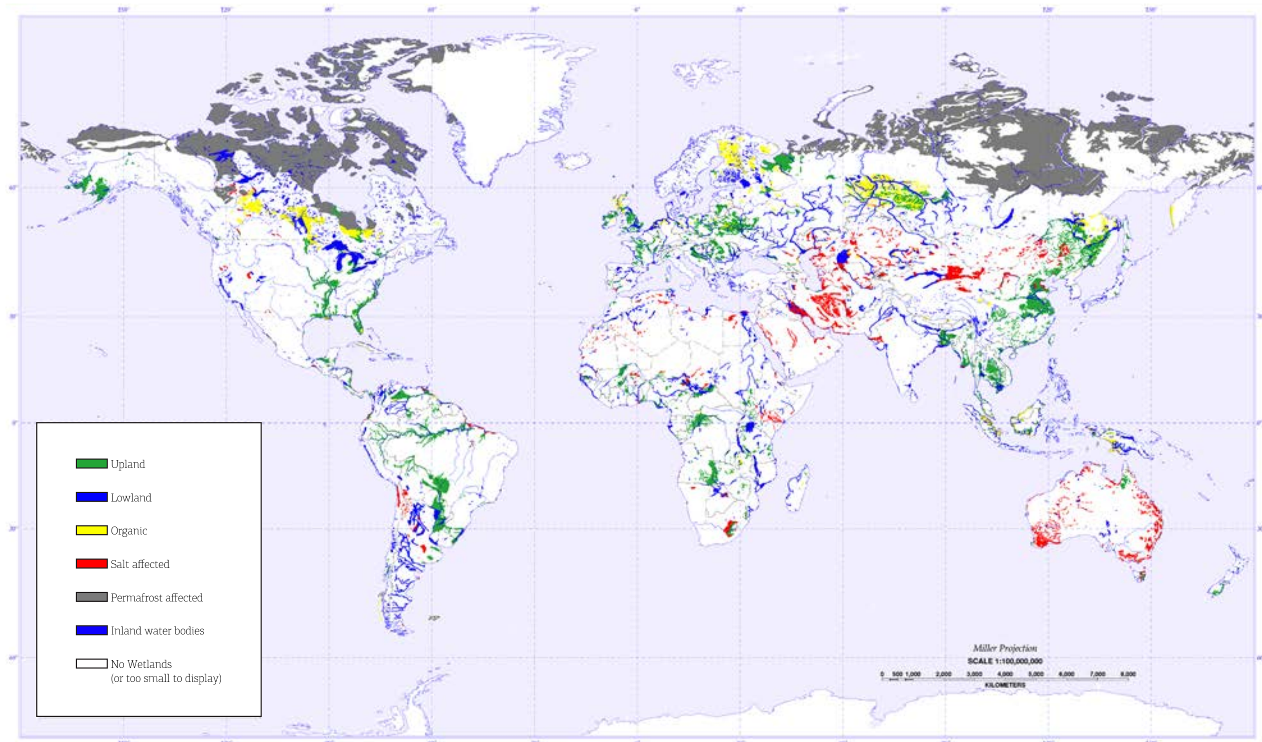


FIG.1 World distribution of wetlands. Source: US dep. of agriculture.

1.1 Wetlands.

1.1.2 *Inhabiting Wetlands*

Unep.org. (2016). More than a Billion People Depend on Wetlands for Livelihoods, Says Ramsar Convention Secretariat on World Wetlands Day - UNEP. [online] Available at: http://www.unep.org/newscentre/Default.aspx?DocumentID=26862&ArticleID=35883 [Accessed 11 Sep. 2016].

The urbanisation of the world has come at the cost of environmental degradation and loss of natural habitats. Cities have become the most prominent form of human settlement creating a divide between production and consumption of natural resources. Far from being self-sufficient entities, cities are strongly dependent on the extraction of resources that most of the times lie outside its boundaries and form a different type of landscape. Cities are the focal point of human activity while productive landscapes are the support mechanism for human activity. In this regard, it is critical to rethink the relationship between patterns of human occupation and utilisation of natural resources.

In search of new models of human habitation, wetlands offer a fertile ground for investigating the relationship between human settlements and natural resources. Throughout time the development of human settlement has been tightly linked to a productive relationship between land and water.

Early forms of human settlement originated in close proximity to river ways, coastal lines and water basins. It is no coincidence that ancient civilisations appeared next to major rivers. First, Mesopotamia between the Tigris and Euphrates, then Egypt along the Nile river and later other civilisations also emerged along the Yellow river in modern day China. It is precisely in this transitional zone between land and water, where humans first began to transform native ecosystems into agricultural fields, pastures and other engineered environments in support of long term settlement. By doing this, humans triggered a process of unprecedented population growth, societal development and planetary transformation. In this sense, the land of Mesopotamia can be thought of as the first productive landscape, where extensive tracts of land were transformed to serve human occupation.

1.1 Wetlands.

1.1.3 *The Wetlands of Mesopotamia*

The wetlands of Mesopotamia continue to be an area of inmense importance for investigating alternative models of human occupation. While the history of human settlement concentrates on the evolution of the city from small town to large metropolis, there are other examples of patterns of occupation that offer an alternative models for human settlement in which the relationship between human and natural environments are integrated more productively.

Up until the 1970's, it was estimated that a population that ranged between 300,000 to 500,000 people, who called themselves "the marsh arabs", lived in the surrounding areas of the Mesopotamian wetlands. Most of them were farmers whose lives depended on the natural resources of the marsh for rice production, raising livestock and fishig. A fraction of them, a population estimated to be between 50,000 to 100,000, were marsh dwellers who lived within the marsh area and owed their entire existence to the marsh ecology. The marsh dwellers constructed a human habitat intricatelly linked to the wetlands blurring the line between human-made and natural environments. This model of human settlement is not unique to Messopotamia. Other examples of wetland occupation can be found today in different regions of the world such as the wetlands of Lake Titikaka in Peru or the wetlands of Sudd in South Suddan. Little attetnion has been directed to more integrated models of human settlement in wetlands and much can be learnt from these existing communities.

S. Alwash,
Eden Again: Hope in the
Marshes of Iraq

Apart from the rich biodiversity that wetlands have to offer, there are significant climatic advantages that promote ideal conditions for life to take place in them. Particularly in regions with high summer temperatures such as Iraq, wetlands can have a possitive effect on the climate of a region by providing natural cooling. Wetlands are special in their microclimate because they display climatic properties of both, terrestrial and water systems. Due to surface evaporation and plant transpiration, the degree of humidity of wetlands can have significant impacts on the climate of the region. The precense of water and vegetation make the wetland operate as cooling device for the area covered.

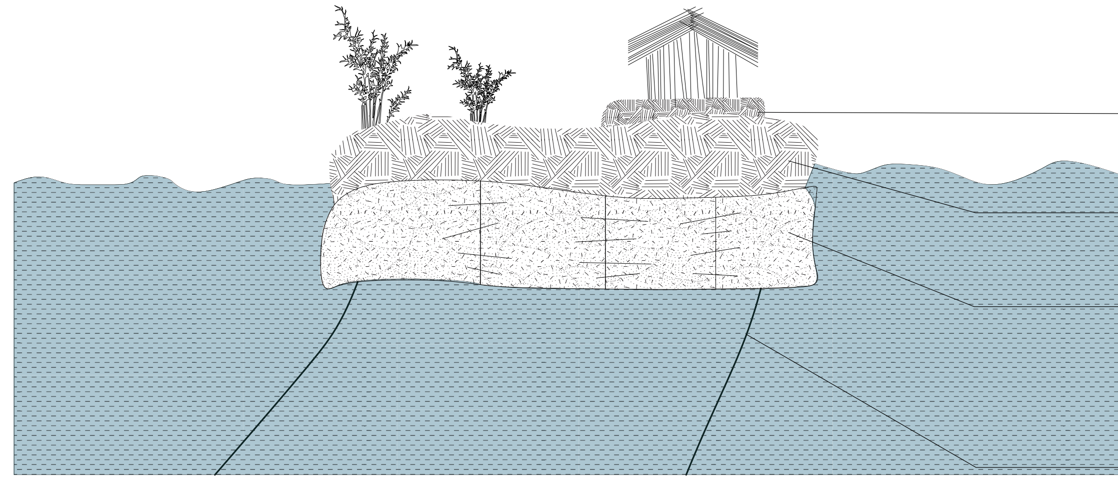
1.2 Case Studies

1.2.1 *Wetlands -Inhabiting Semi-Aquatic Environments*

1. The floating islands of Uros in Lago Titicaca

The artificial floating islands of the Uros people can be found in lake Titicaca, about 3 miles east of the port town of Puno in Peru. Their basic construction material is the totora reed, a floating type of reed that can be found in abundance on the shallows of the lake. The Uros islands in lake Titicaca were originally constructed for defensive purposes and they could be moved if a threat arose. The islands contained mainly houses, providing the main terrestrial means of inhabitation; semi-stable ground and some of them also contain watchtowers largely constructed of reeds.

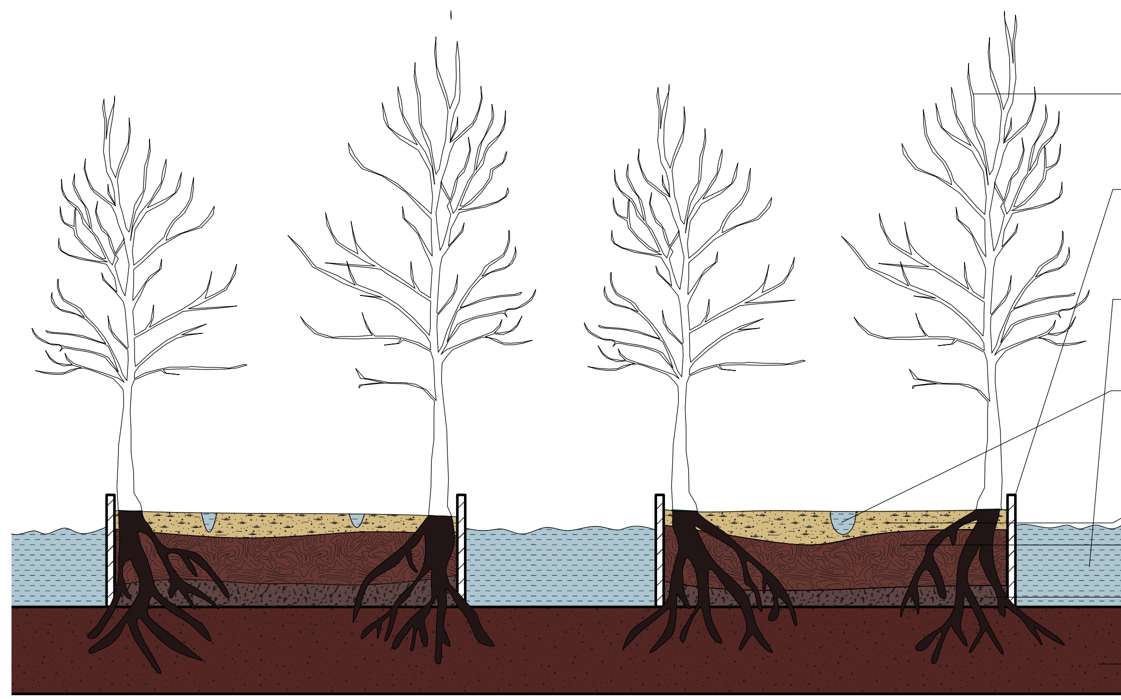
Each island usually hosts about five families, the large islands can host up to ten and the small ones, which are about 30m wide, host two to three families. To construct their islands, the Uro people harvest the soil root base of the totora reeds, which can float due to the air trapped between the roots and the sloppy soil. They cut these root-soil blocks into rectangular pieces with their size varying from 2m to 3m per side, which they lash together using large stakes in order to compose the base of the floating island. This first layer of the island acts as floating foundation and is normally 1m to 2m thick. This first layer is either anchored to the bottom of the lake or connected to another neighbouring island. The second layer is made out of cut totora reeds and is also about 1 meter deep. This layer creates a spongy and mostly dry surface with a lot of spring that exceeds the lake's water level. Over time the reeds in touch with the water rot, while those out of the water deteriorate because of their exposure to the sun. The Uro people have to continually add new reeds (every 1-3 months depending on the season), replacing the decaying ones, in order to ensure the island's floatability. If an island is well preserved, it can last for 15-20 years before they will need to construct a new one.



2. The Chinampas

The Chinampas are artificial islands that the Aztecs created by building up soil extensions into the shallow areas of lakes and wetlands. Chinampas were commonly used in pre-colonial Central America and especially in the Valley of Mexico. Before 1519, when the Spanish conquistadors arrived in Mexico for the first time, 5 to 6 million people inhabited the Aztec empire. Therefore, the Aztecs had to intensify the agricultural production by exploiting efficiently the land available. Consequently, they developed the Chinampas, which maximized the productivity of the available land giving up to 7 harvests per year. The Aztecs were cultivating various crops on the Chinampas including tomatoes, peppers, beans maize and flowers.

Chinampas were linear, organized between a system of canals where canoes could fit to transfer people and goods and their dimensions were varying according to their geographical location. The first step of the Chinampas' construction process was the positioning of wooden stakes that defined the outline of the structure. The stakes were weaved using wattles and a rectangular fence was created. Then the fenced enclosure would be filled with layers of mud, lake sediment and finally decaying vegetation, until the level of the Chinampa plot is above the lake's level. To ensure the stability of the plot, trees (usually willows or cypresses) were planted along the perimeter and acted as anchors while reducing the effects of soil erosion due to their dense root system. Furthermore, the Chinampa beds had ditches that allowed the plants to have constant access to the lake's water and grow independently of rainfall or artificial irrigation. The Chinampas were always separated with canals, which were wide enough to allow for canoe movement and transportation.



1.2 Case Studies

1.2.3 Industrial Ecology
- The Sahara Forest Project

The Water Project. (2016). Water In Crisis - Spotlight Middle East. [online] Available at: https://thewaterproject.org/water-crisis/water-in-crisis-middle-east [Accessed 9 Sep. 2016].

Inhabitat.com. (2016). Sahara Desert Project to grow 10 hectares of food in Tunisian desert. [online] Available at: http://inhabitat.com/sahara-desert-project-to-grow-10-hectares-of-food-in-tunisian-desert/ [Accessed 8 Sep. 2016].

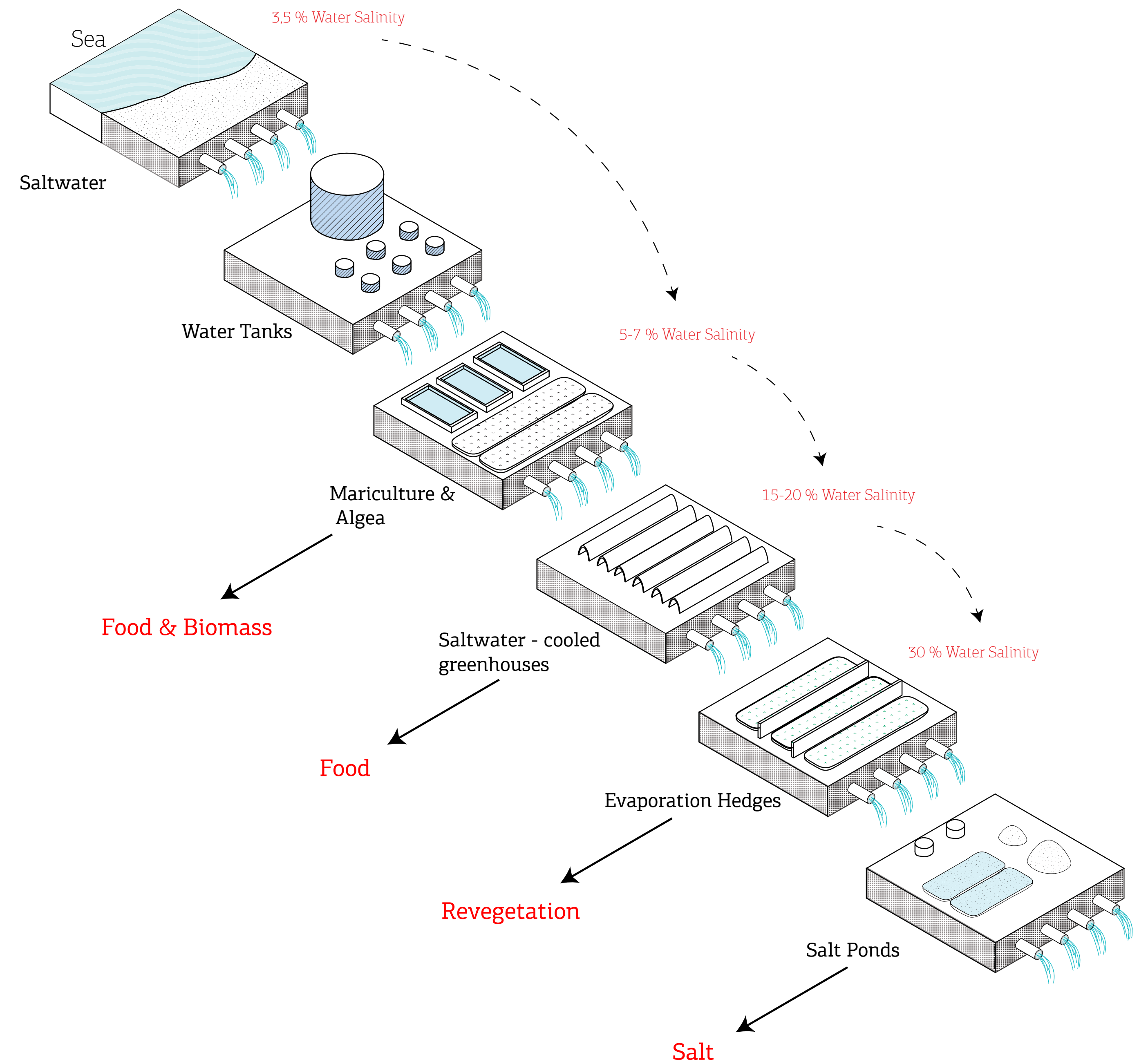
Sahara Forest Project. (2016). Sahara Forest Project -. [online] Available at: http://saharaforestproject.com/ [Accessed 8 Sep. 2016].

In general the Middle East is currently experiencing many environmental challenges. Water resources are becoming scarce, especially in countries that share the same problems, like poor water management and lack of water resources. For example Saudi Arabia, Jordan, Yemen and Iraq face similar challenges. The Middle East has some of the largest oil reserves in the world. Nevertheless, the region's climate and environment make life conditions harsh, creating a need for finding alternative solutions for accessing water resources and suitable land for agriculture. The Sahara forest project is a sustainable solution that aims to provide fresh water, food and renewable energy in hot and arid climates. The project proposes a combination of saltwater-cooled greenhouses with Solar Power technologies, either directly using Photovoltaic (PV) or indirectly using concentrated solar power (CSP) and technologies for desert re-vegetation.

Seawater Greenhouses use solar power to convert salt water into fresh water, which is then used to grow fresh vegetables and algae (to absorb CO2). Concentrated solar power (CSP) utilises mirrors to generate heat for a steam turbine, which produces the electricity necessary to power the seawater greenhouses while purifying the water and pumping it through the space. Together, these two technologies ensure that food can be grown throughout the year.

Seawater is also used to cool and humidify the facility while the extracted salt is sold commercially. The desalinated water is used to irrigate the plants and can even be used for as fresh drinking water.

The Sahara Forest Project was created by architect Michael Pawlyn, Seawater Greenhouse designer Charlie Paton, and structural engineer Bill Watts.



1.3 *Climate and Land Productivity*

1.3.1 *Climate*

Regional Climate

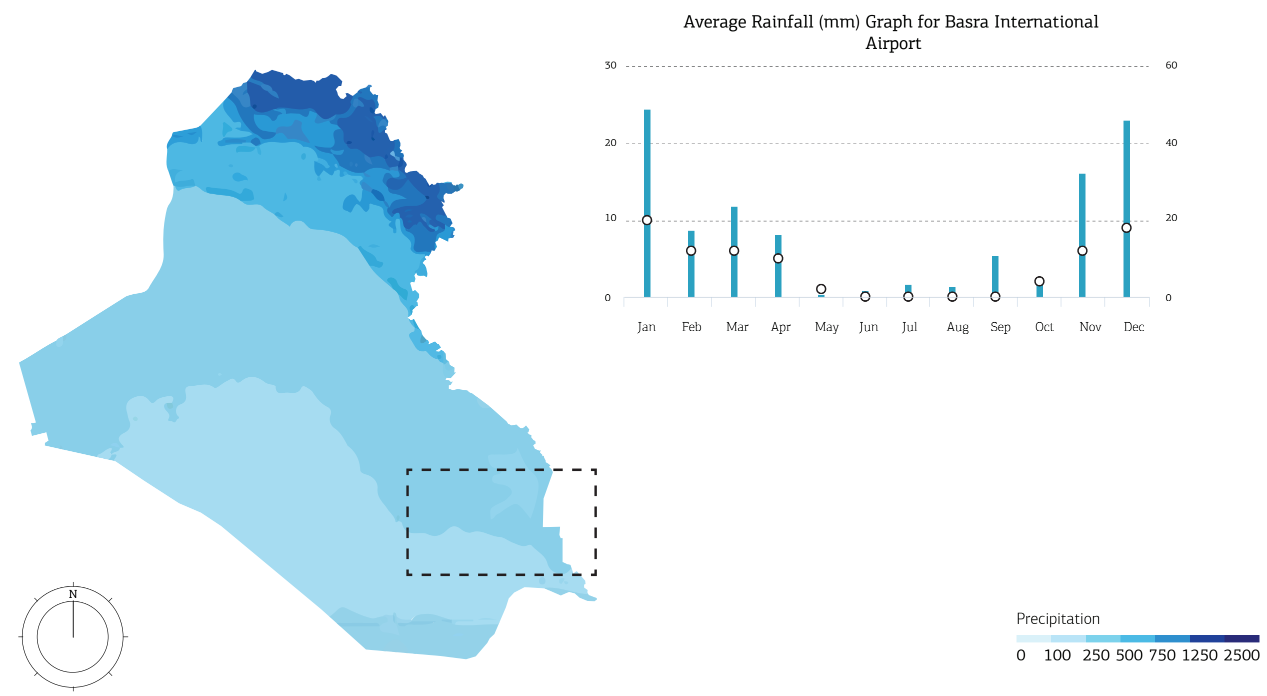
Extreme high temperatures and shortage of rain throughout the year make much of Iraq's territory a desert. During summer time temperature rise above 40 degrees and during winter temperature can drop below 0 degrees. Especially in the south-east region, the climate is mostly hot and dry with few cloud formation and little precipitation. The mean annual rainfall is less than 100 mm.

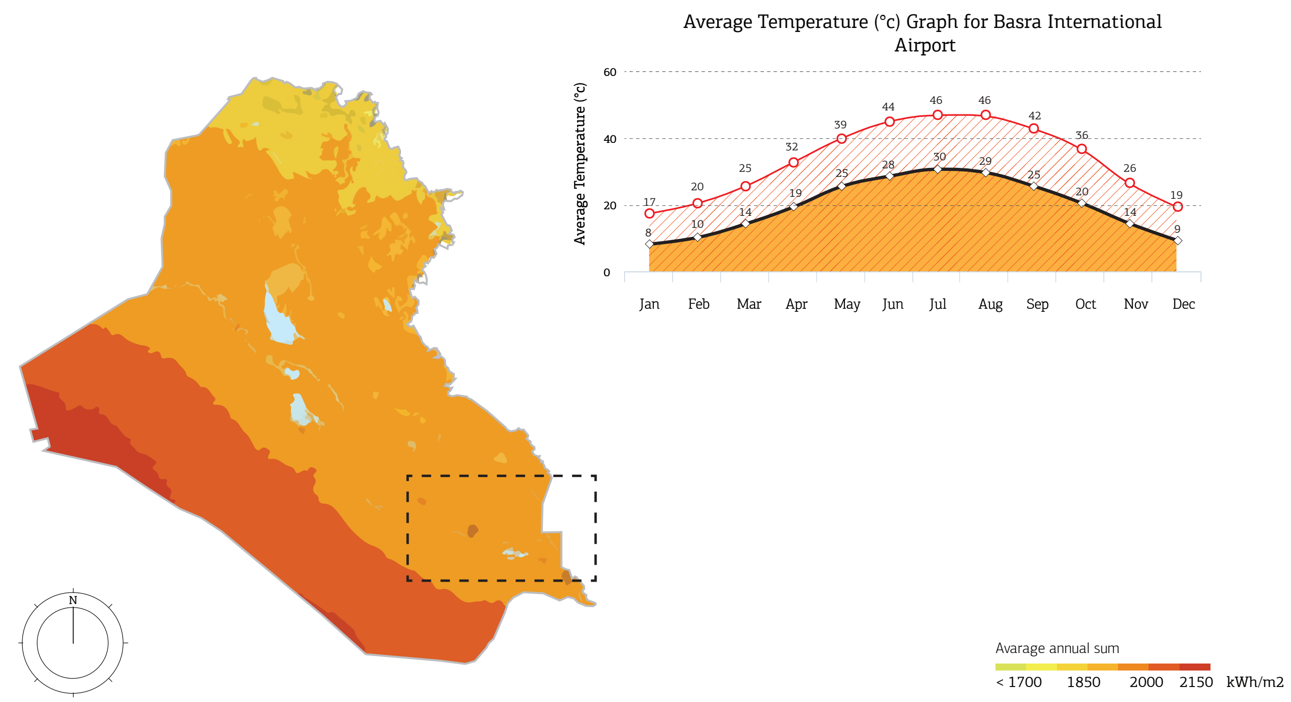
Rainfall increases gradually to 1000 mm towards the mountain regions in the north-east. Dominant winds come from the northwest and north in the central and northern parts of the country. In the south winds come from the west and northwest, so north-westerly winds are the most dominant. The combination of arid-dry climate and wind currents generates dust storms in the desert and the Mesopotamian plain. Wind speeds can reach 100 km per hour. Sometimes the whole country is covered by a cloud of very fine dust. It is estimated that on average about 2.5 mm of dust falls on the whole area of Iraq every year.

As a result of high temperatures, strong winds and low rainfall, the evaporation is very high; it is 2170 mm at Abu Dibbis Lake in the central part of the country. During summer (June, July, and August) the evaporation is 250 mm to 300 mm per month or about 10 mm per day.

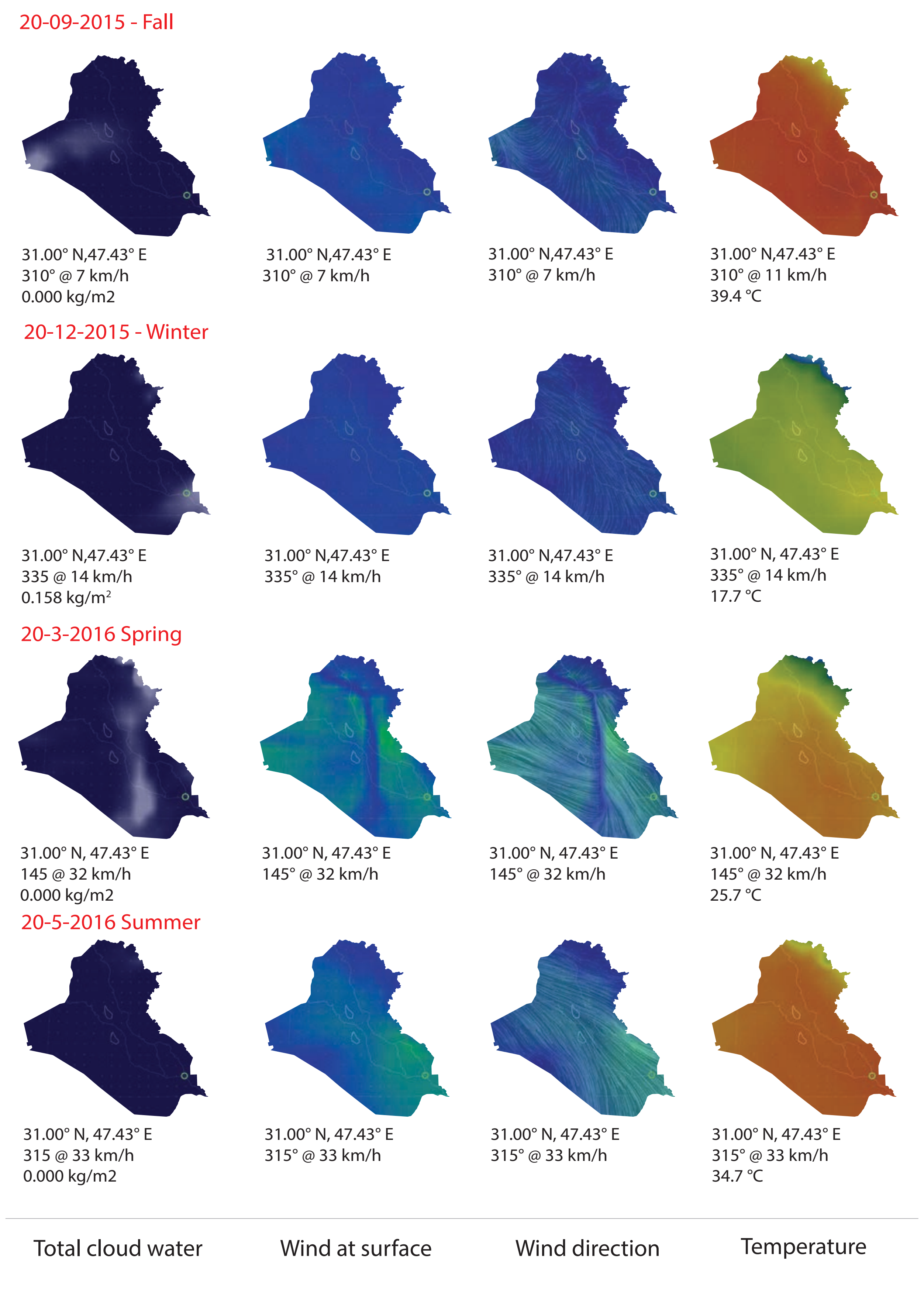
Local Climate Effects of the Marshes

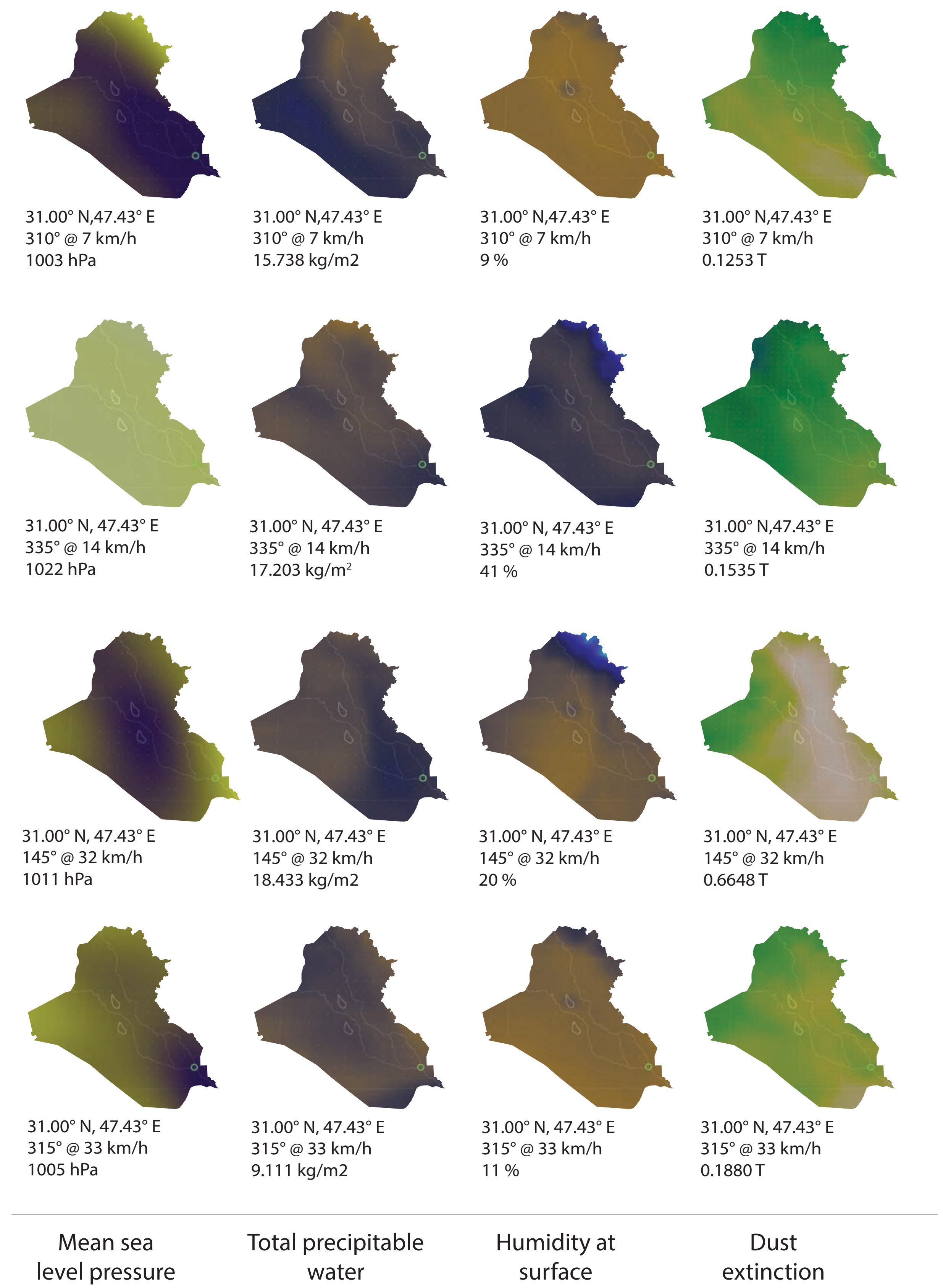
The presence of water features in desert-arid climates has important effects on the microclimate of the surrounding areas. Because of evaporation, water features can provide natural cooling in regions with high temperatures. Water bodies are noted to be remarkably good at absorbing radiation while showing very little heat response due to its relatively high specific heat capacity. Nearby or above a body of water like a river or a lake, the air temperature is much different from that over land due to differences in the way water heats and cools. In this sense, wetlands provide similar climatic effects from having high concentrations of water. Moreover, the presence of vegetation provides shading and additional moisture from plant transpiration. This is the case of South-West Iraq, where the area of land in between the Tigris and Euphrates river is covered with water creating an extensive marsh within a larger desert area.





1.3 Climate and Land Productivity





1.3 Climate and Land Productivity

1.3.2 Economic Activity

Globally, the need for natural resources and energy is increasing which encourages the investigation for new renewable resources. In Iraq there are various natural resources from multiple geographic sources but oil is the most important raw material to the economy of Iraq which makes Iraq mostly dependent on oil industry. The certified oil reserve in Iraq is estimated at 115 billion barrels. Therefore, Iraq is considered to have the second largest oil reserve in the world after the Kingdom of Saudi Arabia [2].

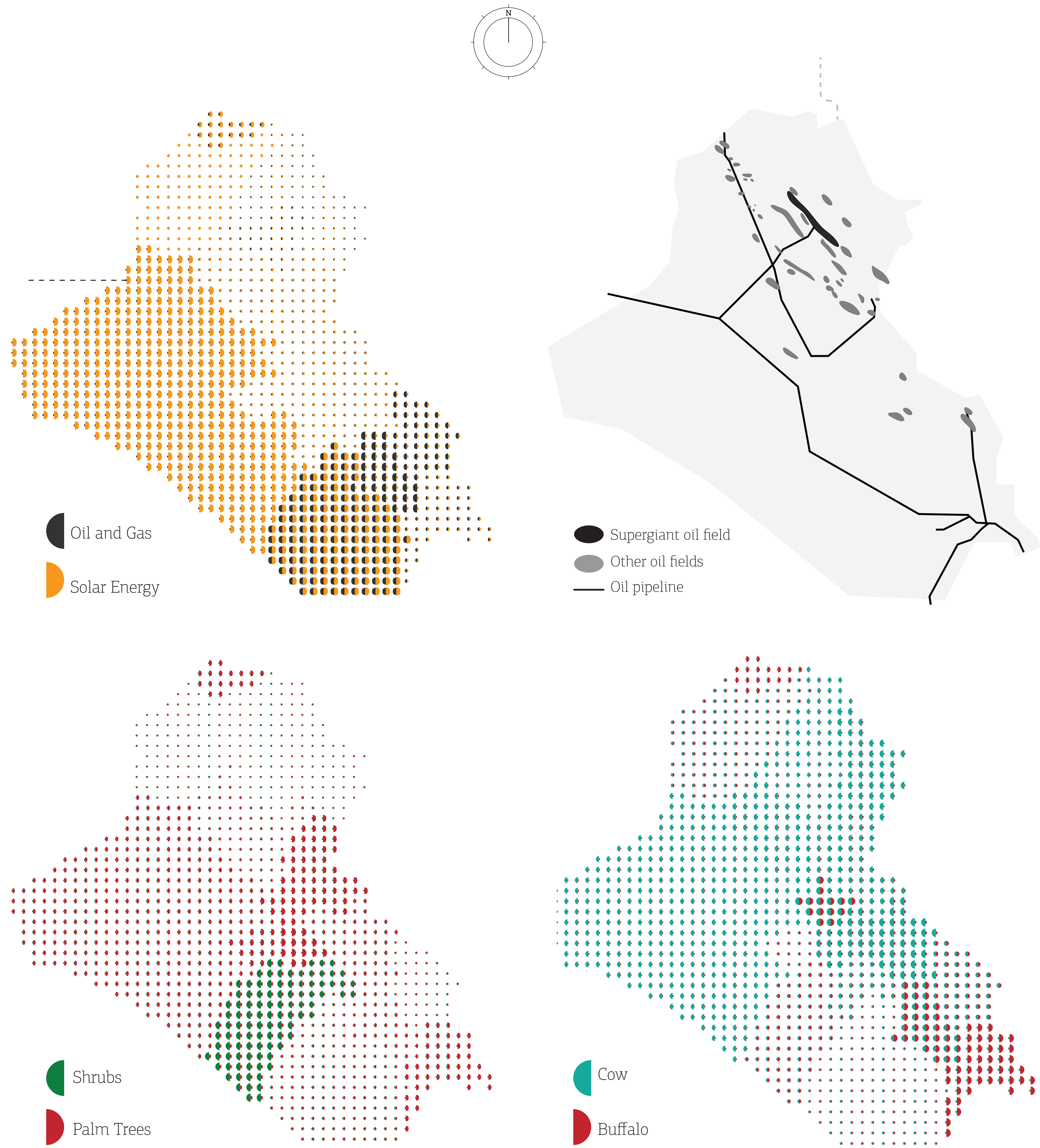
On the other hand, Iraq is heavily dependent on imported food to satisfy local demand. Agriculture and agribusiness support nearly 7.5 million people (27% of the population) in Iraq. The total area which has been used for agricultural production is about 80 000 km2 which is almost 67% of the cultivable area. However, It is estimated that the average area of cultivated land is decreasing due to certain limitations such as soil salinity, drought, shortage of irrigation water in summer, following the unstable political situation [1].
Fishing was a major economic activity in the marshland area. However, after the lands were drained, many marsh dwellers turned to agriculture in an attempt to earn a living.

Based on the soil map of Iraq there are two main zones for agriculture first one is located in the northern part of the country where the soil is Mountainvalley Soil and the climate is transitional to semi-arid and the other is the central to southern zone which is approximately 30% of Iraqi territory Formed by the combined deltas of the Tigris and Euphrates Rivers. This region begins north of Baghdad and extends to the Gulf passing by the marshland where generally the climate is hot desert climate but the micro climate of marshland makes it more humid and suitable for agriculture.

Iraq has 19 governorates, Due to the climatic, geographical and topographical changes in these governorates; the productivity concentration varies from one governorate to another. The following maps illustrate the variety of different products in each governorate. Every two products from the same category are combined in one map which makes it comparable to each other.

[1]Fao.org. (2016). Iraq country profile. [online] Available at: http://www.fao.org/ag/agp/agpc/doc/counprof/iraq/iraq.html [Accessed 5 Jun. 2016].

[2] Kazem, H. and Chaichan, M. (2012). Status and future prospects of renewable energy in Iraq. Renewable and Sustainable Energy Reviews, 16(8), pp.6007-6012. Fao.org. (2016).



1.4 Transfomation of the Marshes

1.4.1 Evolution and Environmental Changes of the Mesopotamian Marshlands

The Mesopotamian marshlands have gone through a series of transformations over the past 5000 years. Most of these changes have taken place in the last 50 years. Historically the marshes were spread out over an area of 20,000 km2. Due to anthropogenic manipulation the area of the marshes had decreased to 10% of its original size by 2003. The once fertile land that accommodated the dawn of civilization, has now been transformed into salt-encrusted desert.

Around 3000 BC the marshes went through its first transformation. Humans started inhabiting the area and modifying the landscape to make it inhabitable. Small islands were developed in the marshes in order to house reed huts and buffalo farms. Over time, these islands were reinforced and gradually built up with reeds and mud as they would be eroded by the annual spring flood.
In the 1970's the construction of dams began along the Euphrates and Tigris. Dams used for hydro power, flood control, water reserves and irrigation, disturbed the natural flow of the rivers and significantly reduced their annual discharge. This marked the first step of the dessication of the Mesopotamian Marshes. Later in the early 90's the deliberate dessication took place during the former regime when Saddam Hussein attempted to find the rebels forces that were taking refuge in the reeds. New dams and embankments were constructed, and large systems of ditches and canals were dug out in order to drain the marshes, which left them at only 10% of their original size.

Without any water supply, the remaining water in the marshes was left to evaporate, leaving salt affected soils in the former marshland sediments .

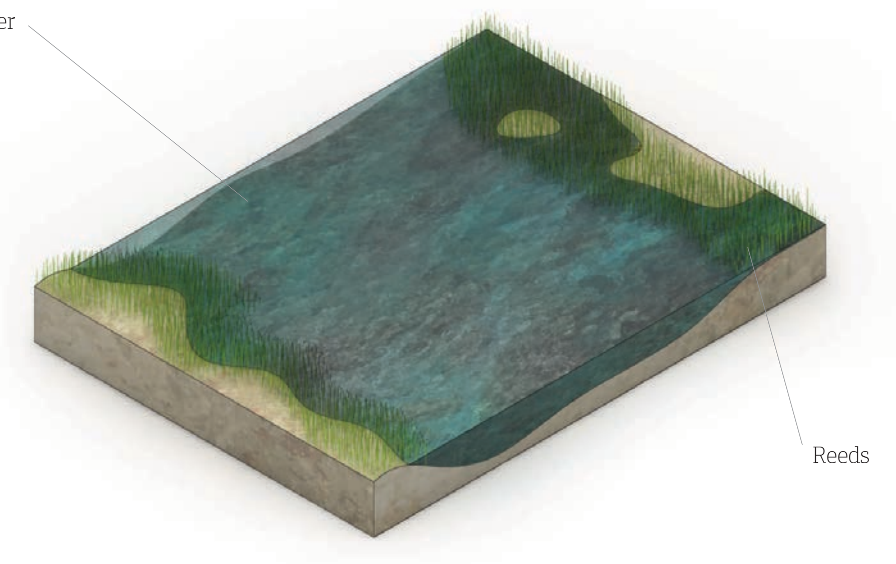
R.W. Fitzpatrick,
CSIRO Land and Water

Following the draining of the marshlands in Saddam Hussein's attempt to search out the rebels, the dried areas were burned in order to fully dessicate the marshes and ensure that nothing would grow there again. The burning of the dried marshland soils have severely destroyed the original soil components and formed high concentrations of magnetic cemented/ceramic-like gravel in the upper 1-50 cm restricting the root growth of plants.

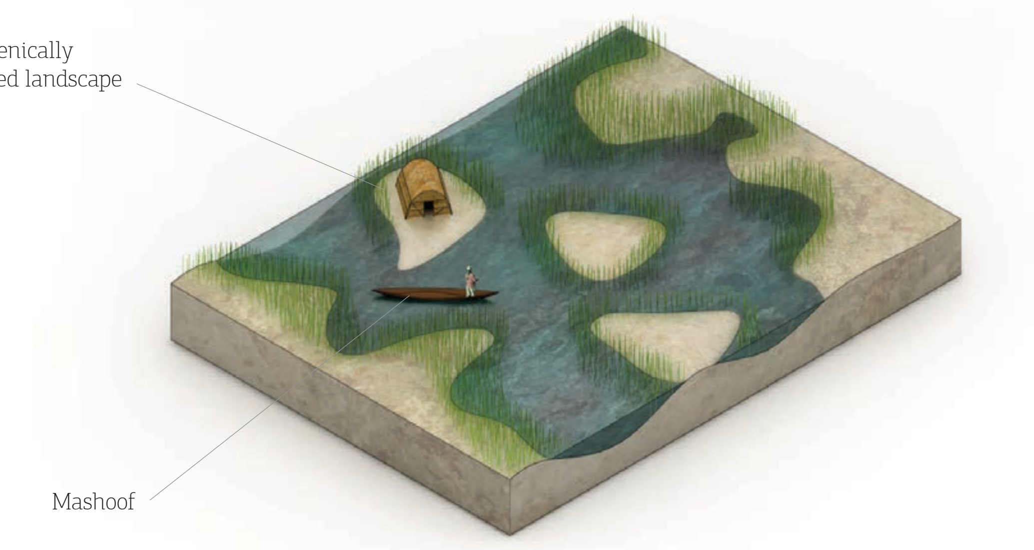
The dessication forced the local marsh dwellers out of the marshes. The nearly 500,000 people had to move out to the rivers where they had access to water. This is how regions like Al-Chibayish and Al-Hammar changed from the historical inhabitation of vernacular islands to the more compact riverside settlements that can be seen today.

After the dessication some marsh dwellers made an attempt to level the dry land in the marshes for agricultural purposes. However, the soil had been severely harmed by the dessication process and was no longer suitable for growing crops, due to its reduction in water storage capacity and loss of organic matter.

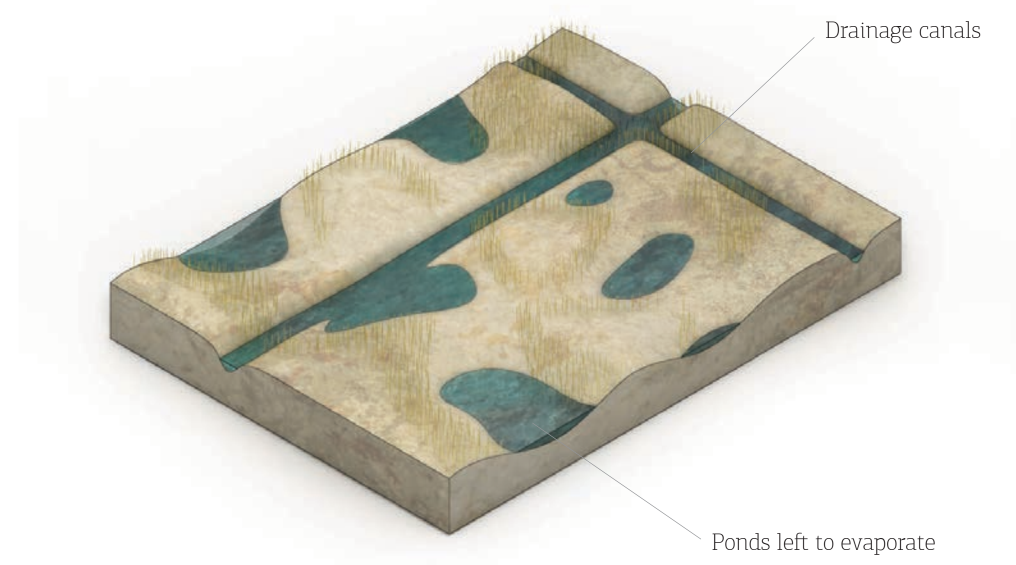
After the change of regime in 2003, the former marsh dwellers re-flooded the marshes by breaching embankments along the Euphrates river. Large areas that were re-flooded were unable to be restored due to the unproductive soil. The input water merged with the saline soil and remains of burnt reeds, leaving red toned ponds of water without any natural growth.



Before humans started inhabiting the marshes, the marshlands spread out over approximately 20,000 km2. They consisted of shallow lakes and reeds and accommodated a wide range of wildlife.

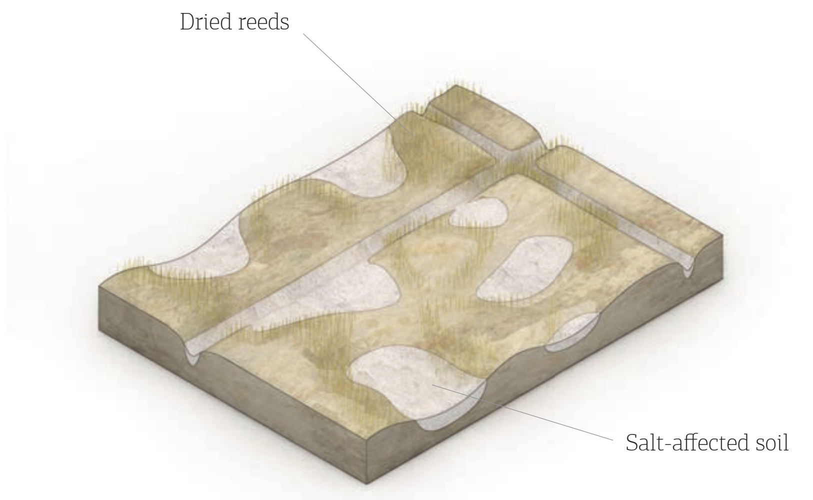


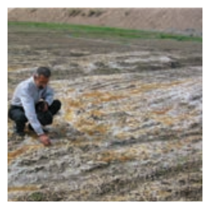
Around 3000 BC humans moved in to the marshlands. They manipulated the landscape by constructing islands which they inhabited and used for buffalo farms. They built their homes out of reeds, and used a specific boat called mashoof to get around the marshes and collect the reeds.



After what came to be known as the "Era of Dams", the Euphrates' and Tigris' water discharge to the marshes decreased significantly. During the dessication period in the early 90's, ditches were dug in order to extract the marshes' water using giant pumps.

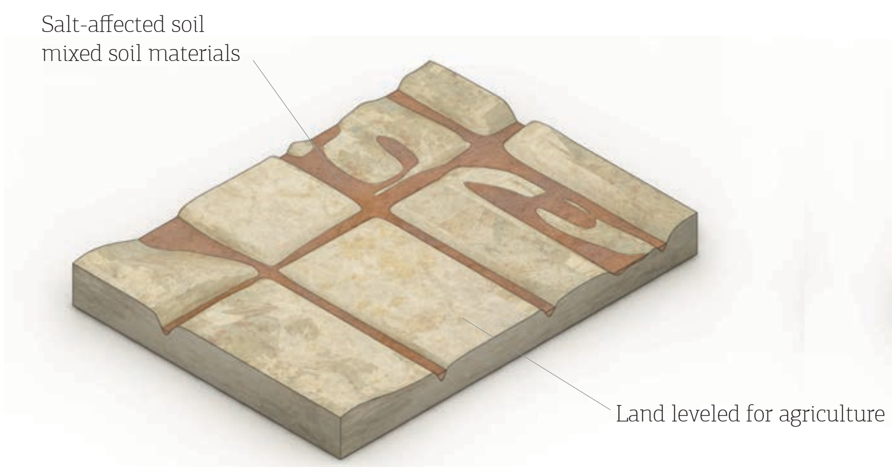
1.4 *Transfomation of the Marshes*





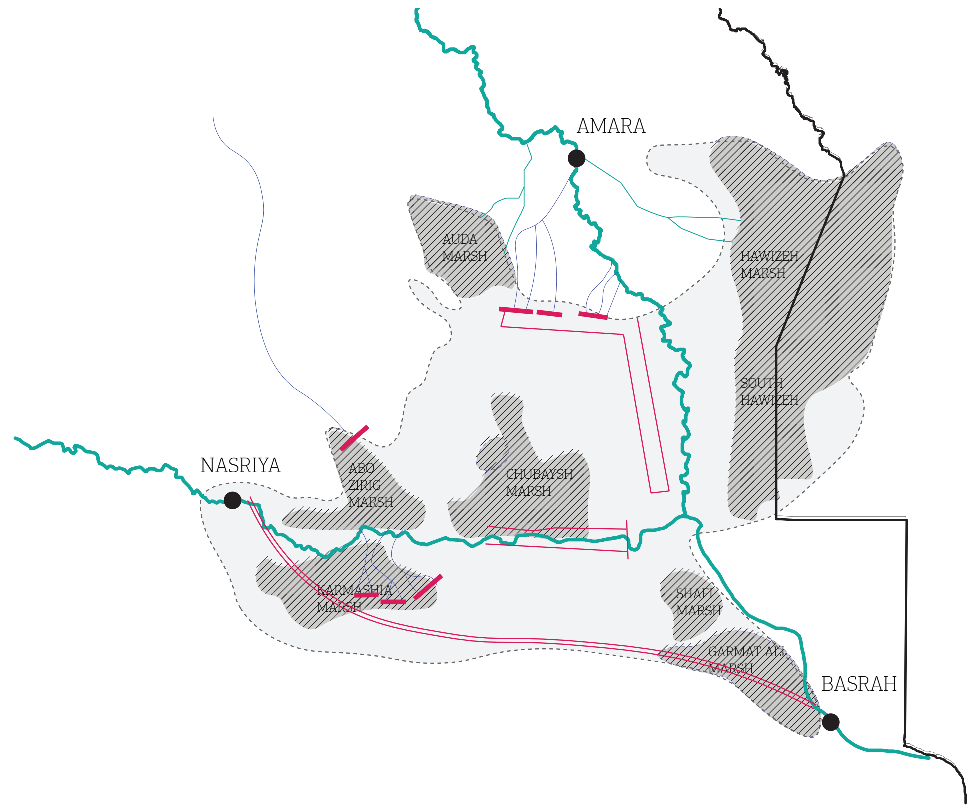
When the marshes had been drained the remaining water was left to evaporate, leaving large areas of salt encrusted soil. Without any water supply the natural growth died and the land was covered with dried reeds.

In the mid 90's the next step of the dessication process took place. The dry lands of the former marshes were burned in order to prevent any possibilities of restoring the marshes.

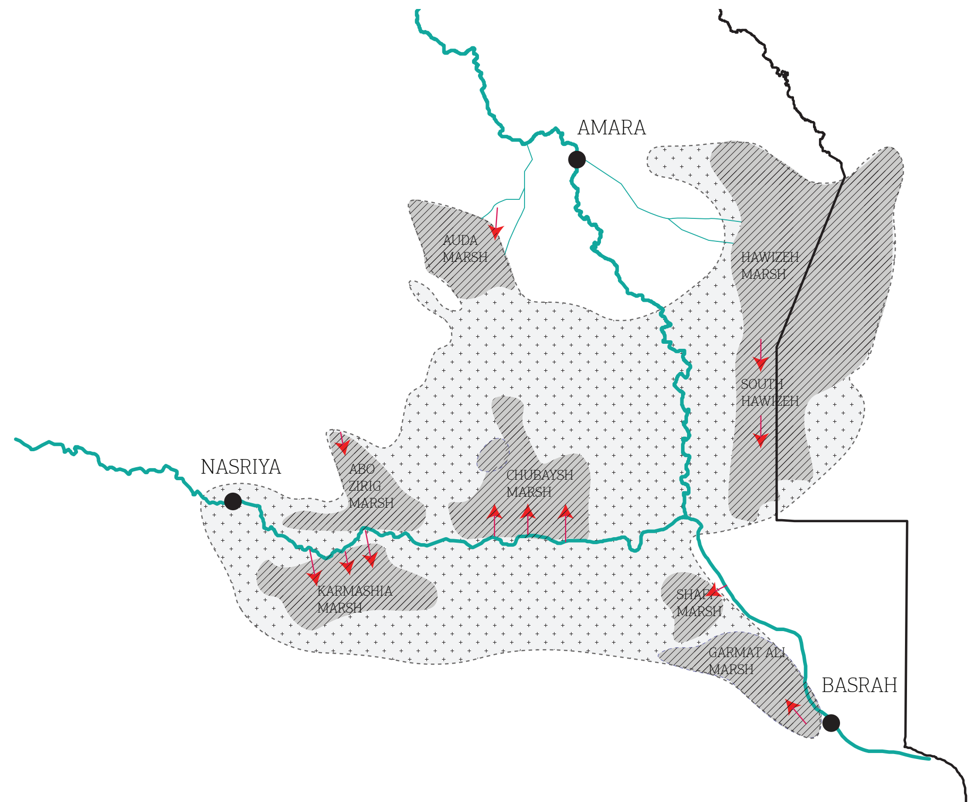


After the dessication local marsh dwellers made an attempt to recover the unproductive land by leveling it for agricultural purposes. The burnt soil lacked necessary qualities and was no longer suitable for growing crops.

In 2003 the locals breached embankments along the two rivers in order to restore the marshes. However, due to the burnt and TDS(Total Dissolved Solids) effected soil, large parts of the marshlands could not be recovered. Instead the input water caught a red tone from the iron and salt in the soil and red colored ponds covered the dry land.



During the desiccation process in the early 90's embankments, dams and canals were constructed in order to redirect the water from the marshes .



In 2003 the reflooding process began. Pumps that were constantly draining the marshes were stolen by local residents and the embankments along the rivers were breached.

1.5 Site Characteristics

1.5.1 Water Scarcity

- Current Problems

One of the great problems that prevents the restoration of the Mesopotamian Marshes is the lack of water. The marshes are supplied with water through the two main rivers Euphrates and Tigris. Both rivers originate in the highlands of south Turkey. Although tributaries from Syria, Iran and Iraq contributes to the rivers' flow along their expanse, Turkey still generates their majority of water (Euphrates 88%, Tigris 56%).

After the 1970's the water flow of both rivers change drastically due to what is referred to "The Era of Dams". Within a few years over 30 dams were constructed along the two rivers, to be used for hydro power, flood control, water reserves and irrigation. The construction of dams was the first step to cause the decrease in size of the Mesopotamian Marshes.

H. Partow,
UNEP The Mesopotamian Marshlands: Demise of an Ecosystem

N. Al-Ansari,
Hydro-Politics of the Tigris and Euphrates Basins

The dams did not just decrease the mean flow of the rivers by redirecting the water to other uses, but the large reservoirs that are supported by the dams, contain shallow still water, which in combination with the hot low-pressure climate results in high levels of water evaporation. The total evaporation loss from the reservoirs on the two rivers is 8 BCM (Billion Cubic Meters = Km3), which is approximately 60% of the current annual flow of the two rivers. Evaporation is also occurring further down along the rivers within irrigation canals and in the marshes, due to poorly constructed irrigation systems and minimal change in altitude resulting in very low water velocity.

- Solutions

Evaporation occurs due to three factors, temperature, pressure and surface area. In order to prevent water evaporation the ideal scenario would be low temperature, high air pressure and minimal exposed surface area.

When dealing with large mass of water such as basins and reservoirs, the only solution for preventing evaporation is covering the surface, which will minimize the surface area and reduce the temperature of the surface. There are three different types of covers: Monolayers, Shadecloths and Floating covers.

Evaporation suppressing monolayers are materials which when applied to water will self-assemble and create a thin film on the surface. They're usually created from the compound hexadeconal, which can be extracted from tallow, sperm oil or coconut oil. It is able to form a 15 x 10-4 mm thick monomolecular film on the water surface, which prevents evaporation while still allowing the penetration of raindrops. These monolayers are cost efficient and can cover large areas. They reduce evaporation with approximately 30%.

Shadecloths are fabric cloths suspended above the water surface with a cable structure. They are only suitable to cover an area under 5ha. The shadecloth reduces wind speeds at the water surface and reduces evaporation by 70%.

Floating covers has shown to be the most effective way of preventing evaporation. The most efficient floating cover is the AWTT INC. Hexprotect™ cover system. The system contains of self-assembling hexagonal plastic modules that creates a thermal insulation barrier on the water surface. The system is wind proof, allows penetration of rain and is able to reduce evaporation up to 95%.

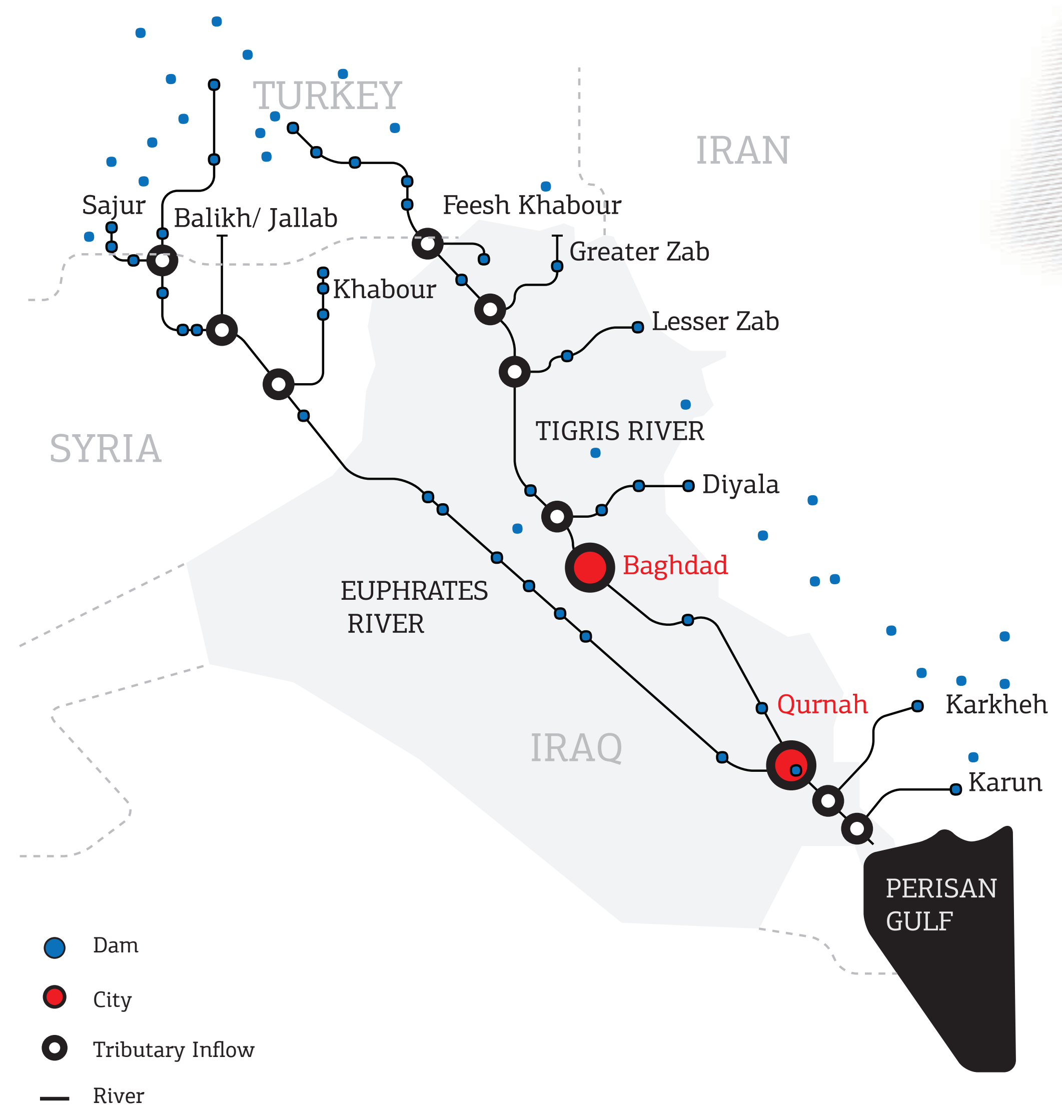
https://www.researchgate.net/post/what_ways_for_reduce_evaporation_of_surface_water_lake_river

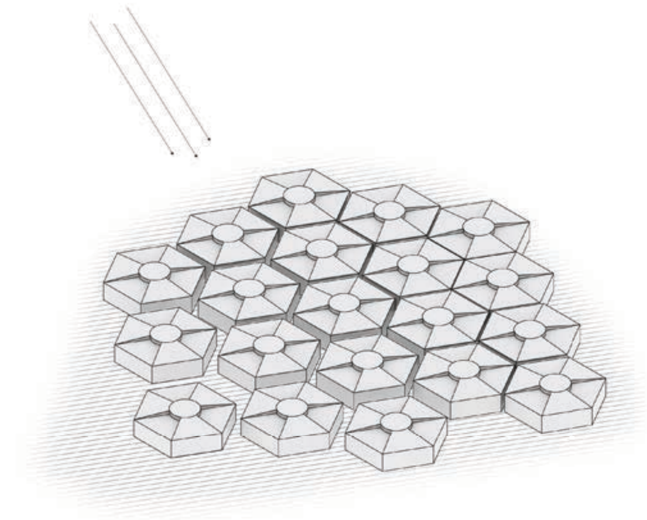
http://www.irrigationfutures.org.au/imagesDB/topicItem/NWC-Schmidt.pdf

http://www.yourarticlelibrary.com/water/evaporation/top-3-methods-of-reducing-evaporation/60462/

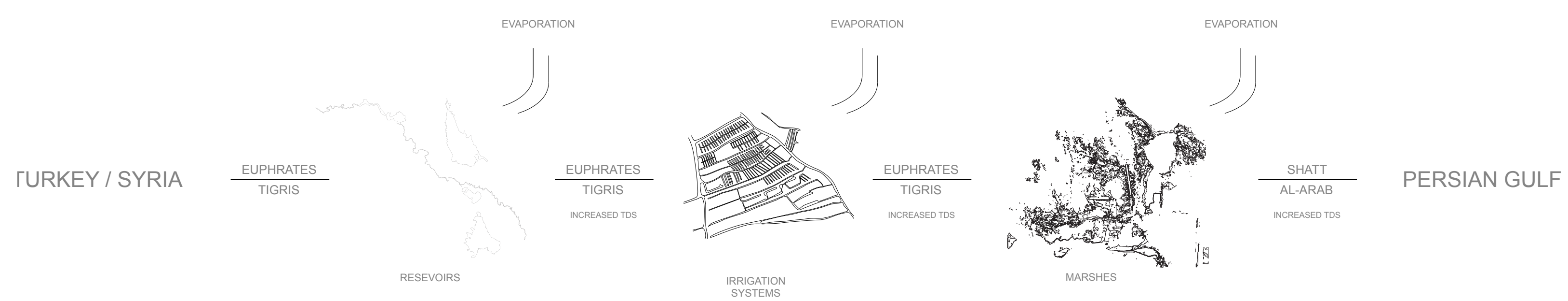
https://moreprofitperdrop.files.wordpress.com/2011/07/bap_suspended_covers.pdf

http://www.awtti.com/hexprotect_cover.php





The Hexprotect units self-assemble on the surface of a resevoir or basin and creates a floating cover which follows to the water's movement and reduces water evaporation with 95%, while still letting in rain water.



1.5 Site Characteristics

1.5.2 *Water Salinity*

- Current Problems

During the re-flooding of the marshes in 2003 it was found that large areas could couldn't be restored when flooded, due to high levels of salinity in the soil.

Salinity in water is usually expressed as TDS(Total Dissolved Solids). It is measured in ppm(parts per million = mg/l). Increased salinity in rivers is a worldwide problem.

If water's salinity level rises above 1000ppm, it is no longer potable for human consumption. At 3000ppm it looses its ability to be used for agriculture.

Because of the reduction in water discharge along with the increased amount of agricultural irrigation, the salinity concentrations at the water inputs of the marshes were significantly increased. During the pre-dam era (-1973) levels of salts and other TDS could be detected in the water, and in late summer when the highest rate of evaporation would occur, salinity would increase and large pieces of land would be left dry leaving the soil salinized. What made the marshes survive the annual drought and resist getting over salinised, was the annual spring flood. The two rivers' fresh spring pulse would flush away all the surplus salts that remained after the later summer drought, and restore the seasonal marshes.

The constructions of dams along the two rivers diminished the spring pulse, which took away the natural purification process of the marshes. This necessary process has not been replaced and this has lead to an annual increase of salinity, which has left large parts of the marshes unrecoverable.

N. Al-Ansari,
Hydro-Politics of the Tigris and Euphrates Basins

S. AlMaarofi, A. Douabul, H. Al-Saad,
Mesopotamian Marshlands: Salinization Problem

A. Hussein Al Bomola,
Temporal and Spatial Changes in Water Quality of the Euphrates River - Iraq

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- Solutions

TDS increases in water through pollution from industries and mainly agriculture. When the water is exposed to conditions that allow for high evaporation, the surface water evaporates and leaves a higher concentration of TDS. As over salinised water is a world-wide problem, several solutions have been explored over time. The most efficient ways of de-salinising water are: Reverse Osmosis, Phytoremediation and Solar Still.

Reverse Osmosis is a water purification technology process where TDS are removed from water through a semipermeable membrane. It's mostly used for desalination of seawater for coastal cities without any fresh water supply, like Dubai and San Diego.

Phytoremediation is the natural process of water, air and soil purification through plants. This method has been used in restoring abandoned mines where the soil has been severely polluted. The plants don't just reduce TDS remains but can also reduce contaminates such as crude oil.

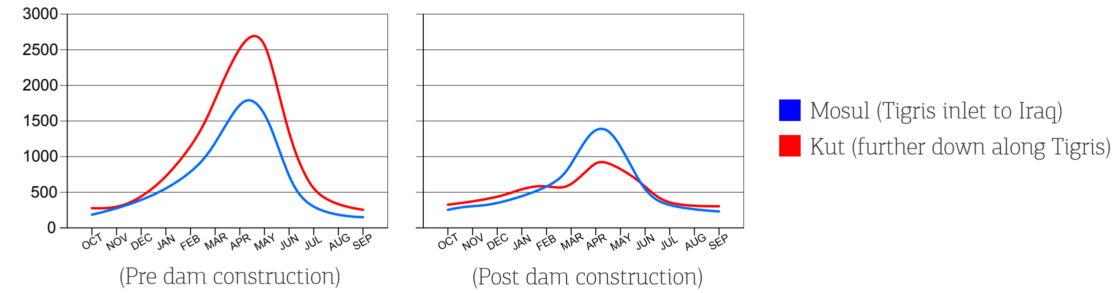
Solar Still is a method of producing distilled water through heating up saline water within an enclosed space and collecting the evaporated water. This is a method developed by the US military as a emergency solution for getting drinking water. At a large scale this method could solve both evaporation and salinity problems.

http://science.howstuffworks.com/reverse-osmosis.htm

http://www.unep.or.jp/letc/Publications/Freshwater/FMS2/1.asp

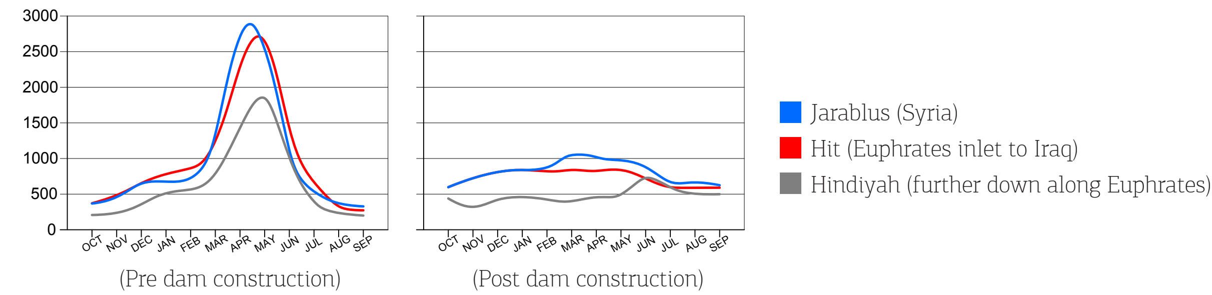
http://www.solaqua.com/solstilbas.html

Tigris mean monthly discharge (m^3/s)



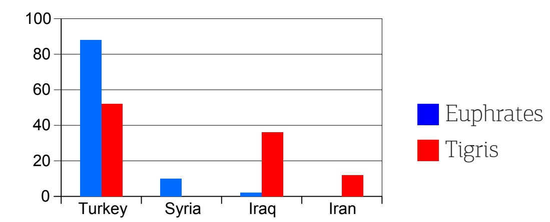
After the construction of dams along the two rivers, the monthly flux in water discharge decreased severely. The spring flood of the Tigris still exists, however it has decreased to less than 1/3 of its historical flow.

Euphrates mean monthly discharge (m^3/s)



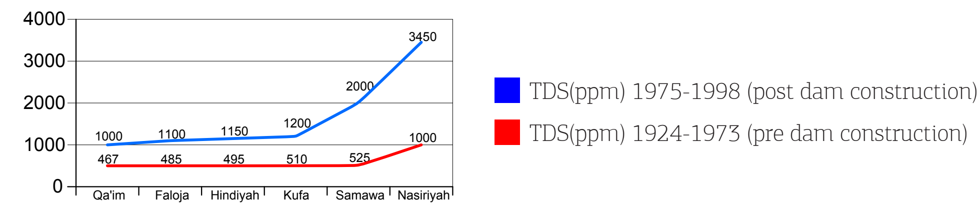
The Euphrates' monthly fluctuation of discharge is now close to nothing. There is more or less a constant flow of water, which prevents salinity in the marshes from being washed away.

Percentage of contribution to the flow of Euphrates and Tigris



The majority of the two rivers' water originates from the highlands of south Turkey.

TDS levels of Euphrates before and after the "Era of dams"



After the consruction of dams in the 70's, the rivers have become significantly more polluted. The input water to the marshes contain such high levels of TDS that it's no longer suitable for agriculture.

1.8 Ambition

Wetlands are among the most productive and bio-diverse ecosystems in the world. These environments produce a wide range of products and services that are essential to support life on the planet. Apart from being vital reservoirs of plant and animal life, wetlands can be used to extract and process resources to support human life. Wetlands also provide a number of ecological functions; they can filter, clean, control and store water. In this regard, they can be thought of as ecological infrastructure, as it naturally regulates water supply. Additionally, wetlands are unique in their microclimate as they display climatic properties of both, terrestrial and aquatic systems. Due to surface evaporation and plant transpiration, wetlands can provide natural cooling in regions with high temperatures or intense hot summers. Despite the great benefit that wetlands represent to sustain life in the planet, around 64 per cent of the world's wetlands are at risk of disappearing. Many of these ecosystems are suffering from irresponsible agricultural practices or have been endangered as a result of urban development. Nonetheless, there are many vernacular examples around the world that show evidence of the possibility of a more integrated co-existence between human habitats and natural environments. As wetlands exist in a transitional zone between land and water, they offer a unique opportunity to rethink the relationship between natural resources, water supply and human occupation.

"The Value Of Wetlands". Wwf. panda.org. N.p., 2016. Web. 9 Sept. 2016.

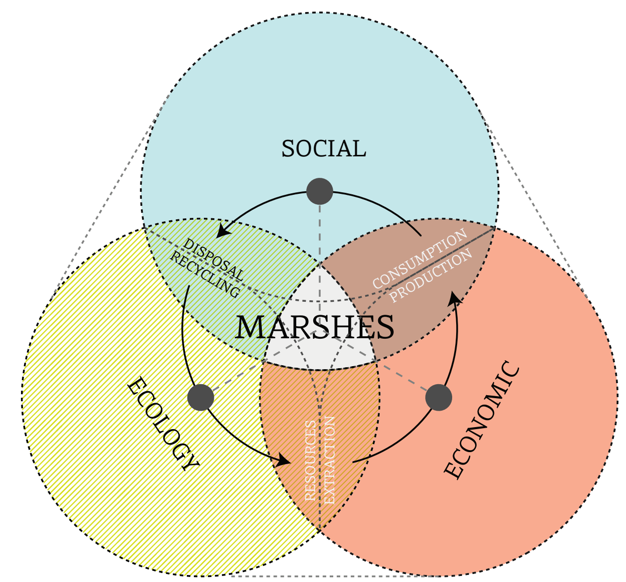
In order to examine this subject, the wetlands of Mesopotamia have been selected as an area of intervention. Throughout history, the Mesopotamian Marshlands have been a significant site where land has been exploited to support human activities and urbanization. Initially and for many centuries, the fertile soil of the marshes was harnessed to support large scale agricultural activities. During the past fifty years, the character of the site has changed multiple times due to various environmental, political and social transformations in the broader area. Today, this site still serves the urban growth by providing enormous amounts of oil while being populated by nearly one million people who are occupied with small scale agricultural activities. Unlike previous forms of land use, the oil extraction industry is leaving long-lasting traces, which combined with the climate change; pose a big challenge concerning the future of the wetlands and those who depend on them.

The goal of this research is to offer a new model of human settlement for re-occupying the wetlands of Mesopotamia integrating agro-industrial functions in a sustainable way. By reorganizing the territory, based on an appropriate distribution of land use and human occupation, the wetlands of Mesopotamia can be used as a platform to integrate ecological processes with human activity in a more proactive way. On a regional scale the proposal aims at understanding the relations between the existing human settlements and the productive sites around them. This territorial mapping and understanding process will lead to suggest a comprehensive system of aquatic infrastructure and natural ecological corridors for the purpose of regional integration. Apart from the territorial scale design, another key aspiration of the project is to address localised interventions focused on reorganizing the existing settlements, introduce small and medium scale infrastructure and propose a series of island typologies that will facilitate ecological, economic and social functions.

Research Question

Recovering the wetlands of Mesopotamia and restoring its ecological functions is essential for the future of the region. In a time of intense urban growth and increasing resource demand, this project investigates the following question:

- Can the integration of agricultural and industrial functions lead to recover, re-inhabit and enhance the ecology of the Mesopotamian marshlands?



Integration of Processes

2.0 Methods

2.1 Methods

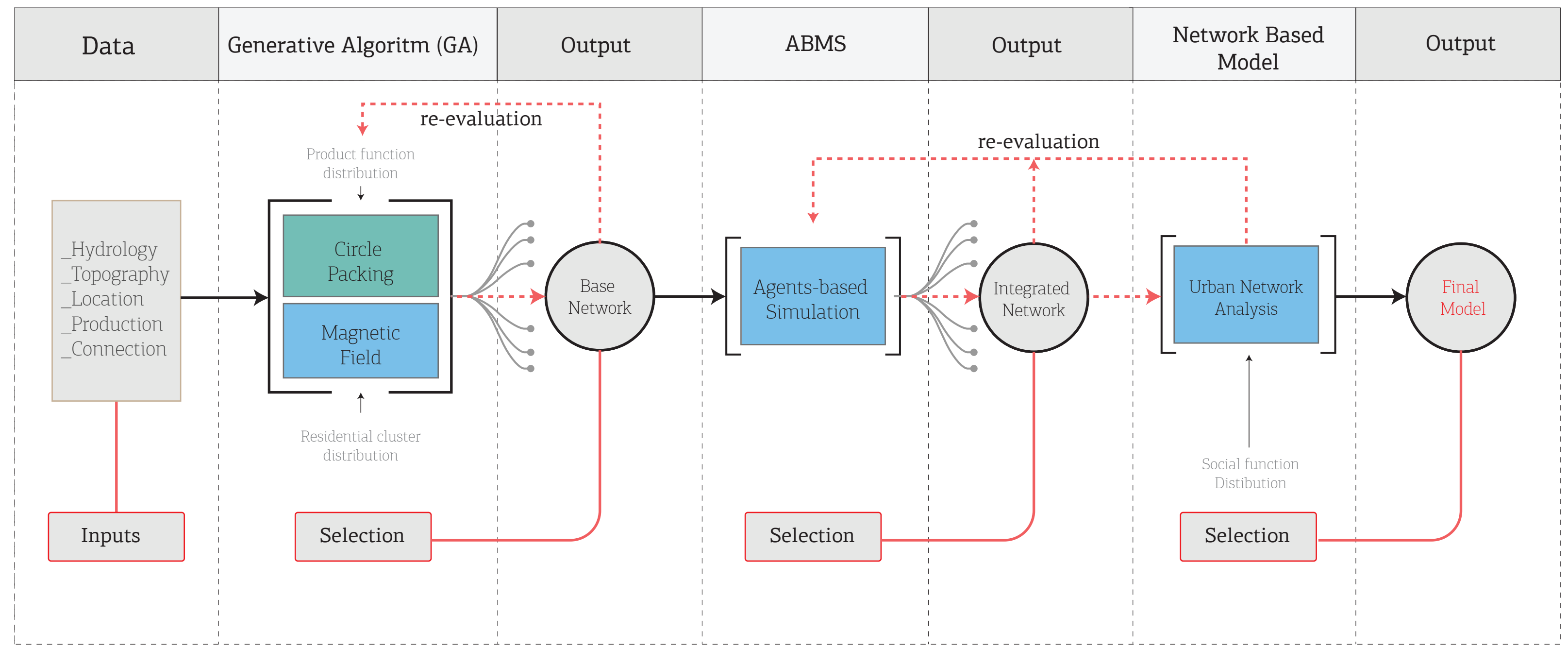
2.1 Methods

2.1.1 *Design Process Overview*

Part of the aim of this project is to advance the use of computation and explore the opportunities that these design tools afford. To this end, a design workflow involving various analytical and generative design tools was established. The design experiments were conducted using parametric models in Rhino 3D and Processing. Generative algorithms and associative modeling was implemented throughout the design process, with only a few number of instances where explicit modeling was necessary for the experiments. The working method involved the use of evolutionary algorithms for multi-objective optimization and agent based simulations for developing multiple instantiations of design options. For analytical purposes, at multiple stages throughout the design process, the design was evaluated with various network analysis tools (Space Syntax, UNA toolbox, Syntactic). The design process focuses on the integration of ecological, social, agro-industrial and infrastructural systems. Multiple variables need to be coordinated and used as inputs for the design. Data gathering and research was conducted to identify the key parameters that would form the basis of the design.

The workflow initiates with data collection from GIS databases. In order to define the initial parameters for the project basic spatial, environmental, geographical information is gathered. Starting from the whole area of the Middle East to understand the regional context and moving down to the country of Iraq and marshes of Mesopotamia, various sets of data are collected to inform the design. At the same time, the design goals and the overall design objectives of the project are established and translated into measurable (geometric and numeric) inputs. The collected data from GIS and the design objectives are used as the starting parameters for a parametric model. This model is based on an initial algorithm applied to the defined area of intervention. The algorithm is used to determine the distribution of uses and settlements and the possible configurations that can be achieved in the site. Multiple design alternatives for land-use distribution are achieved by means of an algorithm based on the circle packing theorem. Simultaneously, clusters of residential units are generated by using a magnetic field algorithm which works in combination with the results obtained by the circle packing distribution. This results in a number of network configurations that are evaluated through network analysis tools. The design option that best matches the design criteria is selected to be further developed. Using agent based simulations (ABMS), the base network is extended to connect all the residential clusters with each other. The design option that has the highest integration and connectivity values between the residential clusters is selected to be further developed.

At this point, the information obtain from the previous processes can be used to inform design decision for developing specific areas of the project. A sample area of the project is selected to distribute social functions (education, health, recreation, etc.). A network based model (UNA) is used to distribute these functions. The final outcome is a model that comprises all the uses and functions tied together by a network that connects residential units to productive and ecological zones.



2.1 Methods

2.1.2 Agent-based modeling and simulation

Abbas, M. and Machiani, S. (2016). Agent-Based Modeling and Simulation of Connected Corridors—Merits Evaluation and Future Steps. IJT, 4(1), pp.71-84.

[2] Bonabeau, E., Agent-based modeling: Methods and techniques for simulating human systems. 2002. 99

Fig.1 redrawn from: Abbas, M. and Machiani, S. (2016). Agent-Based Modeling and Simulation of Connected Corridors—Merits Evaluation and Future Steps. IJT, 4(1), pp.71-84.

Agent-based modeling is a computer simulation based on a bottom up approach that mimic collective behavior and interactions between individuals. Unlike a top-down modeling approach, where the designer prescribes all actions, AMBS is a bottom-up approach, where the agents or the decision makers follow given rules that are defined by the designer. Agent-based modeling methods are widely used in simulating natural behaviors. In urban design and architecture, this method has been used in exploring various areas of transportation including simulation the flow of vehicles and pedestrian movement, route choice modeling, lane changing, car-following models, and traffic simulation. [1] When the interactions between the agents are diverse, complex, non-linear, separate and the agents' location in the space is not fixed, more complex results can be achieved from the simulation. [2] The mathematical model of the agents' behavior in this work is developed to follow the basic rules of flocking behavior. In flocking simulations, there is no central control and each agent behaves autonomously. There are four distinct advantages in using an agent based system to develop artificial decentralized networks: Flexibility, robustness, decentralization, self-organization. This tool was used in this work to generate and instantiate design options for various networks.

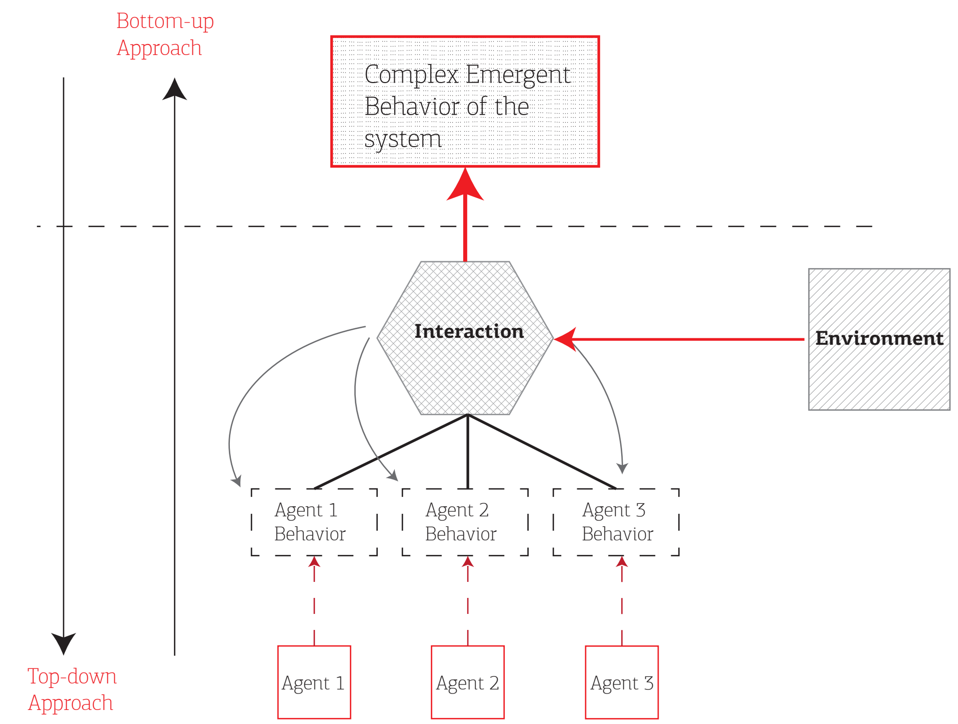


Fig1: top-down , bottom-up ABMS modelling

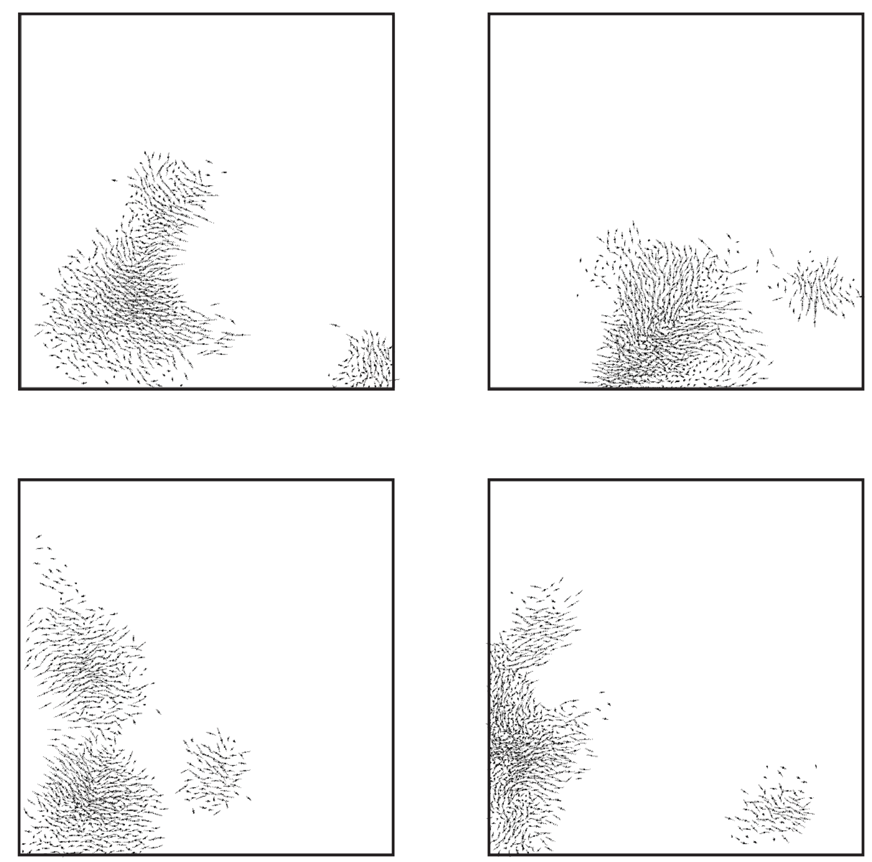


Fig2: Flocking behaviors simulation

2.1 Methods

2.1.3 Genetic Algorithms

A genetic algorithm (GA) is a search algorithm based on ideas of evolution, natural selection and genetics. Genetic algorithms are used as a problem solving method to generate optimised or trade off solutions to a given problem. In this sense, the algorithm can search for solutions even when the objectives contradict each other.
Multi-criteria optimisation or multi-objective optimisation algorithms is a powerful unbiased optimisation technique that takes into account multiple criteria simultaneously. When the criteria in the system are contradicting then a range of options for solutions is produced. [1]

If set correctly, the genetic algorithm optimisation technique can produce several and non-dominant individuals in the generations without determining the best solution which gives the decision maker the opportunity to decide which individual of the provided solutions is the fittest. [2] Selecting the individuals is based on the specific criteria of the given model; the principle of selecting the solutions is "survival of the fittest". Based on an evaluation function the operator identifies and chooses the 'better' individual in the population for reproduction. [1]

In this work the genetic algorithm optimisation is used to optimise the function distribution and the relationship between uses. Additionally, the script is used to optimise the shortest pipe network that would be needed to distribute water supply to each productive area.

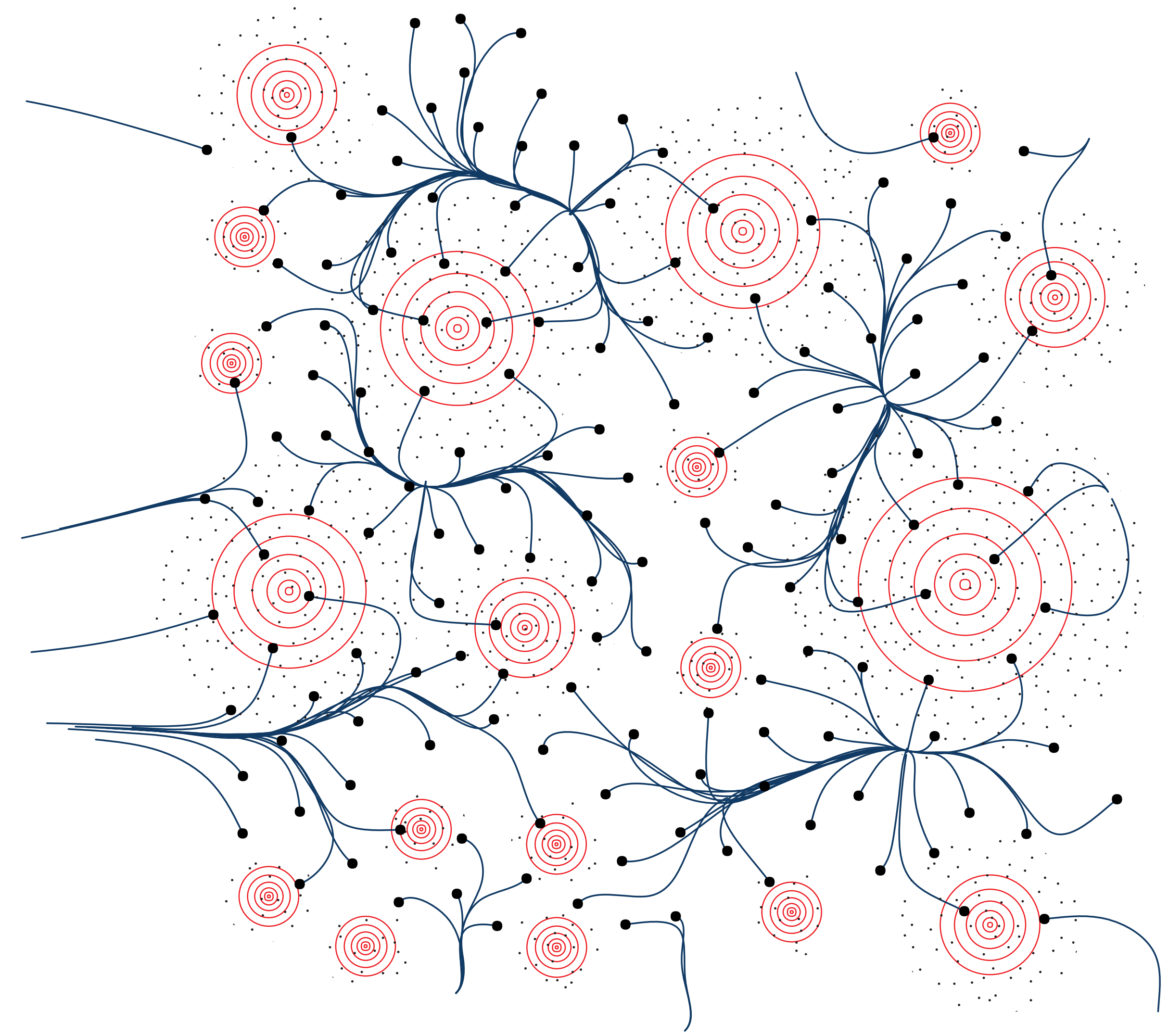
Circle packing

Circle packing is a method that uses the technique of arranging circles of different sizes in a way that they touch each at tangent points without overlapping. In this project each type of the production is represented as circles with a fixed radius which were assigned as input values for the circle packing algorithm to distribute the different productive functions across the site. Through the use genetic algorithms, the circle packing is optimised to achieve a desirable configuration.

Magnetic field

Magnetic field algorithm is a method used to visualise the strength and direction of a vector field that is generated through a field of magnetic charges. In this research the magnetic field was used to generate the residential clusters as the paths from the residential nodes were pushed out from the production areas and forced to connect, creating clusters with a central path.

[1] Tabassum, M. (2014). A GENETIC ALGORITHM ANALYSIS TOWARDS OPTIMIZATION SOLUTIONS. IJDIWC, 4(1), pp.124-142.
[2] M. Melanie (1999), "An Introduction to Genetic Algorithms", Cambridge, MA: MIT Press. ISBN 9780585030944.



2.1 Methods

2.1.4 Urban Network Analysis

City Form Lab. (2016). Urban Network Analysis Toolbox for ArcGIS — City Form Lab. [online] Available at: http://cityform.mit.edu/projects/urban-network-analysis.html [Accessed 10 Sep. 2016].

UNA is an urban network analysis tool. This toolbox can be used to evaluate five types of graph analysis on spatial networks: Reach; Gravity; Betweenness; Closeness; and Straightness. Redundancy Tools additionally calculate the Redundancy Index, Redundant Paths, and the Wayfinding Index.

The tool integrate three main features which make it specifically suitable for spatial analysis on street networks; the first feature is that the tool can account for both geometry and topology in the input networks. Secondly, in addition to evaluating nodes and edges, UNA can include buildings in the network analysis. Thirdly, the UNA tool allow the user to assign different values to nodes according to their particular characteristics, volume, population and importance, therefore, buildings can be specified to have stronger or weaker effect on the network.

UNA tool is used in this research to find the location of the distribution centres by running a reach and centrality analysis. The outcomes were evaluated in search of the highest average reach index for the whole site.

3.0 Site

3.1 Selected Site

3.2 Site Strategy

3.1 *Selected Site*

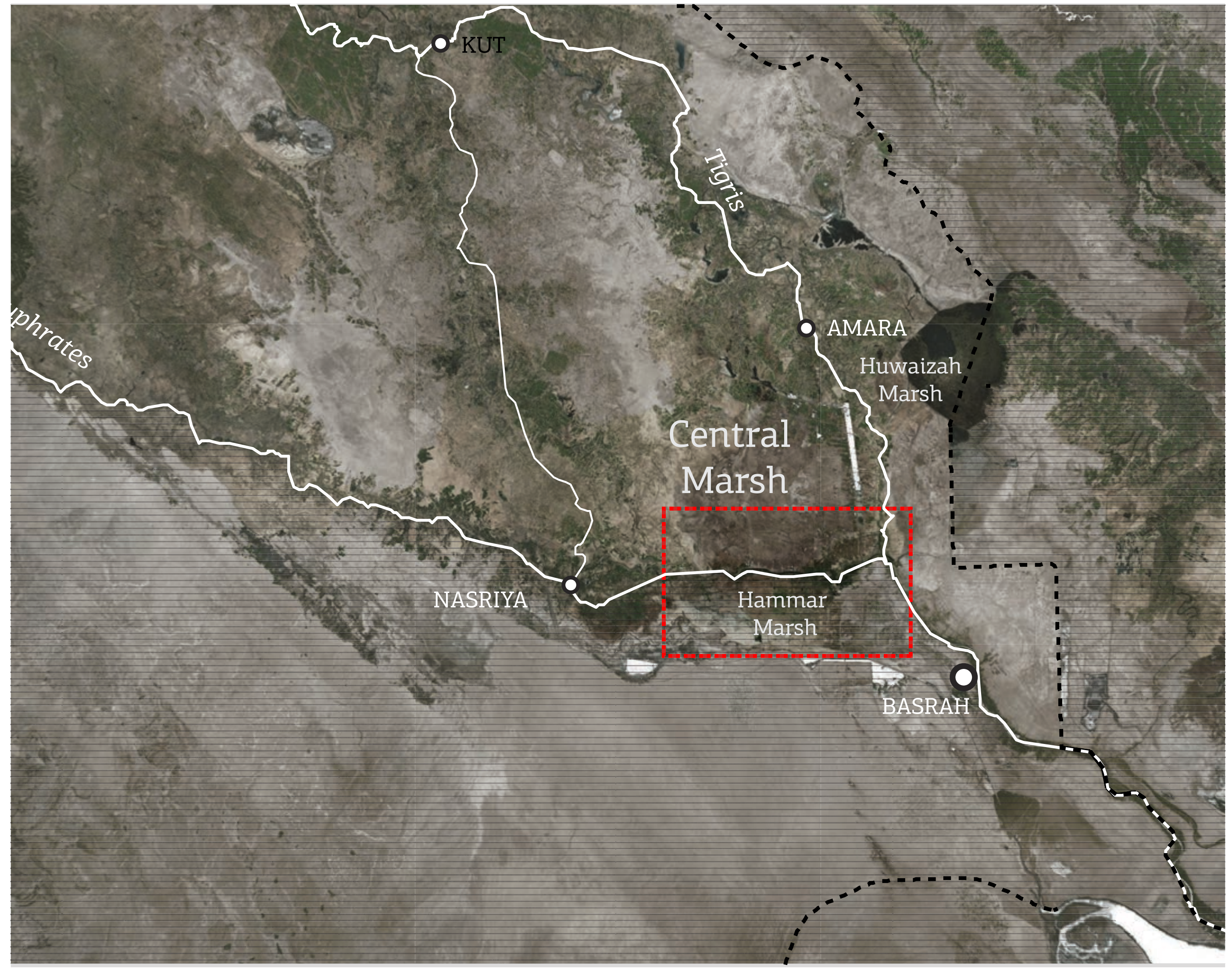
3.1.1 *Region of Intervention*

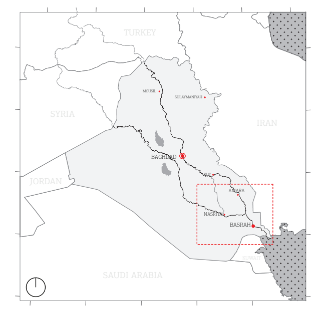
Tigris and Euphrates are the two defining rivers of Mesopotamia. Originating from eastern Turkey, Euphrates River flows through Syria down to Iraq. When approaching southern Iraq Tigris and Euphrates begins to split like tree branches, forming vast inland deltas. The levees gradually become lower and broader, ground water rises to the surface and eventually the channels disappear and the marshland begins. After passing through the marshes Tigris and Euphrates meet again near the city of Qurna where they form the river known as Shatt Al-Arab which continues down towards the city of Basra in the south of Iraq.

The Mesopotamian marshes can be divided into three broader areas defined by the natural boundaries of the two rivers: the central marshes between the Tigris and Euphrates Rivers; the Hawizeh marsh east of Tigris River; and the Hammar marsh south of the Euphrates River. This vast ecosystem historically covered around 13,000 sqkm and exists in a state of fluctuation between permanent and seasonal marsh, shallow and deep-water lakes, mudflat and flowing rivers. The central marsh has the highest potential for human habitation. Historically, it covered about 2,600 – 3,800 sqkm. Between the Tigris and Euphrates river, hundreds of water-based villages existed within its reed forests. Prior to 1990s, water had poured into the marshes from the north through tributary channels that branched off from the Tigris near the town of Amara. During the 1990s the Iraqi government desiccated the central marsh by diverting its water to a massive engineered canal known as the "Glory canal". The central marsh remained dry until late 2003 when local initiatives aimed to breach the left bank levees of Euphrates and water returned to the marshes by summer of 2004. The restored water allowed the marshes to turn green as algae population began to re-establish itself in the area, thereafter reeds and other vegetation began to regrow. By 2005, a lush permanent marsh covering around 440 sqkm had been restored.

The studied area in this work is situated in the central marsh along the Euphrates River between the cities of Al-Nasriyah and Al-Basra. The site of intervention spans between Al-Hammar village to Qurna where Euphrates meets Tigris. Along the area of intervention, various types of agro-industrial activity are observed. The primary economic activities centre around agriculture, livestock and the oil industry. Contrary to historical patterns of habitation which occupied the land of the marshes, most villages today are positioned along the river forming a linear pattern of habitation structured by the spine of the river. This work explores the possibility of re-inhabiting and distributing productive functions in the central marsh.

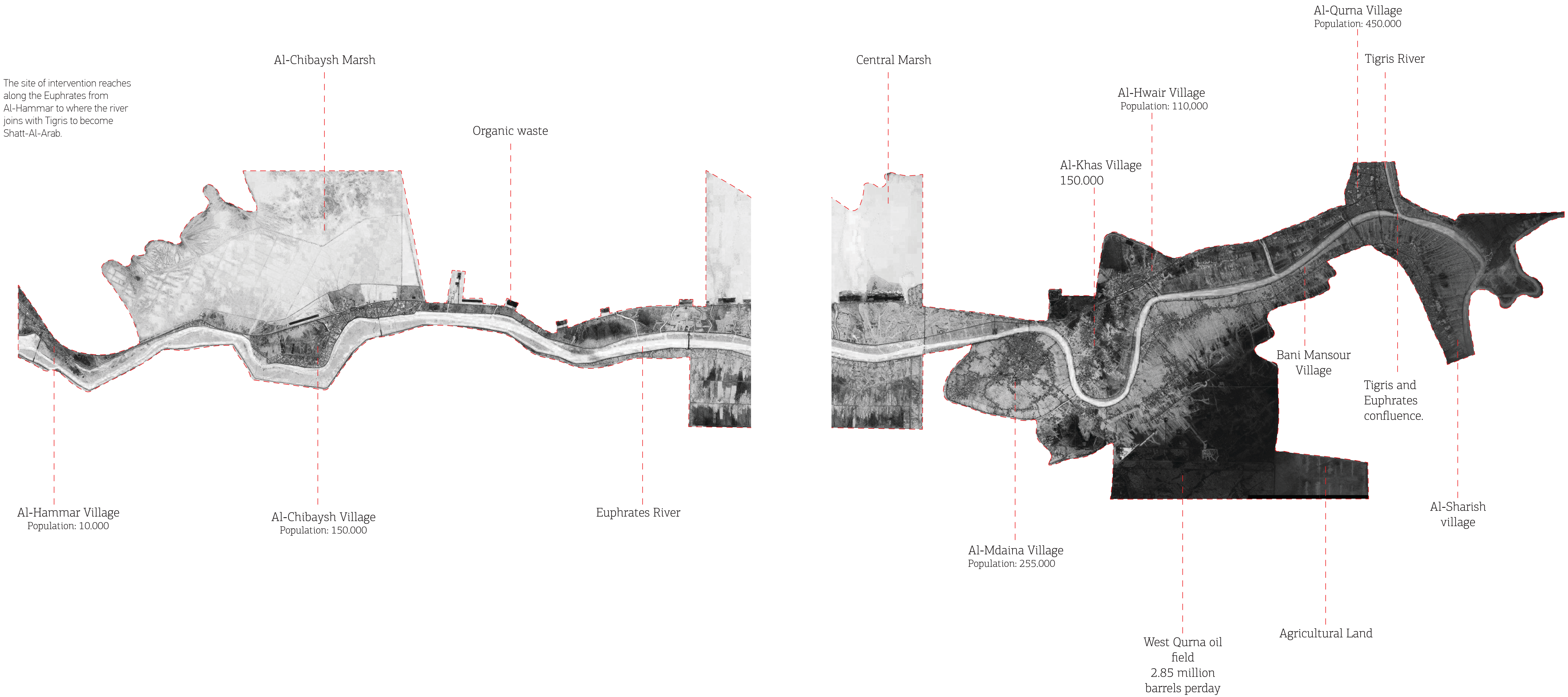
23-Alwash, S. (2013).Eden again. Fullerton,wCalif.: Tablet House Pub





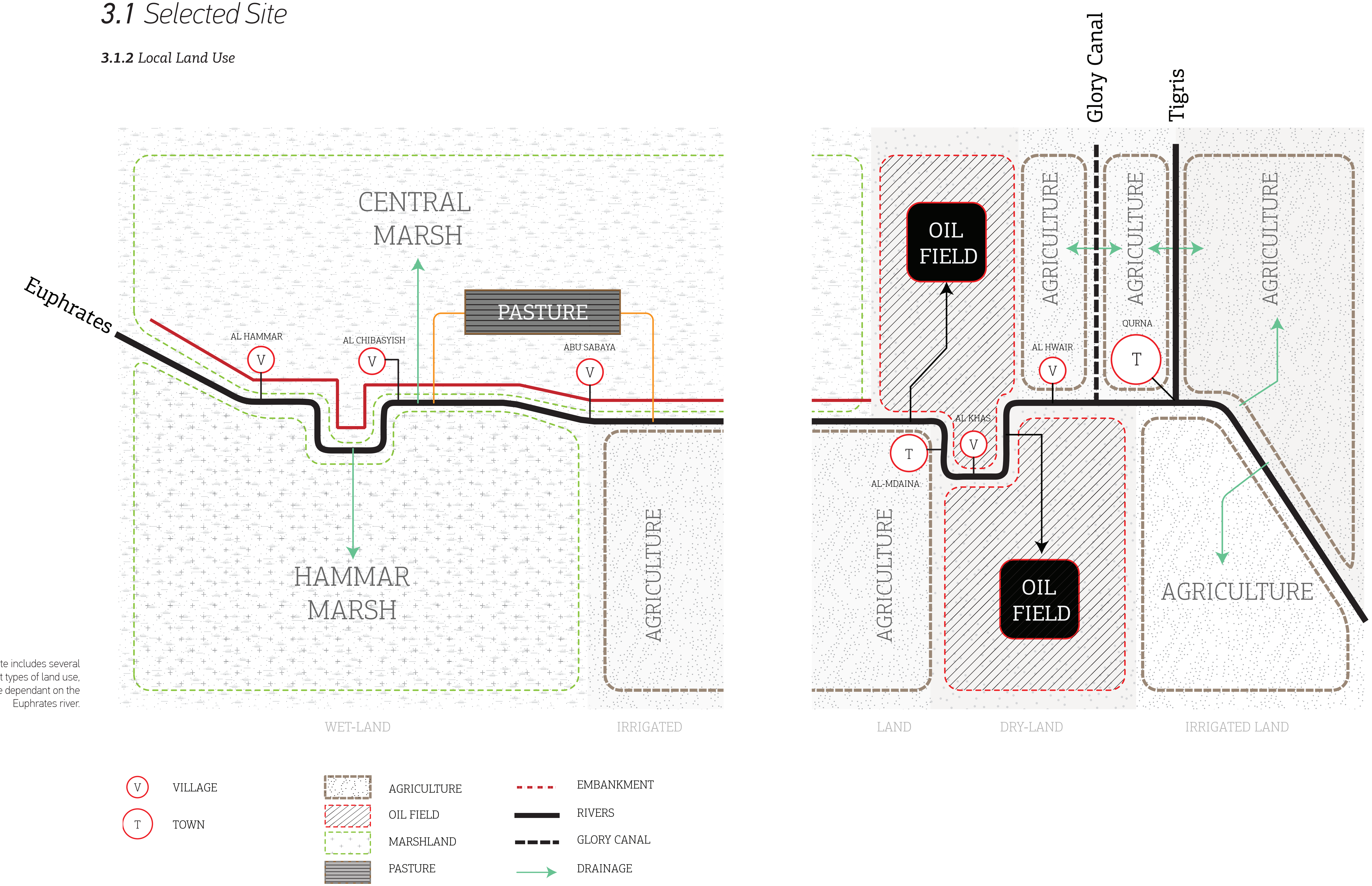
3.1 Selected Site

The site of intervention reaches along the Euphrates from Al-Hammar to where the river joins with Tigris to become Shatt-Al-Arab.



3.1 Selected Site

3.1.2 Local Land Use



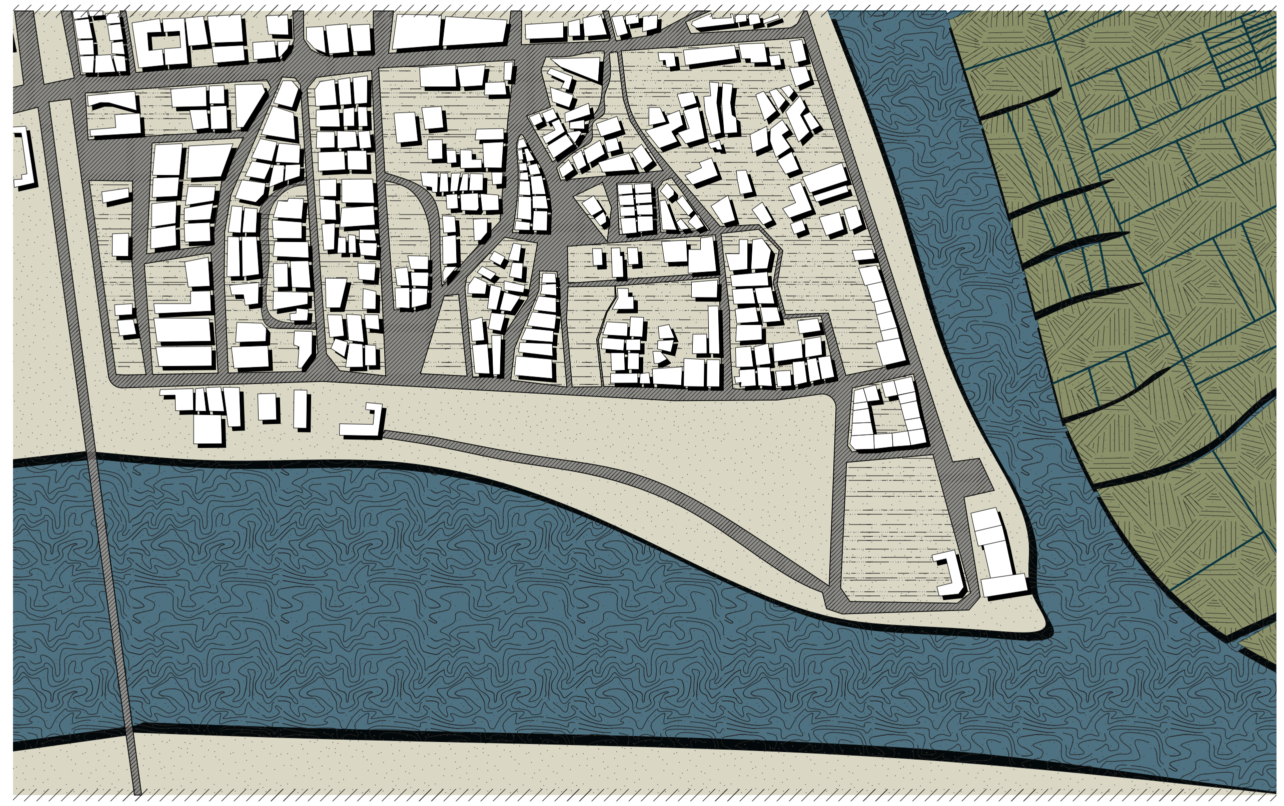
The site includes several different types of land use, which all are dependant on the Euphrates river.

3.1 Selected Site

3.1.3 Current Inhabitation

In the settlement of Al-Mdaina, the houses are arrayed along the main roads. Each house usually hosts a family, with the family members being from 5 to 25 ("extended" family). Most of the family members are occupied with agricultural activities and each house has normally it's own agricultural land, which appear as their "backyard". In most cases, these settlements does not involve any kind of social provisions and public infrastructure. Therefore the inhabitants of these settlements, including Al-Mdaina, are forced to travel many kilometers to the major neighbouring cities for many aspects of their social lives.

The majority of the former island configurations that once hosted thousands of people are nowadays surrounded by dry land. Most of the land surrounding them that used to be flooded and covered by reeds has been reclaimed as agricultural land. The canals that were constructed to drain the marshlands are now widely used as irrigation systems. A few houses have been built around these islands, used as temporary residencies for people working on the surrounding agricultural land.



Al-Qurna is a town located at the confluence point of Tigris and Euphrates, about 74km Northwest of Basra and is the starting point of the river Shatt al-Arab. Al-Qurna has population of 500,000 and is thereby the largest town within the selected site.

Since the re-flooding efforts started in 2003, the authorities have been trying to re-flood the Central Marsh using the water from Euphrates river, which is the southern natural border of the Central Marsh. To regulate the water flow, they have been using a series of locks along Euphrates, which interrupt both the agricultural land and residential areas. There are also many man made rectangular platforms which operate as collection points for goods or waste that can be used or shipped elsewhere through Euphrates.

3.1 Selected Site

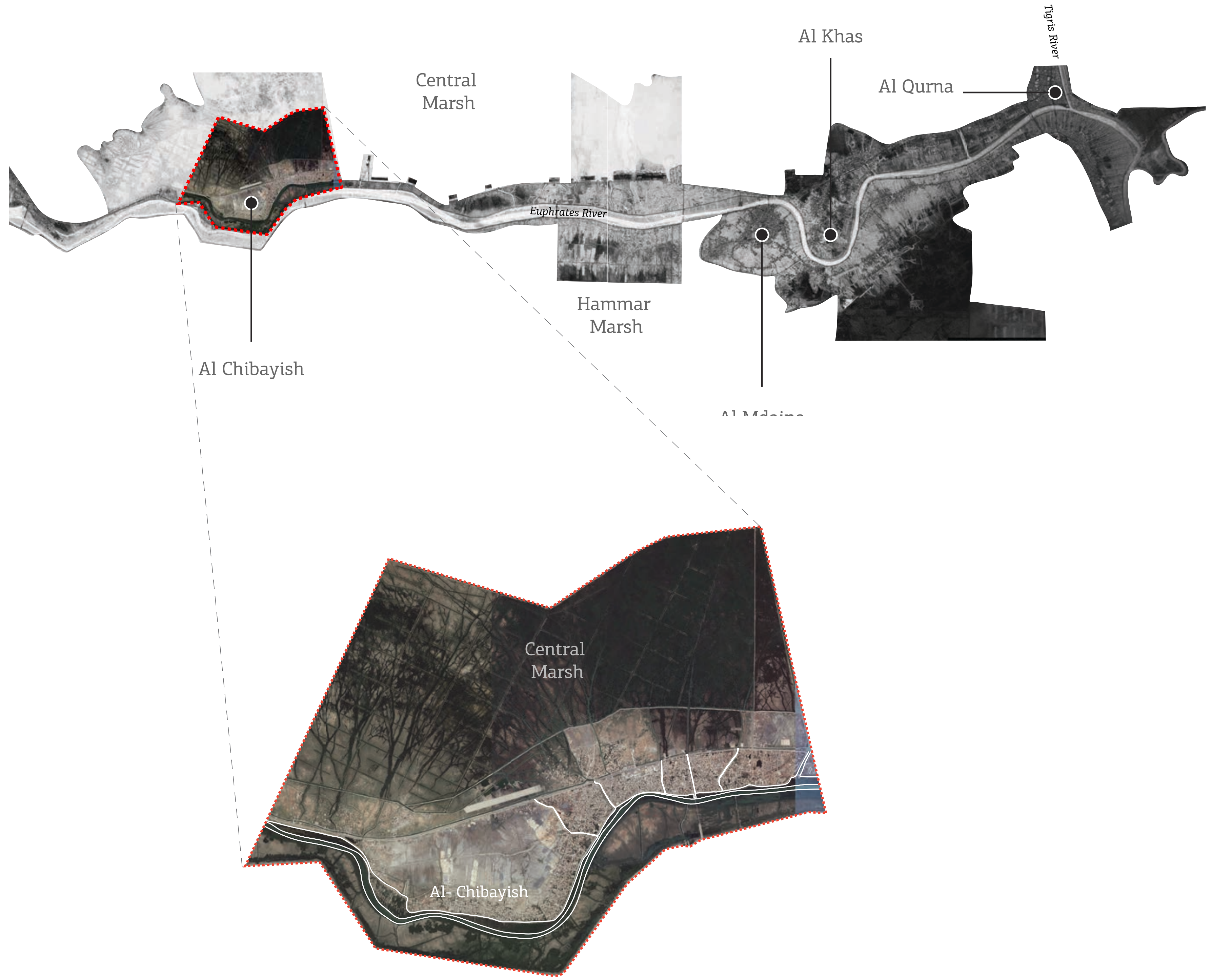
3.1.4 Defined Site

After gathering data for the whole area between Al-Hammar village and the city of Qurna, a 30sqm plot including Al-Chibaysh was selected to be further analysed and designed. Choosing to work on this specific site contextualised the project and offered some very interesting local and regional input that informed most of the design decisions that followed.

First of all, the selected plot is part of the Central marsh area that has been re-flooded with water from Euphrates since 2003. The area above Al-Chibaysh contained more than 1,200 artificial islands until the late 70's. These islands included small and bigger residential units, communal houses (Mudhif), markets, schools, etc. The community of the Marsh Arabs living there were completely self-sufficient by cultivating a few crops, fishing, hunting and trading with the neighbouring tribes. Back then Al-Chibaysh was nothing more than a small village along the Euphrates with relatively important position as a small trading centre because of its proximity to the river. After the complete draught of the marshes, most of the people living there migrated to either Al-Chibaysh or other small villages along Euphrates, creating bigger semi-urban constellations and leaving almost no trace of the earlier inhabitation patterns in the marshes. Al-Chibaysh has been established since then as an important small city of the broader area.

The partial re-flooding of parts of the central marsh (including the Chibaysh area), which started in 2003 and is still in progress, was not a part of a coherent sustainable plan but a spontaneous act from some locals. This caused many problems and challenges that are mostly related with the water quality and with the ability of the marsh area to recover and be re-inhabited by humans and wildlife. A detailed analysis of these challenges will be given in the following pages and will drive in a large extend the design of the proposal.

A novel strategy for recovering and re-inhabiting the marsh area above Al-Chibaysh is following in the rest of the document, suggesting that the people who are going to gradually relocate there will form a novel self-sufficient interconnected community. A similar approach could be then expanded to greater areas of the marshes.



3.2 Site Strategy

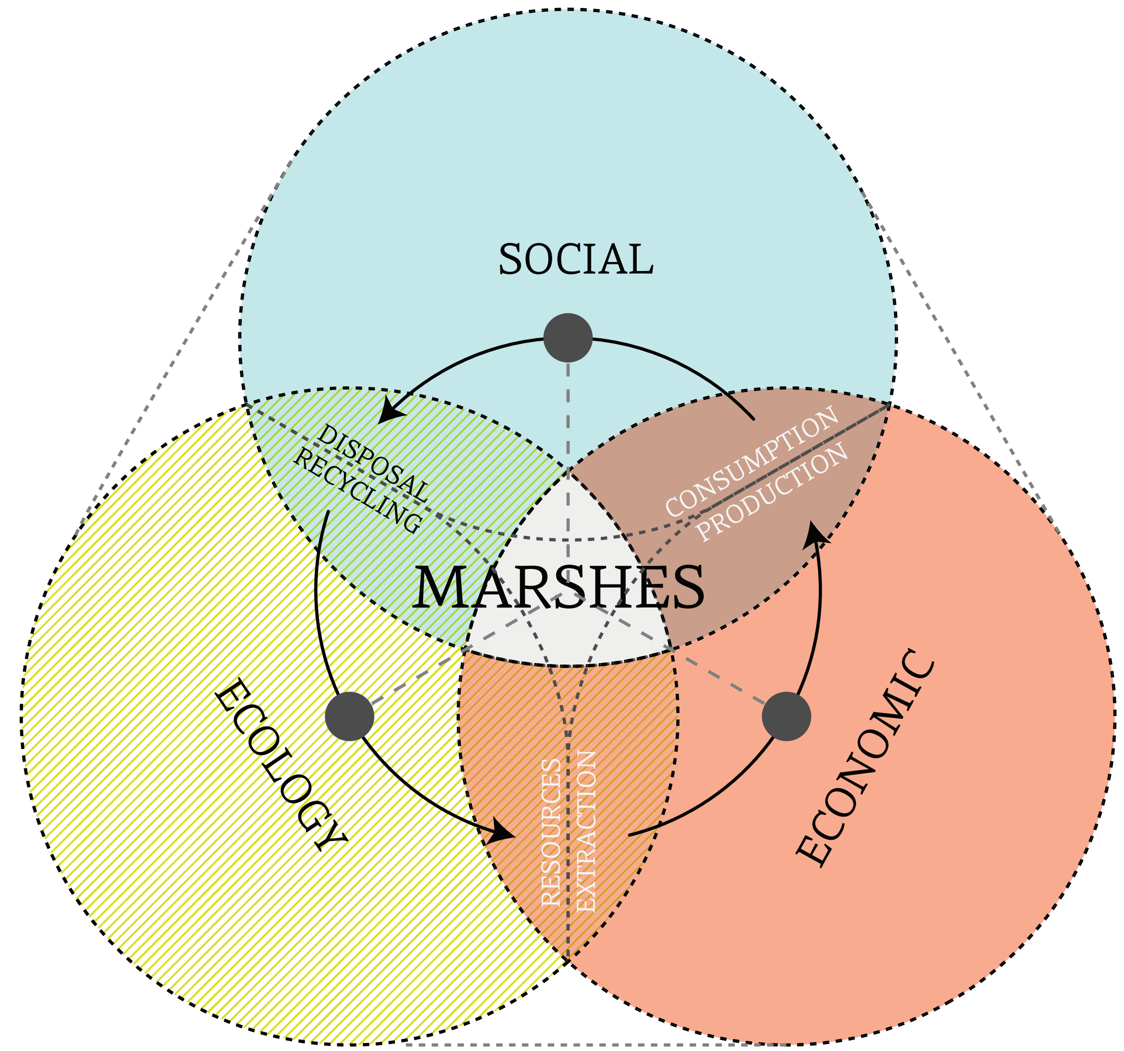
3.2.1 General Strategy

Jørgensen, Sven Erik and Brian D Fath. Encyclopedia Of Ecology. Amsterdam: Elsevier, 2008. Print.

Marsh ecologies are complex adaptive systems, as such they exist at the border between order and chaos, they are too complex to be treated as machines and too organized to be treated as random. In this sense, rather than looking at the constituent elements that make up the system, it is more important to understand the processes and patters underlying the interaction between its elements. The ecosystem of the marshes emerges out of the distributed interaction of multiple elements. The stability of the system depends on its dynamics and its capacity to process movement, fluctuations and change.

While traditional approaches to ecology study ecosystems with little reference to human society; an integrated design approach would include social and economic processes as integral to the system. The initial strategy for the site is based on the idea of bringing together these processes to form a complex web of interactions.
The three main aims of the project are: [1] To help recover the marshes and restore its ecological functions. [2] Organize productive functions to take advantage of the marshes while coexisting and enhancing the natural ecology. [3] Provide a new model of human habitation that suggests the possibility of a settlement type that exists between land and water.

Ecosystems are macro-scale systems composed of biotic and abiotic elements. Plants and animals are the biotic components, while water, sun energy, air and rain are the abiotic components. The networks of interaction that are established between the biotic and abiotic elements give rise to the complex system of an ecology. Wherever there is interaction a system is prone to instability, however, in an ecosystem the biotic and abiotic components could establish productive relationships with each other and bring the system to a state of temporal balance.



Integration of Processes

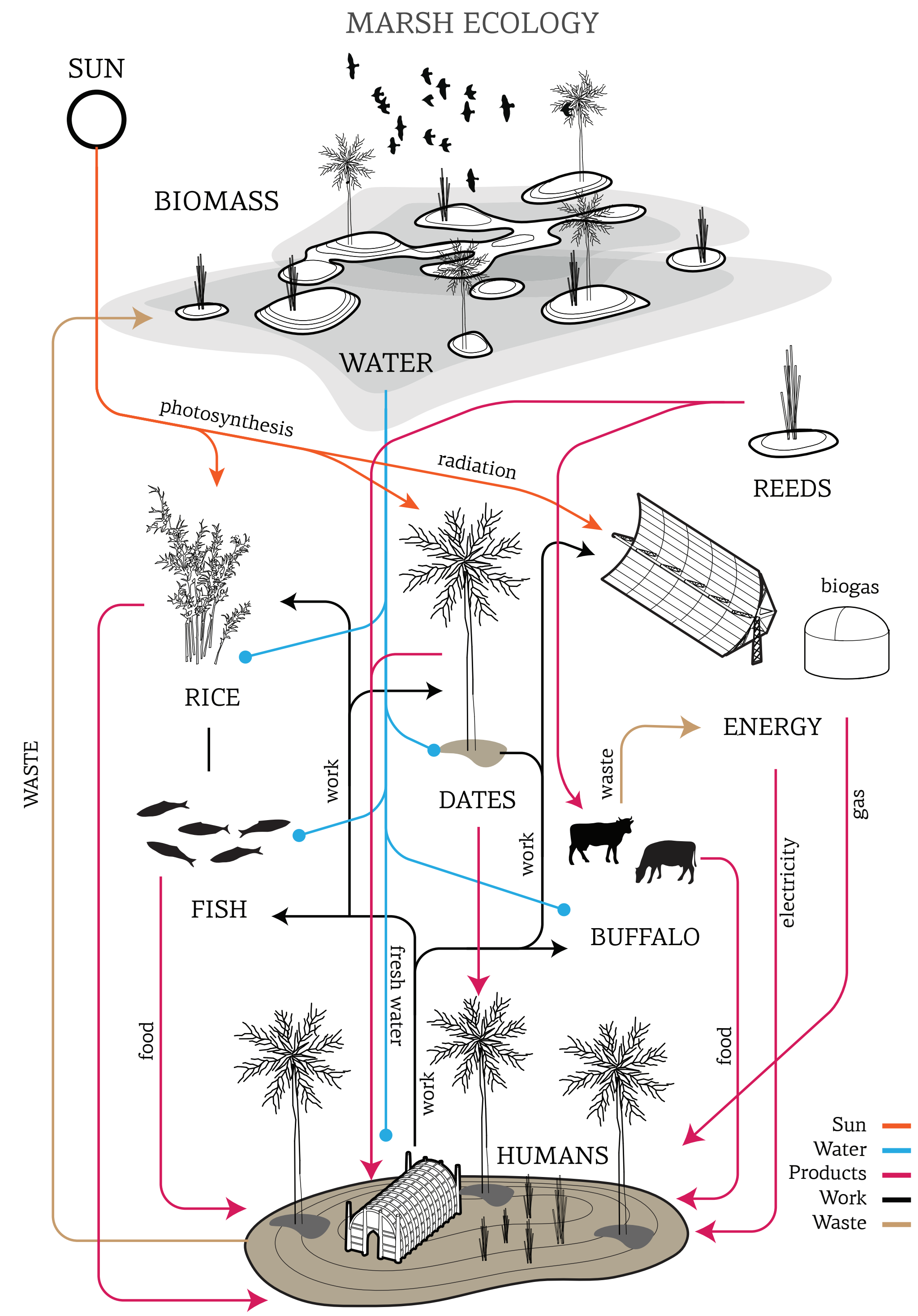
3.2 Site Strategy

3.2.2 Flow of Energy and Matter

An important goal of this project is to set up the conditions that would make it possible for the system to be adaptable over time and resist disturbances. This involves understanding the flows of energy that run through the system. Sanford Kwinter describes this condition as a "Soft System". A system is soft when it is flexible, adaptable and evolving. A soft system is supported by a dense network of active feedback loops and is capable of sustaining flows. Functions and activities can be organised relative to the flow of energy and movement of material. The network relations established between the biotic and abiotic elements of an ecosystem regulate the flow of energy and matter. These flows provide the connection between the different parts of the system and transform a community of random species into an integrated whole.

Sanford Kwinter, "soft systems" in culture lab, ed. Brian Boigon, Princeton architecture press. 1993 P.208

The constant consumption of energy by the ecosystem puts the system in a state far from thermal equilibrium. This creates a special condition which allows for the emergence of order out of chaos. In a state of perfect equilibrium matter is inactive, but if some pressure is applied the system self-organises and moves into higher and lower levels of order through which there is a constant flux of energy and material transformation. Take for example the sun. The sun radiates energy, this energy is trapped and stored in the form of biomass(Plants) by means of photosynthesis. Plants, in turn, are eaten by herbivore animals that store this energy in the form of flesh in their bodies, which then is burnt as the animal ploughs the fields of rice which, in combination with water and sun energy, will produce food for human consumption.



Matter Energy Flows

3.2 Site Strategy

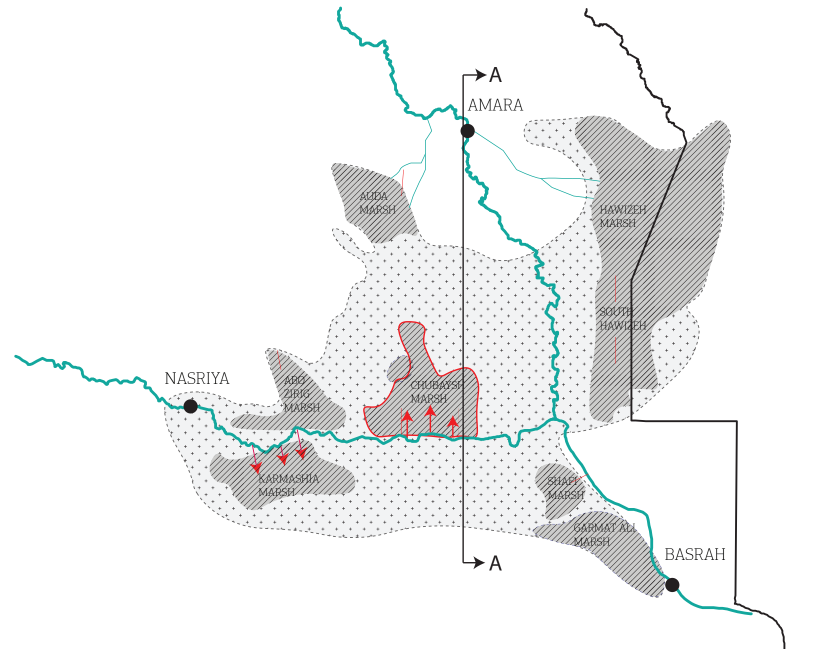
3.2.3 Marsh Recovery Strategy

Water flow

Regarding the ecological aspect of the marsh, as earlier mentioned, there is a severe salinity problem that needs to be dealt with. The rising salinity levels are mainly due to evaporation and the decreasing amount of input water to the marshes. In 2003 when the locals breached the embankments along the Euphrates river large parts of the former marshland were temporarily recovered to its original state. The locals had then created a new water inlet, without planning for an outlet. Without an outlet the water is left to evaporate rapidly in this hot climate. When evaporation occurs, fresh water is released into the atmosphere, leaving a brine behind. This is the main cause for the increasing salinity.

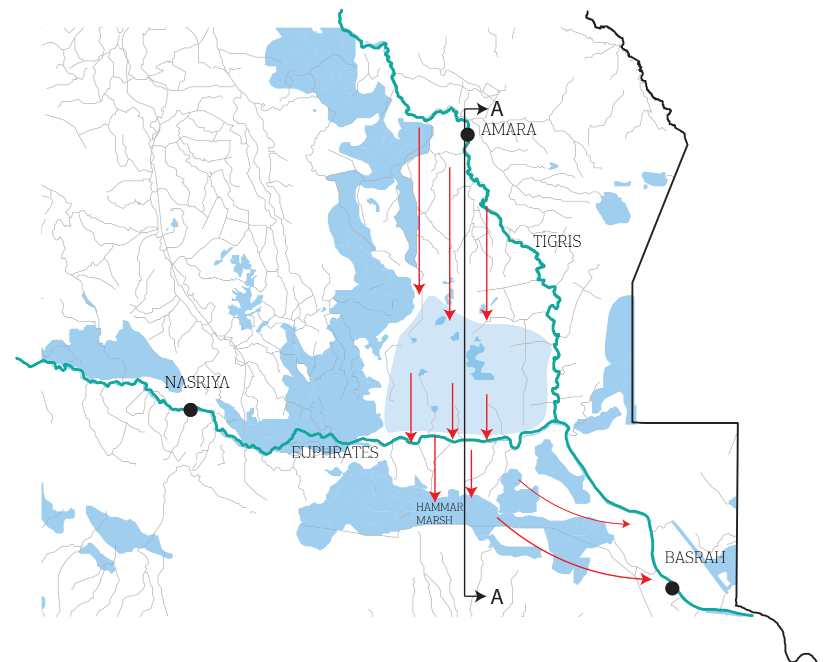
In order to recover the marshes permanently, more water would have to be provided and lead through the marshes, to an outlet. The natural flow of water came from Tigris, went through the marshes, and was lead out to the Euphrates. Re-implementing this strategy of water flow would be the first step the the restoration of the marshlands.

Due to the current annual flow of Tigris, this can not be achieved without an alternative water source. By desalinating water from the sea and leading it through pipes to the marshes, the natural water flow could be artificially restored.



Current Reflooding strategy

During the re-flooding attempt in 2003, the locals provided water to the dries marshes without having a strategy for the water flow. This lead to a temporarily recovered marsh with annually increasing salinity.



Original natural waterflow in the marshland

The natural water flow through the Central Marsh came from Tigris, flushed through the marshes, and went out to Euphrates.

3.2 Site Strategy

Tanks

Restoring the natural water flow though the marshlands is a necessary action. Although, this would not be enough to sustain their restoration since they were highly dependent on another natural phenomenon, the annual spring flood. Every spring when the snow would melt in the Turkish highlands, a vast amount of water would run through the two rivers and flush out the contaminates from the marshes to the sea. This flush was a natural cleaning mechanism that regulated the levels of salinity and other TDS in order to keep the marshlands alive.

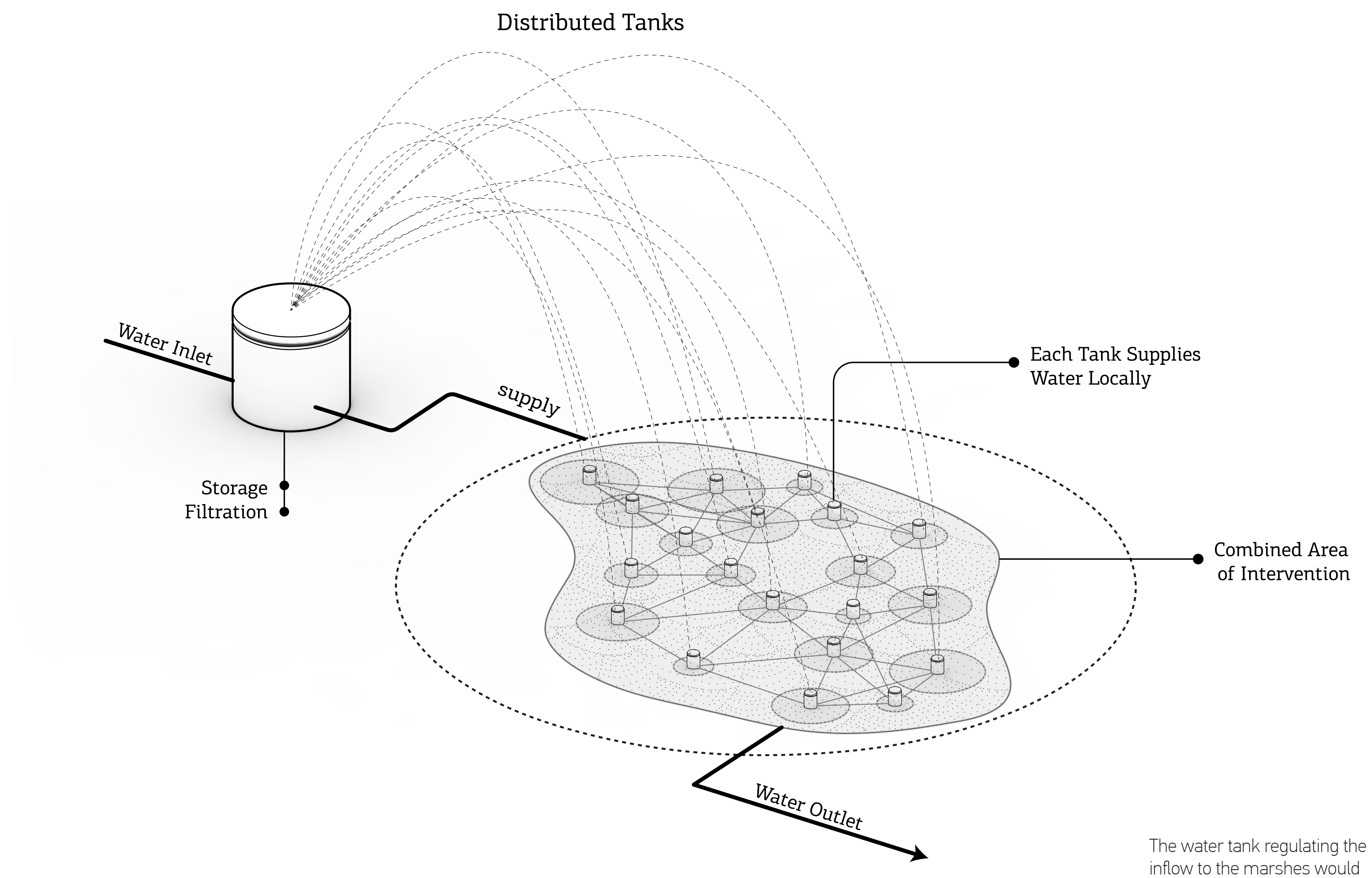
If the water that's being pumped from the sea to the marshes was to be stored in a tank that could regulate the inflow and release a certain amount of water at specific times, this would be a way of mimicking the natural flushing system.

By implementing this technique the marshes would be kept clean, allowing its content to survive. However, due to the required amount of water, this tank would have to be divided into many smaller tanks that would be distributed over the marshes.

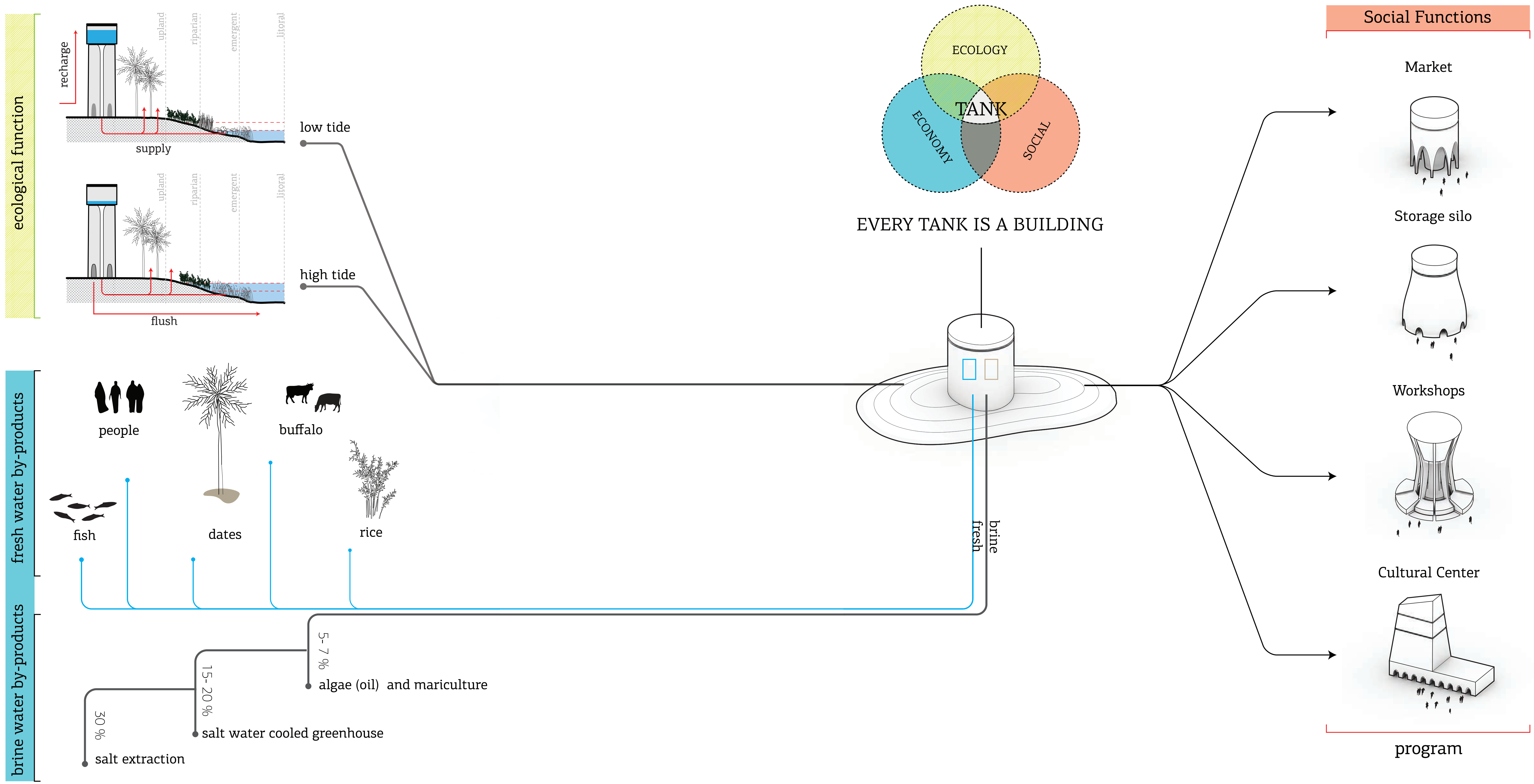
At this point there would be a network of water tanks serving an ecological function, restoring the marshes. With the desire to implement the other aspects of the projects aims, the tank could be utilized to serve more functions.

As the project aims to organise productive functions, these productions would require a large amount of water that has to be accurately regulated. The tank would be able to control the water which is required for the different types of production by both storing reserves and regulation the outflow.

When having these large infrastructural buildings spread out over a rural area one can argue that the actual tank structures should be designed differently and be used to serve as various social functions such as markets, schools, etc.



The water tank regulating the inflow to the marshes would have to be divided into many tanks and be distributed over the marshes due to the large volume of required water.


ecological function
recharge
supply
upland
riparian
emergent
littoral
flush
low tide
high tide
fresh water by-products
people
buffalo
dates
fish
rice
brine water by-products
5- 7 %
algae (oil) and mariculture
15- 20 %
salt water cooled greenhouse
30 %
salt extraction
ECOLOGY
TANK
ECONOMY
SOCIAL
EVERY TANK IS A BUILDING
fresh
brine
Social Functions
Market
Storage silo
Workshops
Cultural Center
program

3.2 Site Strategy

3.2.4 Local Inhabitation and Consumption

The Mesopotamian Marshlands used to be, and partially still are, inhabited by Marsh Arabs, who are usually referred to as Ma'dāns. The Ma'dāns are a self-sufficient people that are mainly occupied with agriculture, fishing, buffalo farming and weaving reeds. They use reeds for building their homes and they also use it in combination with mud for constructing the island which they inhabit.

A research was conducted on the annual consumption of the average Iraqi. The most important products were chosen to be further explored. For each of these products a ratio was calculated between production requirement and area. So for every type of production, it was calculated for one square kilometer, how much water is consumed, how many worker are required and how much of the product is produced.

These ratios in combination with the annual consumption of an Iraqi informs how much productive land is required to sustain a certain population. This data could then be used to define the exact boundaries of the site.

3.2 Site Strategy

Rice
450 Tons/SqKm

Rice Paddy

Dimensions : VARY. TYP DIMENSION (10 X 20 M)
Total Number of Paddies: 880
Number of Paddies per SqKm: 5,000
Amount of workers required: 1000

Energy
6822 GWH/SqKm

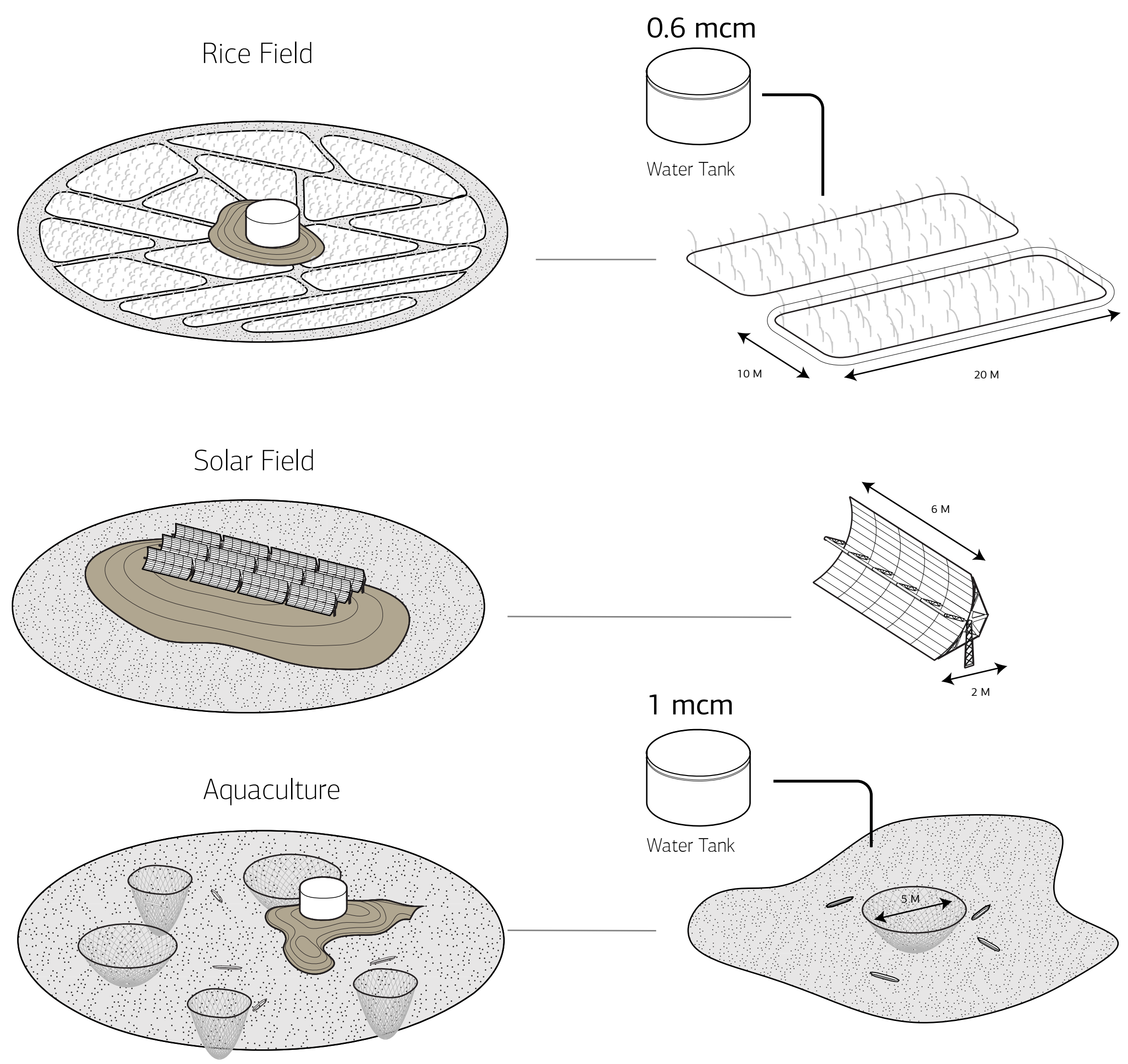
CSP (concetrated solar power)

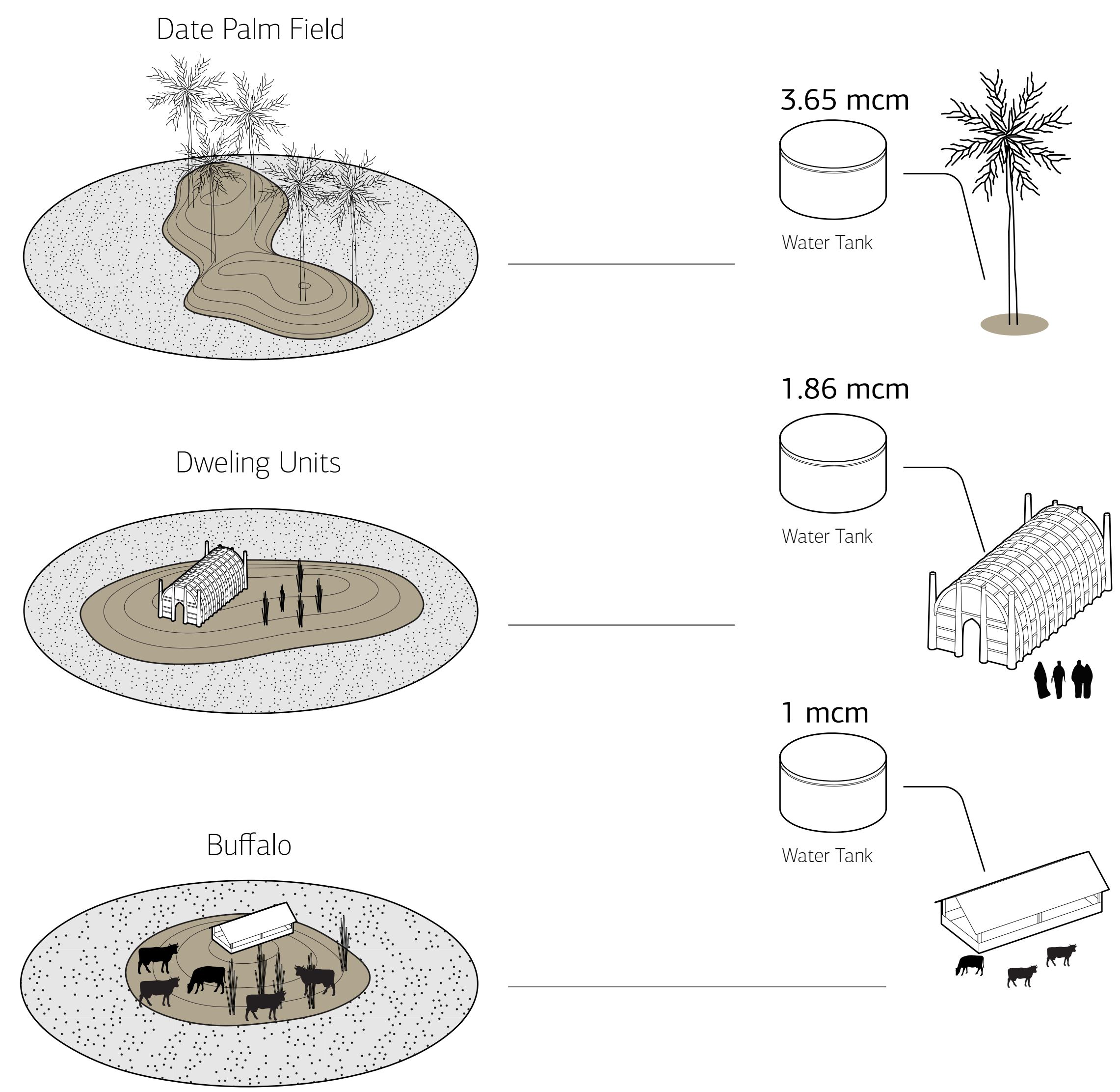
Dimensions : TYP DIMENSION (6 x 2 M)
total Number of units: 1875
Number of units per SqKm: 31,000
Amount of workers required: 45

Fish
10.000 Ton/SqKm

Fish Cage

Dimensions : VARY. TYP DIMENSION (5 M diameters)
Total Number of units: 1800
Number of units per SqKm: 40,000
Amount of workers required: 550





Dates
1150 Tons/SqKm

Palm tree orchard

Palm tree Dimensions : The leaves are 4–6 metres
Number of Palm trees per SqKm: 16,000
Amount of workers required: 960

Population
500 People/SqKm

Dwelling unit

Dimensions : Typ. Dimensions 15 x 5 x 4 m
Total Number of units : 2000

Dairy
16500 Tons/SqKm

Buffalo Stable

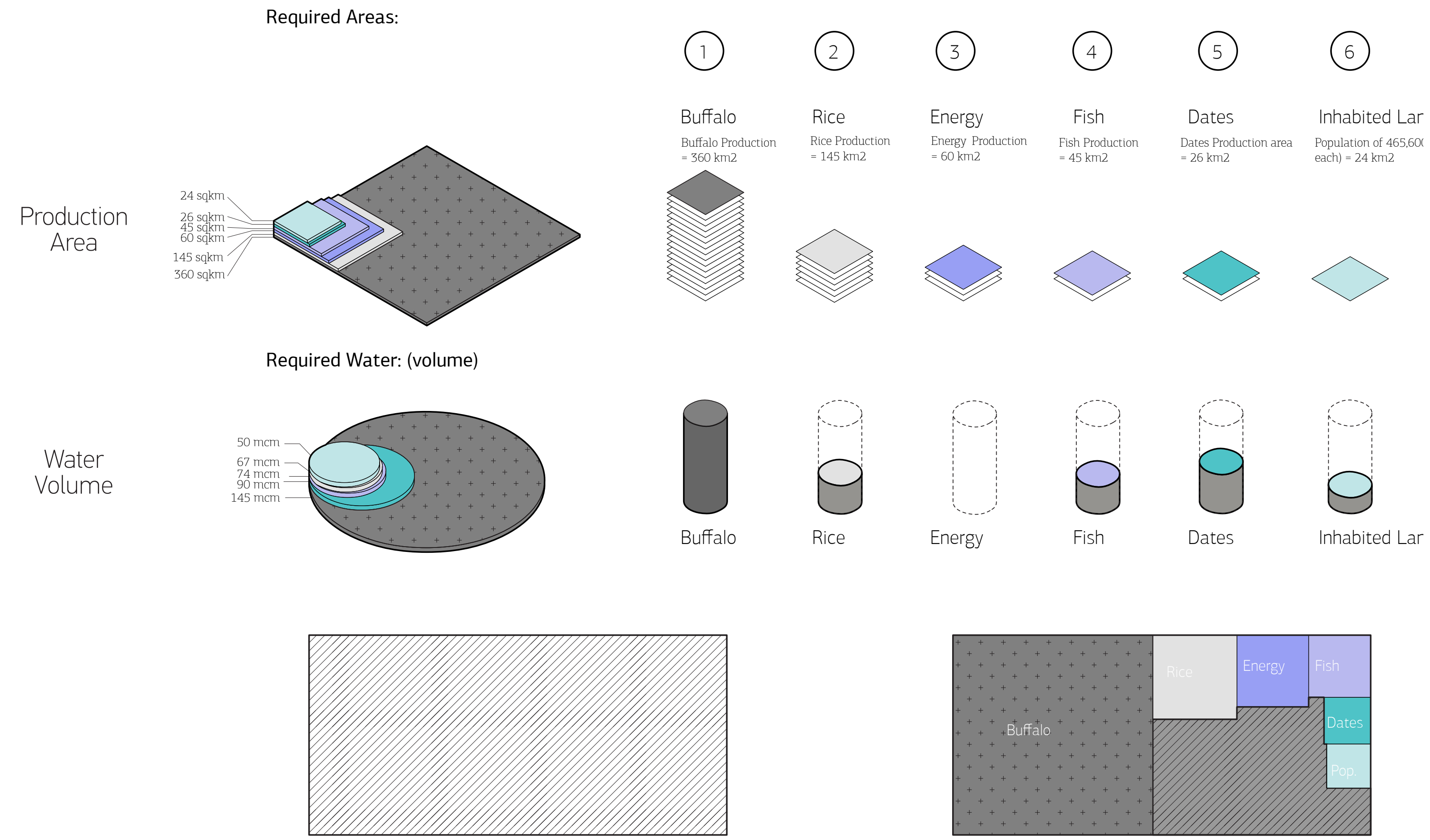
Dimensions : 600 Sqm
Total Number of units : 330 (30 Buffalo each)
Amount of workers required: 2000

3.2.5 Land Distribution

While organising productive functions in the marshes it is important to not overtake their natural wild character. Since the area of the different production types were set to a fixed size, calculated from the requirements to provide for the average Iraqi, a ratio between the seperate productive areas could be set. This could then be use to calculate the required production area for any population size.

The aim was set to keep 75% of the area as marsh, of which more than half would be kept as wild marsh. Wild marsh refferes to the type of marsh that isn't intended for grazing or being used for any of the other types of productive activities which are being introduced to the site. The wild marsh serves as a purely ecological function. The other type of marsh is the controlled marsh, which is intended for grazing. This part of the marsh would be constantly changing as the buffaloes feed on it, and its size ratio has been calculated to fit enough reeds required to feed the amount of buffaloes that are needed to meet the demand for dairy consumption per capita in Iraq.

Date Palms	2.6 %	Rice	8.8 %
Fish	4.9 %	Buffalo	34.6 %
Energy	6.5 %	Marshland	42.0 %



4.0 Design Strategy

4.1 Program Distribution

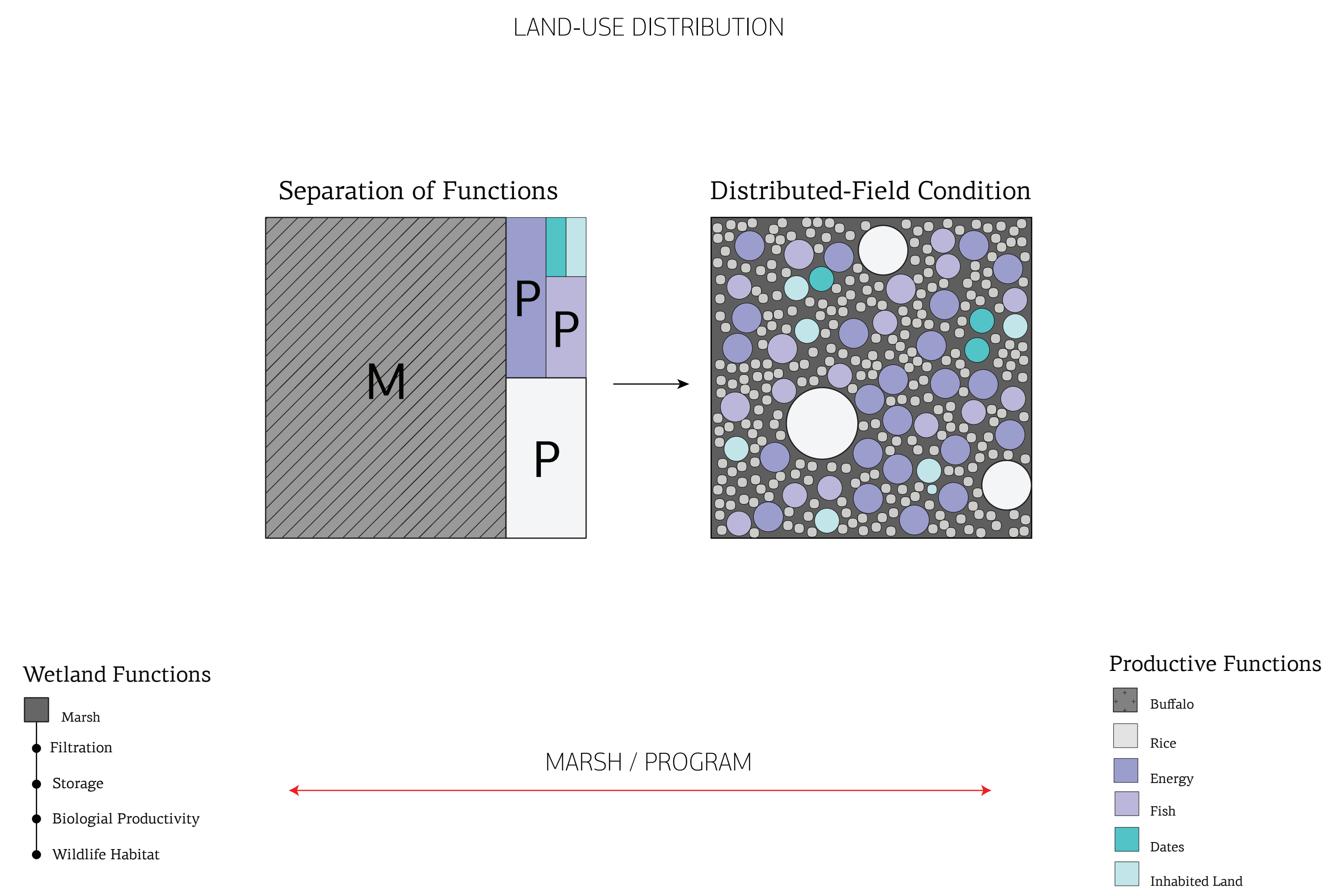
4.1.1 *Distribution of Functions*

Field Conditions by Stan Allen in Points + Lines, 1985

In order to introduce and distribute productive functions in the marshes, it is important to ensure that some percentage of the area is preserved as wild marsh. The ecosystem of the marshes provides a number of ecological services that can benefit the productive functions that are to be introduced. This ecological services are: [1] Filtration. Wetlands can clean water by slowing water letting particles settle and absorbing exess nutrients. [2] Storage. Wetlands can store water; acting like a sponge excesses water can be retained and slowly released over time. [3] Biomass Productivity. Due to high concentration of nutrients in the wetland waters, biomass can grow faster than in any other ecosystem. [4] Wildlife Habitat. Wetlands provide a suitable environment for permanent and periodic animal occupation. For example migratory birds would occupy temporarily areas of the wetland.

For a given area of marsh, the percentage of a certain product needs to meet the demand established to feed a target population based on the average consumption of produce per capita (see *3.2.4 Local Inhabitation and Consumption*). Production should sustain the population inhabiting the selected area and generate surplus product to generate additional value. This numbers are allowed to fluctuate as long as about 50 % of wild marsh is preserved. The marsh ecology needs to be preserved not only for environmental conservation reasons but also because the different products can benefit from interacting with the marsh ecology and its services. Threfore, the distribution strategy aims at increasing the interaction between the various productive fucntions and the marsh.

Instead of separating and concentrating functions in zones, the goal is to create a semi-radom distribution of uses in order to establish the most connections between product to products and marsh to products. This condition can be described as a “field condition” to borrow Stan Allen terminology. A field is capable of unifying distinct elements while preserving its individual identity. Fields are characterized by being permeable and porous. Fields promote interaction between its parts. Fields are loosely bound and its overall shape is less important than its internal relations. In this sense, the field condition offers an ideal arrangement of uses that can extend or contract without destabilizing the whole.

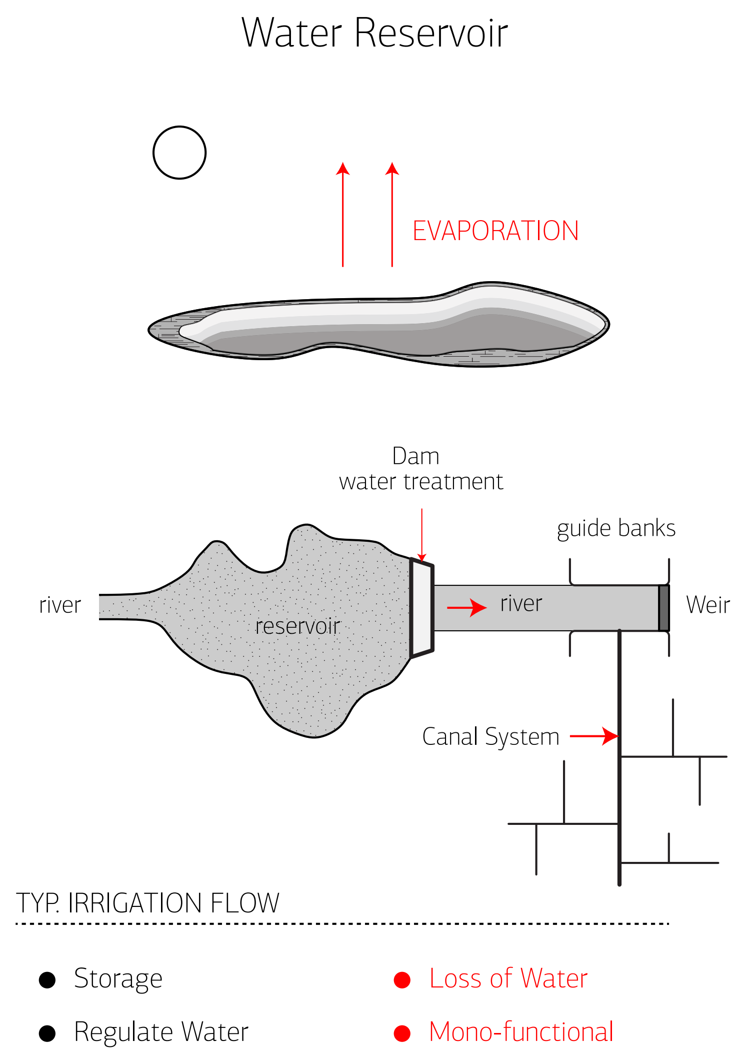


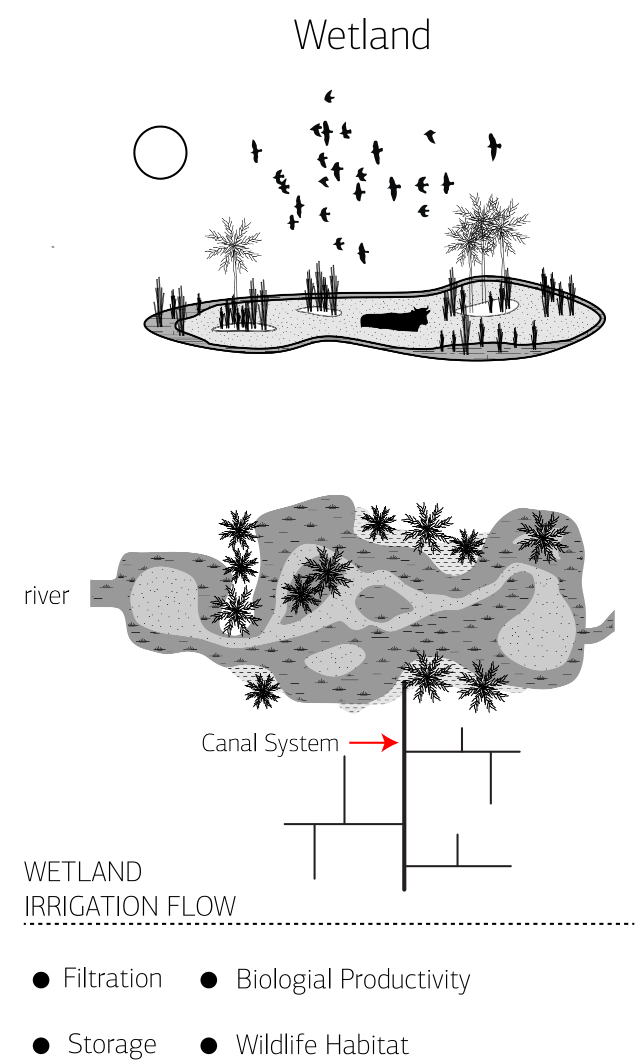
4.1 Program Distribution

4.1.2 Reservoirs vs Wetlands

There are many benefits from coupling productive functions with wetland ecologies. Conventional irrigation schemes rely on a dam and a canal system to supply water to the crop. In a typical irrigation scheme, water flows from a river stream into a reservoir. Water is collected in the reservoir and regulated by a dam. A certain amount of water is allowed to pass through, this water is lead to a main irrigation canal and subsequently distributed to secondary canals until it reaches the crop. Reservoirs are the most common system used to contain large amounts of water. However, in regions with hot climates, like in the case of Iraq, this water management strategy can result in large amounts of water lost. High temperatures produce evaporation which can amount to billions of cubic meters in water loss (see *1.6.1 Water Scarcity - Current Problems*). Additionally, the flow of water in a conventional irrigation schemes is mostly monofunctional. Water is used for one single purpose instead of passing through various stages to serve multiple functions.

A wetland, on the other hand, offers various ecological services such as water filtration, water storage, biological productivity and wildlife habitats (see *1.1.5 Wetland Functions*). Similar to a reservoir, a wetland can store water and regulate water naturally. In the event of an overflow of water, the wetland can absorb the water back minimizing losses. Additionally, wetlands are covered with various layers of plants and trees that prevent evaporation from happening. Furthermore, water can be cleaned and treated through a natural process of filtration. Water with different levels of salinity, silt and nutrients can be distributed to a diverse range of products making the system serve multiple functions.





4.1 Program Distribution

4.1.3 Synergies

Whereas most industrial processes follow a linear behaviour, an alternative designed strategy can be established to promote cyclic and non-linear behaviour by harnessing synergistic relations between the marsh ecology and the set of products that are to be introduced in the site. In simple linear systems, a process constantly utilises the same inputs and produces the same outputs. This results in inputting resources that are extracted from the environment and outputting waste to the environment. The distinction between linear and non-linear has become fundamental and constitutes a paradigmatic change in the new sciences that can also inform design strategies. Linear systems obey, what is often referred to as "the superposition principle" which states that the net gain at a given place and time caused by the interaction between two or more elements is equal to the sum of its parts or equal to the response that would have been caused by each individual element acting separately. Non-linear systems, on the other hand, cannot be explained in terms of its individual parts because their essential properties depend the interaction between its parts. These systems are capable of exhibiting emergent behaviour, which means that the outcome from the interaction of its parts produces a result that is greater than the sum of its parts.

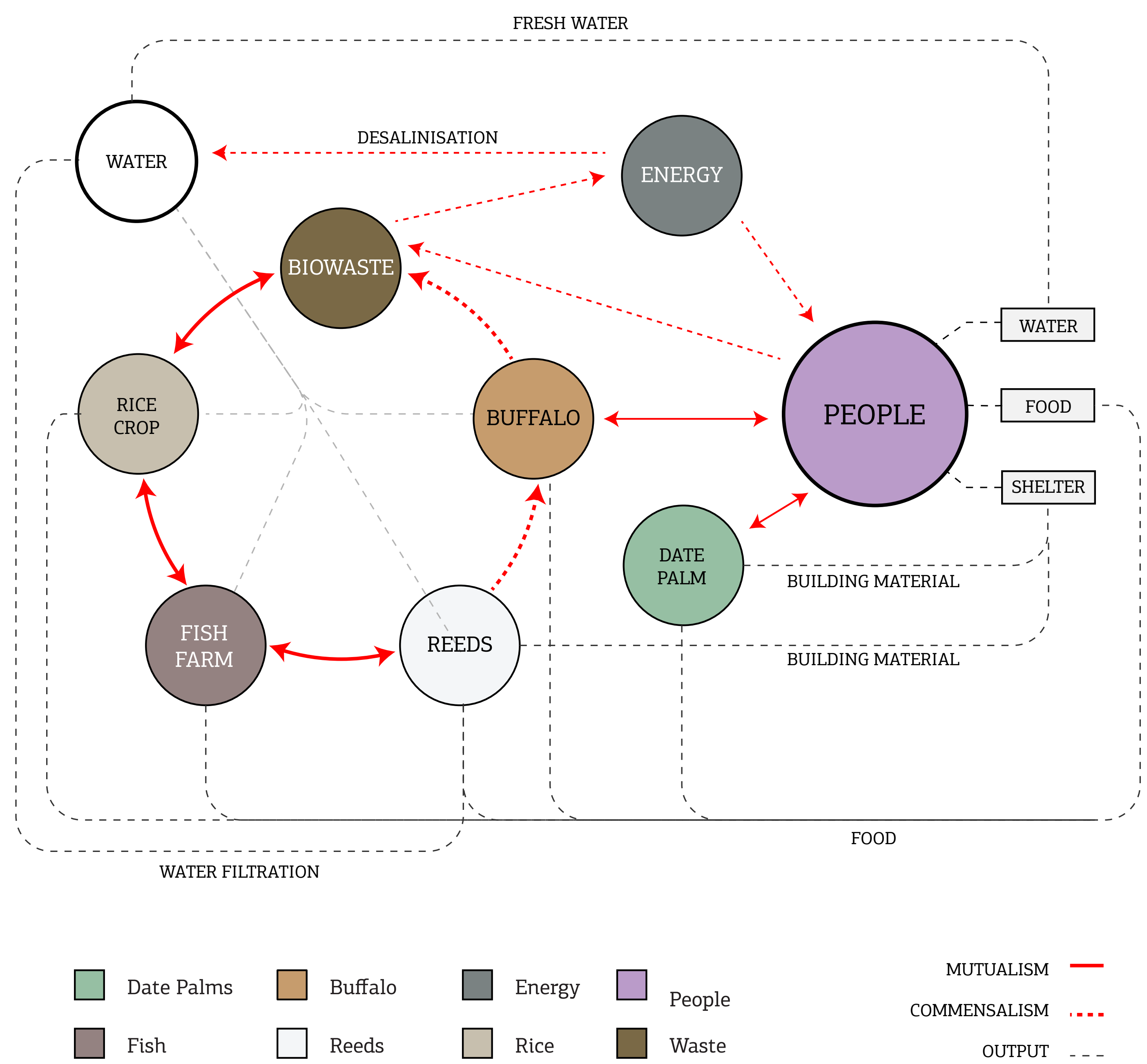
Not all interactions are beneficial and not all combinations are possible. All biotic and abiotic elements in an ecosystem have some boundary condition that defines whether synchronised behaviour and cooperation can take place.

Synergetic interactions occur when two or more elements work together to create an effect that is greater than or less than that of each element in isolation. Synergies can be positive or negative. In biological systems, these elements can produce an amplifications or cancellation effect. In order to produce synergies, the main focus of design needs to shift from the parts to the relations. To achieve synergetic relations there needs to be some degree of diversity of processes taking place on different but parallel levels. When parallel action takes place, different components in the system process different resources and it is possible to connect what is waste for one component to what is an input for another.

In designing these relations the goal is to make positive sum gains the attractor state. To do this, network relations need to be established. This requires an investment in the infrastructure that sets up the relations through which the different elements of the system would interact. In order to establish productive relations between the marsh ecology and the productive functions a set of rules for combining positive adjacencies was established. Positive combinations were identified in order to use them as rules to inform the distribution of functions across the site of intervention. For example, rice production benefits from being close to fish. Rice yield can increase by 10-15% from being close to fish. Fish helps control certain weeds and eats insects such as stemborer and brownplant hopper. Fish bio-waste contains uneaten feeds which can add as fertiliser to the soil. Fish promotes the movement of water increasing the availability of nutrients increasing floodwater productivity. Fish reduces loss of ammonia through volatilising by preventing floodwater pH rise over 8.5. During the time fertilisers are applied, increased plankton production tends to raise the value o pH beyond 8.5, at this level ionised ammonia converts into unionised form and is easily lost.

[Workshop to Produce an Information Kit on Farmer-proven. Integrated Agriculture-aquaculture Technologies (IIRR, 1992, 119 p.)

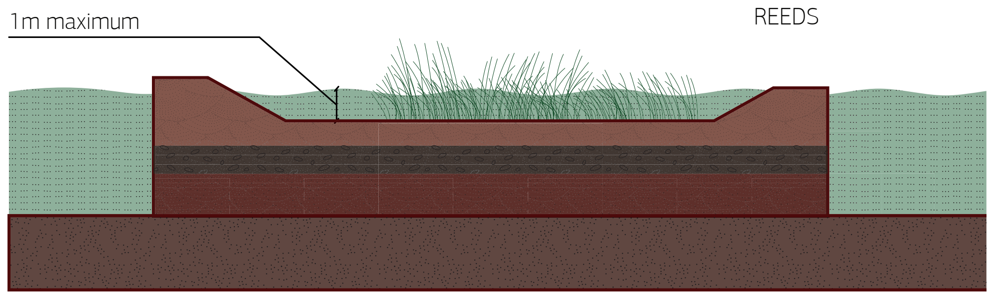
SYMBIOTIC RELATIONSHIPS



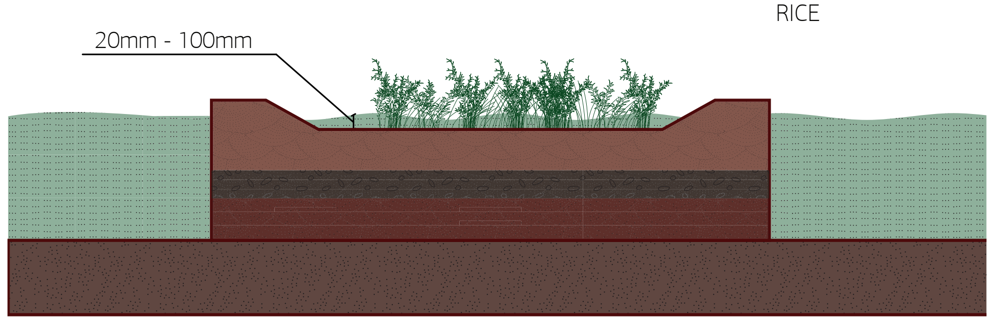
4.1 *Program Distribution*

Each productive or residential island has a different sectional relation with the water, according on the needs of each activity taking place there. Moreover the seasonal fluctuation of the water mainly created by the spring floods (artificially produced by the tanks or not, see distributed tanks site strategy), which is temporary changing the water level, was taken into account.

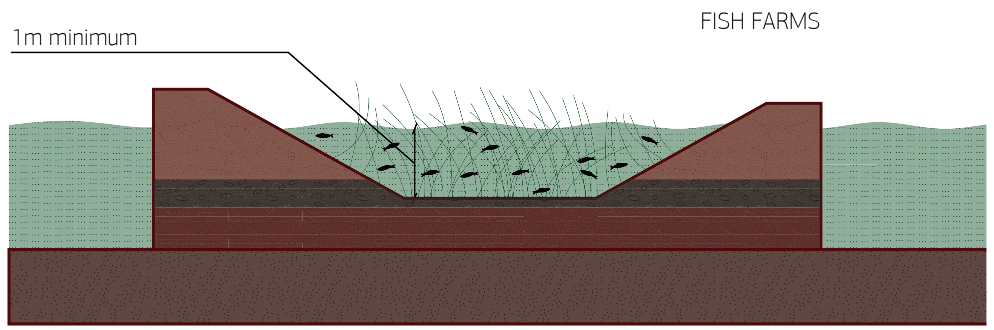
The reeds can only grow on soil covered with fresh or brackish water. The maximum depth of the water where reeds can grow is 1m. There are two types of reeds found on the marshlands; one growing in the areas where water is up to 200mm deep and one growing in the deeper areas.

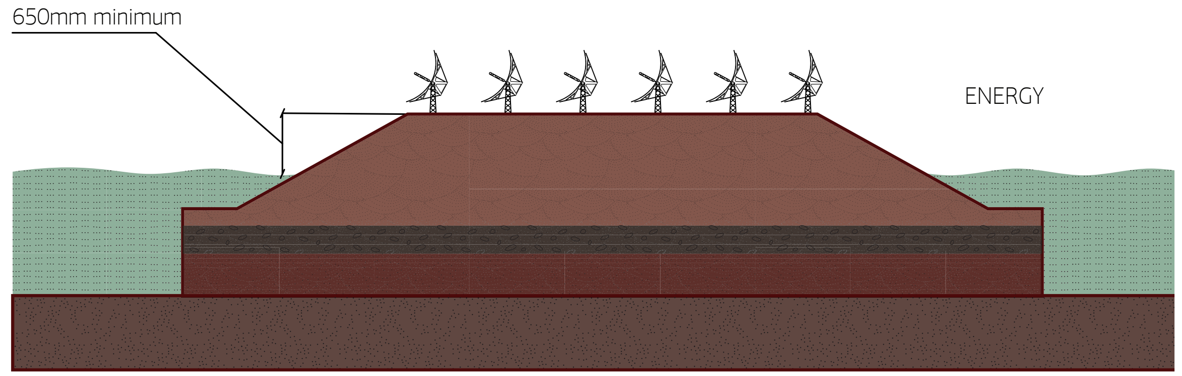


Various different techniques are used for growing rice around the globe, which are mainly dependent on the soil and water types and the local climatic conditions. The water level on the rice patties cultivated for rice production the depth of the water changes based on the time of the year and the specific needs of the crops (different level when growing, collecting, etc).

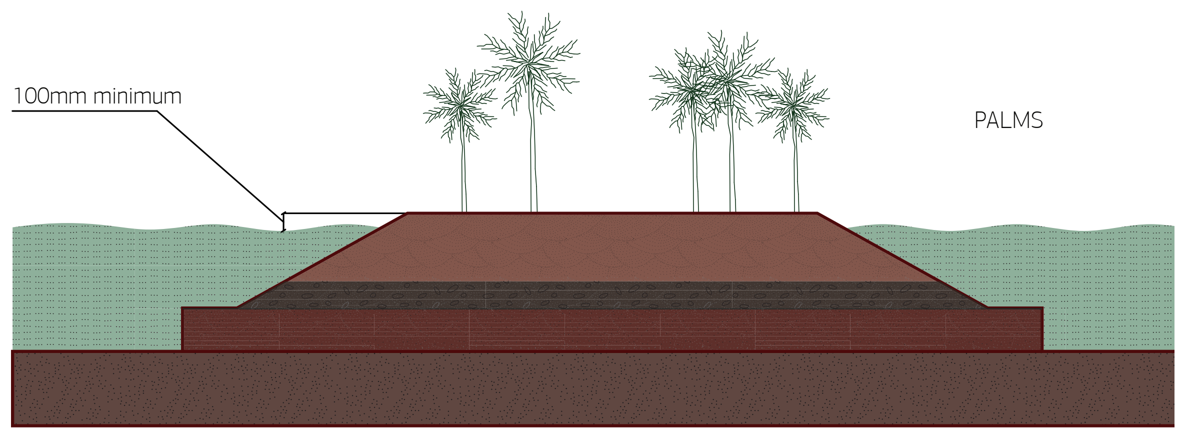


Fishes can be found almost everywhere in the marshes, from the shallow waters covered by reeds to the deeper ponds and canals. In order to systematically produce fish farm the deeper waters (more than 1m) must be chosen for installing aquaculture equipment.

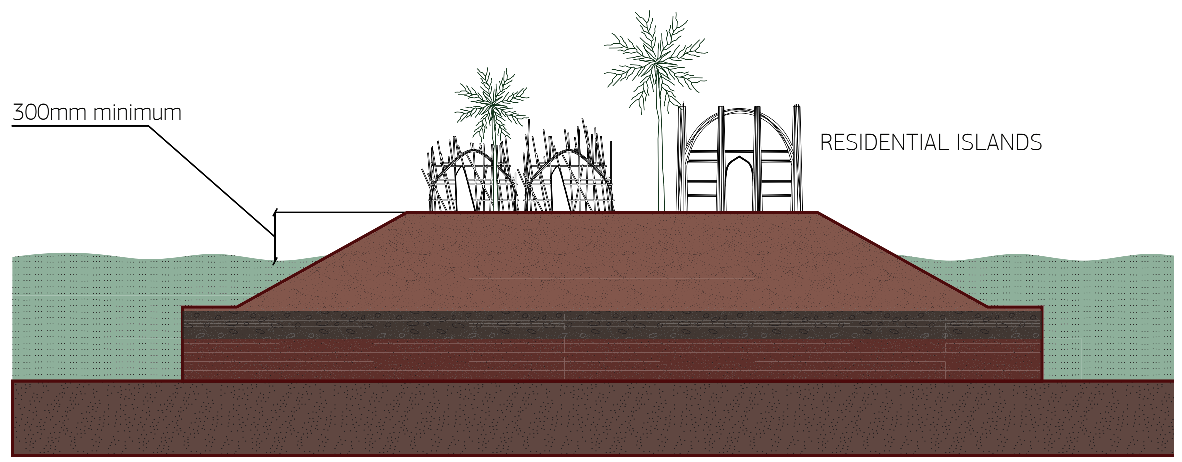




The islands used for electricity production harnessing solar energy must be levelled at least 650mm above the water level, ensuring that their ground remains above the water level throughout the year.



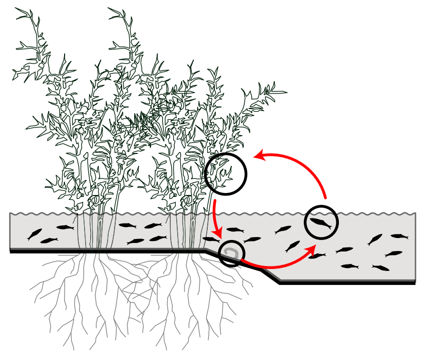
The islands where palm trees are being cultivated to produce dates should be above the water level but they can be partially or fully flooded for short periods of times. This could naturally fertilise the palm trees by adding layers of beneficial organic waste and other nutrients.



The inhabited islands, covered by houses made of reeds and mud, should be above the water level. Traditionally, layers of mud and dry reeds where added on the islands's surface throughout the year to ensure that the reed houses remain out of reach of water.

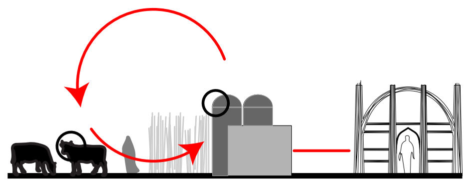
4.1 Program Distribution

RICE



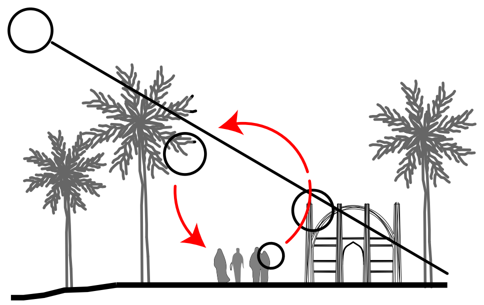
Biogas production benefits from close proximity to buffalos as the waste from the animal can be harnessed to generate electric energy.

BUFFALO

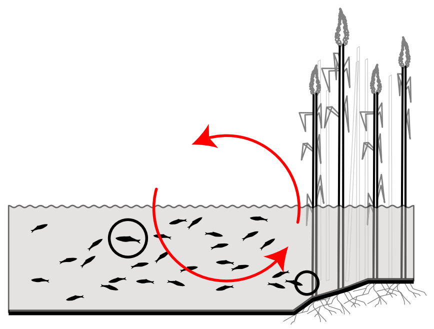


Date palms and humans benefit from being close to each other as palm trees provide shade for humans while humans help to artificially pollinate the palm population.

DATES

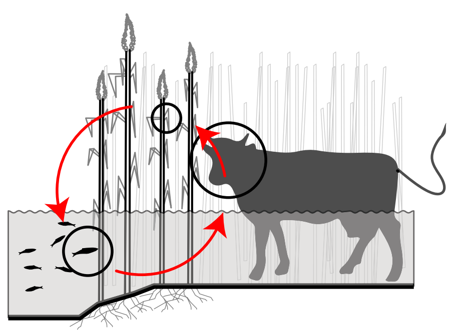


FISH



Wild fish benefits from close proximity to reeds as reeds protect fish from predators. Reeds benefit from fish as they can act as fertilizer increasing biomass renewal and biological productivity.

REED



Productive Sequence

Fish and rice benefit from being close to each other as fish can act as a fertilizer for rice and rice can provide supplemental food for fish.

Buffalos benefit from being close to reeds as reeds provide the main source of food for the animal.

Date Palms	Buffalo	Energy	People
Fish	Reeds	Rice	Waste

4.2 Networks

4.2.1 Network Strategies

In its simplest form, a network is a collection of elements connected to each other in some type of arrangement. "A network (or graph) is simply a collection of nodes (vertices) and links (edges) between nodes. The links can be directed or undirected, and weighted or unweighted."[1] In complex systems, a series of interconnected events occur as the result of local interactions between its constituent parts. If two nodes are not linked, they cannot communicate, interact or affect each other, they exist in different systems and their individual behaviour cannot possibly have an impact on each other. When a network is established, events that happen at one location of the network have the potential to impact any other location of the system. In the absence of a network events are only felt locally. [2]

Watts, Duncan. 2004. Six Degrees: The Science of a Connected Age.

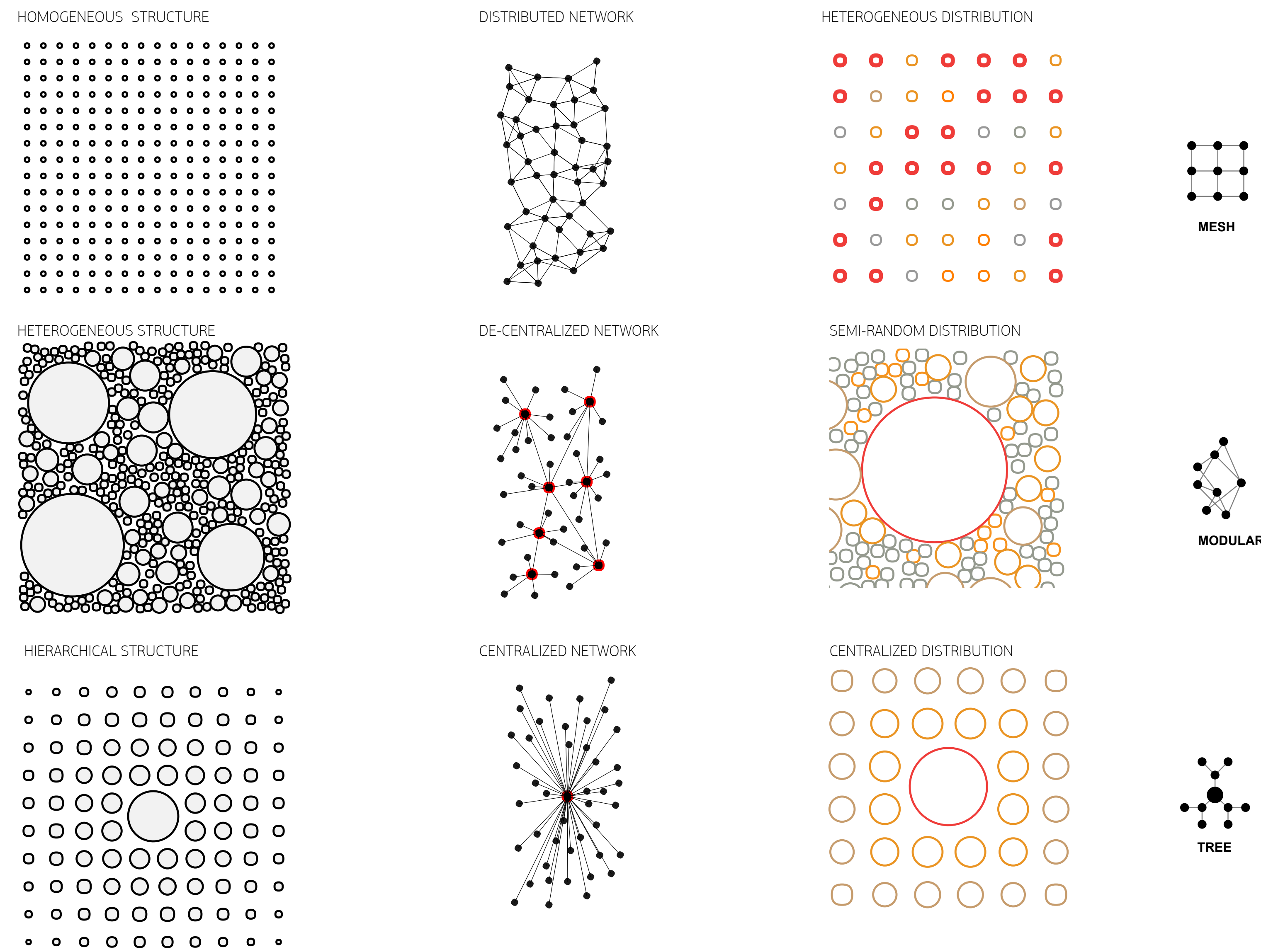
Caldarelli and Catanzaro. 2012.Networks: A Very Short Introduction.

Networks can range from a highly ordered state to a very disordered one. A highly ordered network structure is a regular graph; a grid or tree structure. These types of network topologies are usually man-made and the origin of the order may come from a variety of reasons. For example, trading routes are set up in specific patterns due to commercial interests and geographical proximity. Often times, connections are established based on particular reasons instead of simply made at random. The type of network that represents a highly structured order is the grid. However, many real networks that we found in the world, especially those that evolve without central control, display some degree of disorder; these networks are often referred to as random networks or ER (Erdos-Renyi) graphs.

The difference between a grid (regular graph) and a random network (ER graph), is that the latter one is capable of displaying emergent behaviour by reaching a critical point and suddenly switching from a highly disconnected state to highly connected one in a similar process to what is known in physics as a phase transition. While regular graphs such as grids and trees tend to have long average paths (nodes are far from each other) and a high clustering coefficient (groups of nodes form clusters), random networks have short average paths and a low clustering coefficient. What is common to these two types of networks is that they both have a homogeneous distribution, meaning that the number of connections each node has is very similar.

Sole and Valverde (2004). Information Theory of Complex Networks: on evolution and architectural constraints.

In general most real life networks are not homogeneous, more often than not, networks have a heterogeneous distribution. Most networks have some degree of regularity and some degree of disorder, therefore they fall somewhere between a regular graph and a random graph. In 1988, Watts and Strogatz, proposed a model to describe these types of networks, which they called "Small World Networks" (SW). SW networks have a heterogeneous distribution, a high clustering coefficient and average short paths (hence the name "small world network"). The small world phenomena is a striking feature of this type of networks. Contrary to a regular grid, where the average length path becomes larger in a linear fashion as the system grows, in a SW network the average length path becomes smaller as the system grows. Another important class of network topology are referred to as Scale Free networks (SF), this model was proposed, in 1999 by Barbasi & Albert, to describe networks that have a high heterogeneous degree of distribution and some degree of randomness. An important characteristic of this type of network configuration is that its distribution follows a "power law", with a few important nodes that are highly connected and a "fat tale" of nodes with very few connections. In this type of networks it is easy to identify hubs, which is nodes that are particularly important within the network because of the number of connections they hold.



4.2 Networks

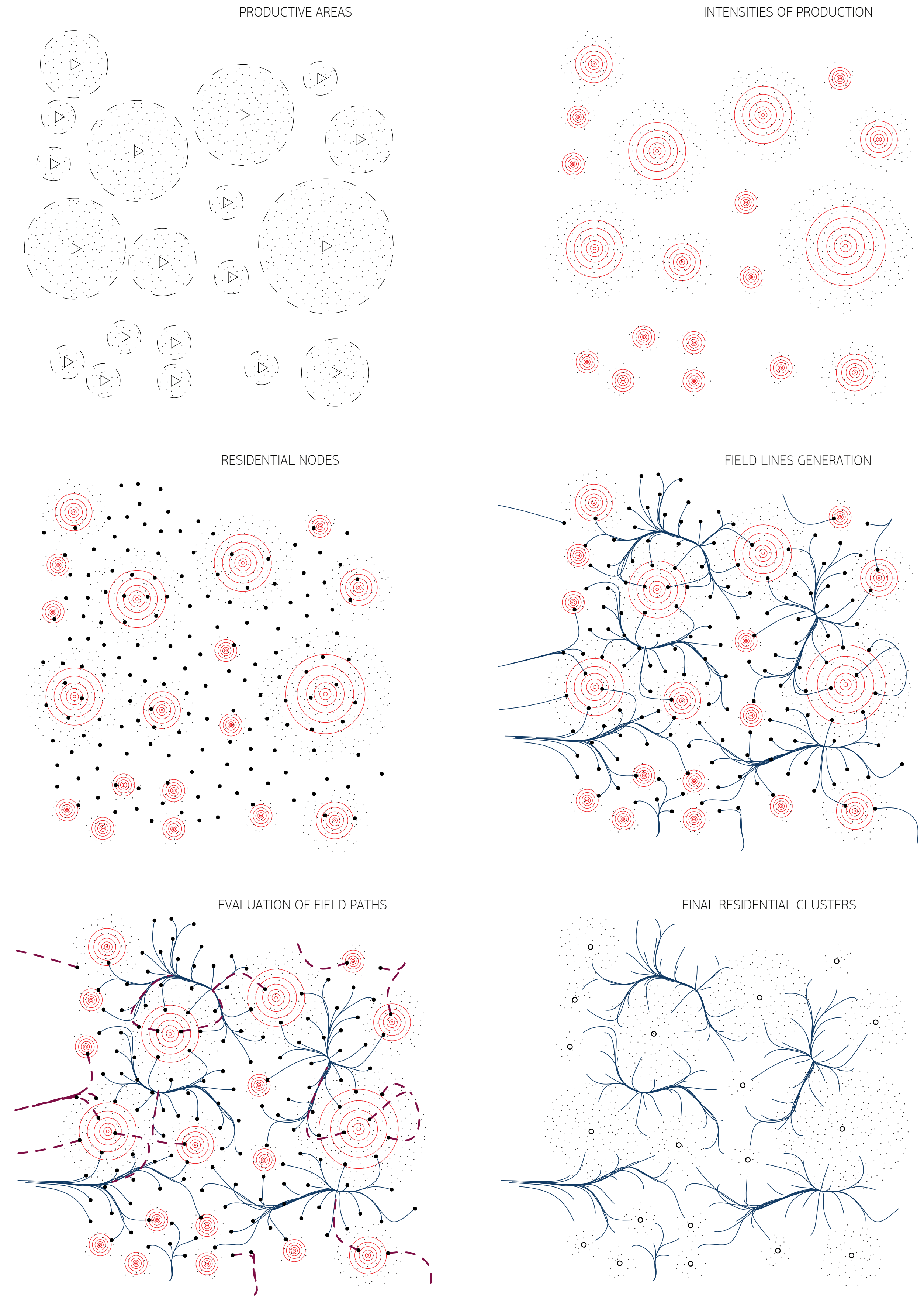
4.2.2 Generation of Base Network

At the macro-scale of a complex system like a city, an ecosystem or an interconnected rural formation, the underlying structure and organisation of a network is more significant than the individual geometrical or morphological characteristics of its component parts. Take for example an animal food chain in ecological systems; provided that an animal is equipped with a basic level of functionality, meaning that the animal is not impaired to perform basic operations such as moving or eating, when considering the system as whole, the individual characteristics of the animal are not as important as the set of activities and interactions the animal engages with. Events that may appear to be unrelated are actually intricately linked by means of the underlying structure of a network. Similarly in urban systems, a building may be shaped in any way; as long as its form allows for the minimum requirements to fulfil a certain function its morphological characteristics are not particularly important. Building morphologies are subject to change over time; buildings are demolished and re-built, they are expanded and subdivided, they transform to give way to new uses and inevitably adapt to respond to new demands and requirements posed by changing circumstances. What is more important, at the macro-scale of the urban system, is where the building is positioned in relation to the rest of the city and how it is connected to other buildings and people. Therefore, in the design of urban systems and other types of human settlements, the essential spatial characteristics of the cities, villages, conurbation, etc are topologic relations not geometric configurations. [1]

Brelsford, Christa et all. 2015. The Topology of Cities, Santa Fe Institute Working Paper: 2015-06-021

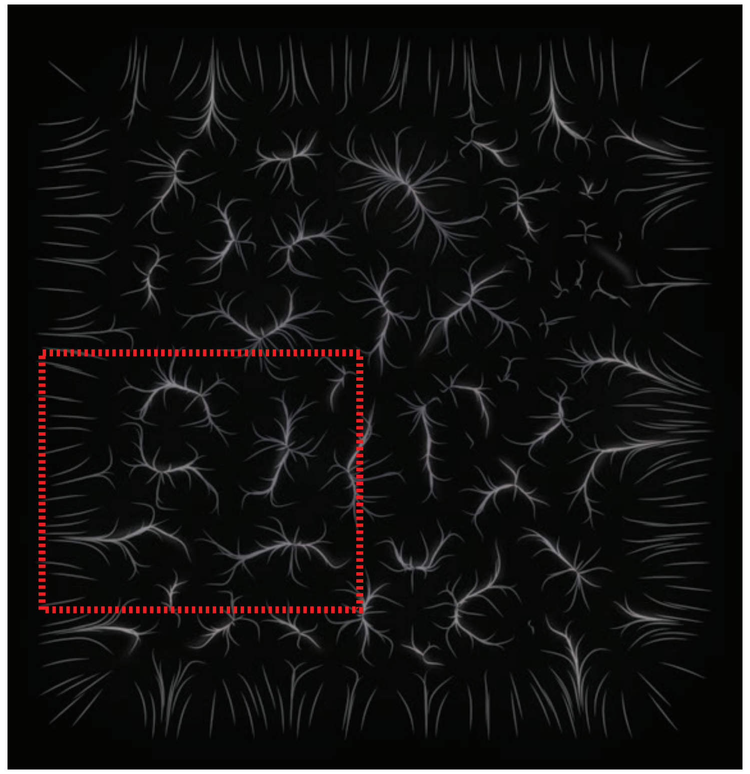
In order to position the different productive uses, a semi-random distribution strategy was selected, as described before. The uses were initially distributed (circle packing), while the ratio of each productive activity was being optimised in order to approach the desired pre-set percentages that would allow for a certain amount of production, with the use of a genetic algorithm. Then another genetic algorithm was used in order to minimise the pipeline network's total length (connecting the tanks position in the centres of the circles shown) and to ensure that the most possible beneficial symbiotic neighbouring conditions between the productive functions would be achieved (as described in the program distribution, symbiotic relationships part).

The functions have been distributed with different circles containing different productive activities. Each circle is representing the area for which the water tank (triangle) will store and provide fresh water according to the different production needs throughout the year. A different intensity is assigned to every centre of the circles (water tanks), according to the intensity of the productive activity that is taking place there. This ensures that there will not be much interruption to the more labour or land -intensive the productive activities. The area of intervention is populated with randomly distributed points. Every point represents a residential unit. The number of points is dependent on the desired population density for that specific area. The amount of inhabitants per unit ranges from 5 to 20 people, according to the residential typologies that will be later placed there. The field lines/canals are created, starting from the residential nodes placed on the previous step and converging along the periphery of the production areas. The field lines are leaving enough space for both the productive activities to happen with the least possible residential interruption and for the wild marsh to grow in order to ensure that no large, solely productive zones will be created along the plot. Then a preliminary evaluation of the field paths is made. The field paths that are not forming clusters (less than 4 intersecting lines) and those that are interrupting a productive activity are eliminated. The remaining curves are the final field lines/canals, which are going to serve as the paths that connect the residential islands with the rest of the network.

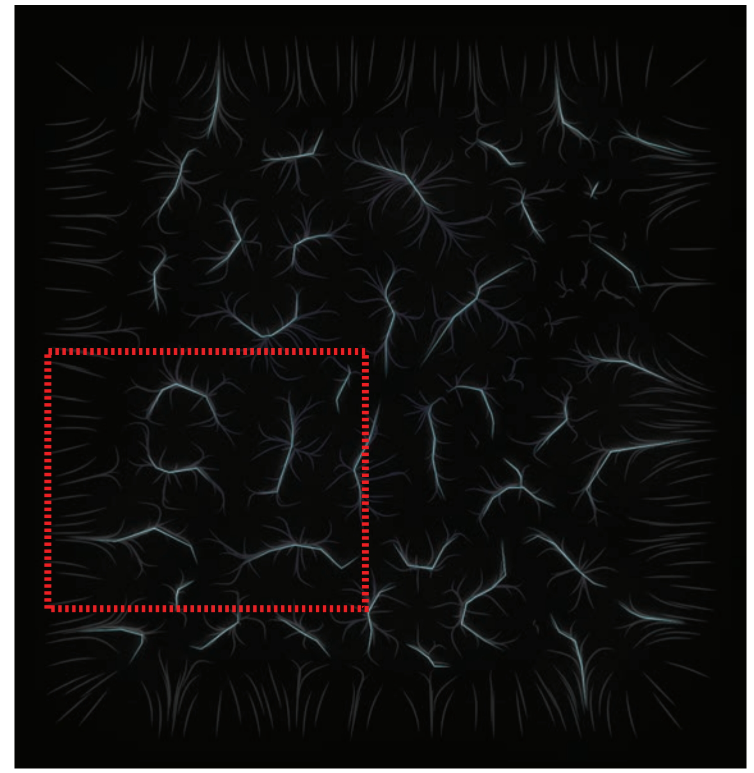


4.2 Networks

Cluster of Paths (Magnetic Field)

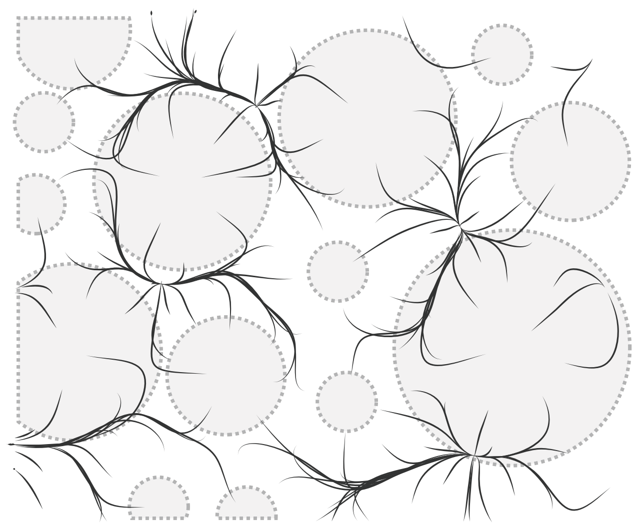


Convergence of Paths

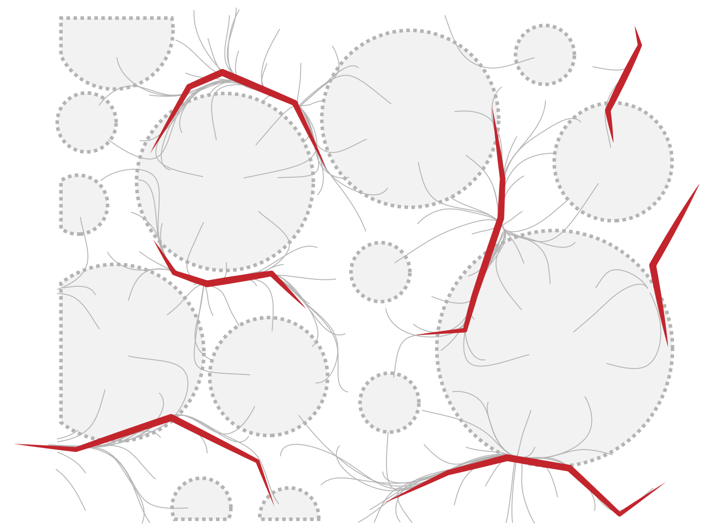


Clusters

The residential clusters are wrapping around and enclosing a productive activity, leaving enough space for the wild marsh to grow.



Central Paths



The central paths were chosen after counting the number of intersections within each cluster. The curve with the most intersections per cluster was selected as the central path. These paths/canals are wider and deeper than the rest of the canals within the cluster as they have to accommodate more small and bigger boats. Agent based modelling was used to connect the central paths with each other and form a complete hierarchical network within the site.

4.2 Networks

4.2.3 *Generation of Integrated Network*

In order to generate a network, all residential clusters need to be connected with each other. Each one of these clusters has a common central path formed by the convergence of multiple local paths. To connect the clusters with each other, an agent based simulation is used which through a mechanism of indirect coordination generate a network by self-organisation without any need for planning.

There are four distinct advantages in using an agent based system to develop an artificial decentralised network.

Flexibility: The system can react to internal and external changes in the environment.

Robustness: Tasks are completed even if some individuals fail.
Decentralisation: There is no central control over the system.

Self-Organisation: Paths to solutions are emergent rather than pre-defined which leads to better utilisation of resources and gives a dynamic character to the solution finding process.

The system is based on a set of simple rules but through a collective collaboration they can perform complex tasks. The agents' movement pattern is sign-based and hence indirect, which means they follow the trace left by other agents. The trace of the agents movement is left in the environment making an indirect contribution to the task being undertaken and influencing the subsequent behaviour of other agents performing the same task.

The mathematical model of the agents' behaviour is developed to follow the basic rules of flocking behaviour. In flocking simulations, there is no central control; each agent behaves autonomously. In other words, each agent has to decide for itself which flocks to consider as its environment.

Basic models of flocking behaviour are controlled by three simple rules:

Separation - avoid crowding neighbours (short range repulsion)

Alignment - steer towards average heading of neighbours

Cohesion - steer towards average position of neighbours (long range attraction)
By following these three rules the agents moves and creates complex motion and interaction which results an emerging path network.

Over much iteration many paths emerge but the agents start using the shorter path and the most exclusively used path thus further reinforcing it which makes it the desired path. (Fig 2)

The rules and the variables (velocity, the rotation axis and the distance they can travel) can be related to the Mashoof boat which is the traditional way of transportation in the marshland). (Fig 1)

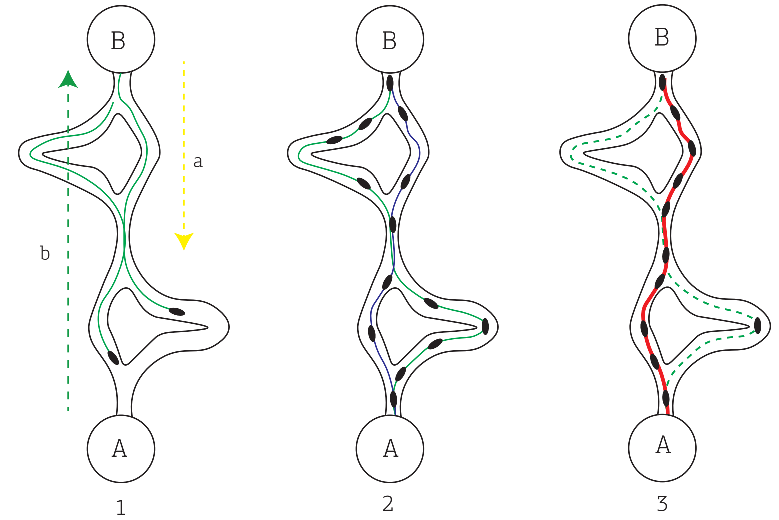
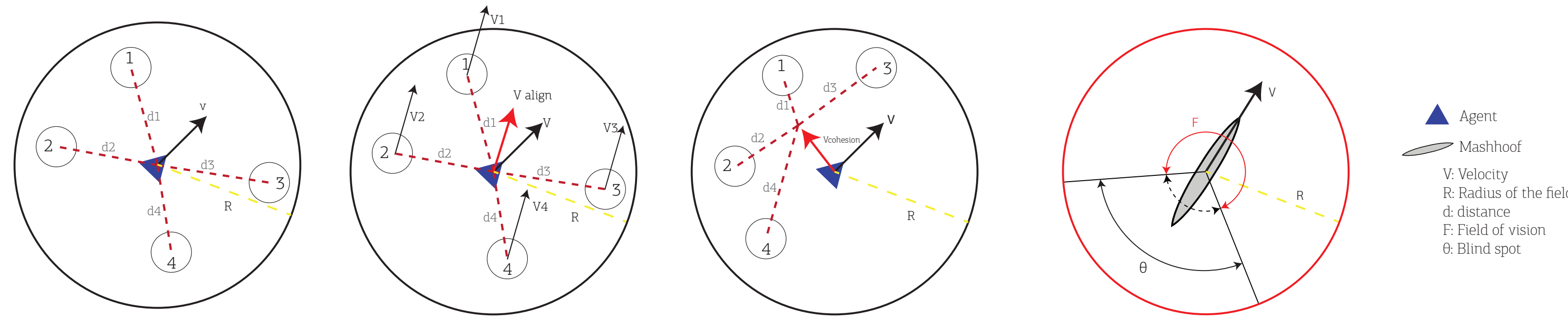


Fig.2



SEPERATION
Move to avoid crowding local flockmates

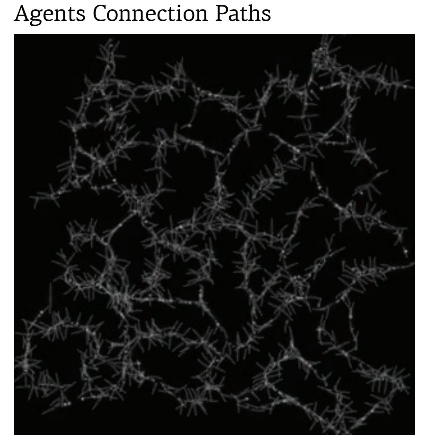
ALIGNMENT
Move towards the average heading of local flockmates

COHESION
Move towards the average position of local flockmates

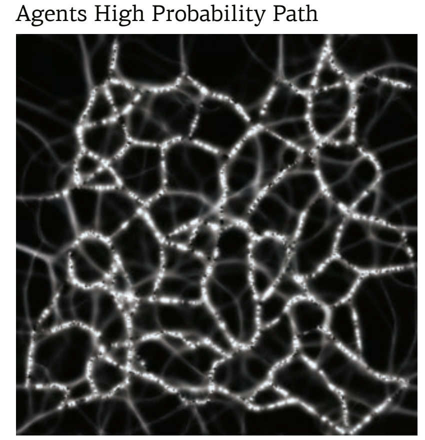
FIELD OF VISION
Radius of Mashhoof rotation limits

Fig.1

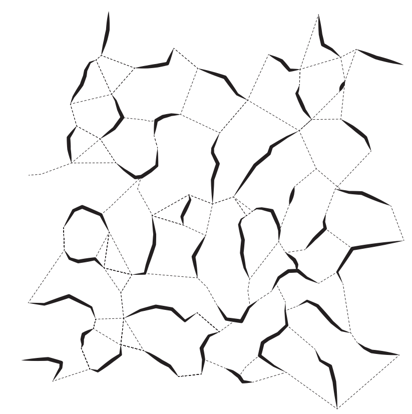
Agents Connection Paths



Agents High Probability Path



Network Connections



4.2 Networks

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S.E 1
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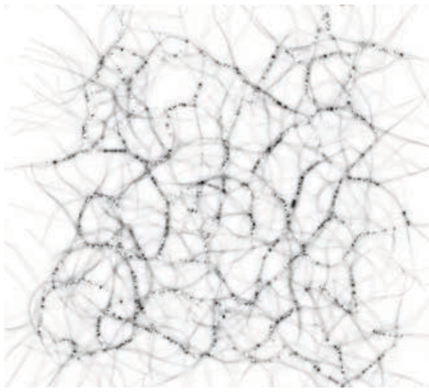
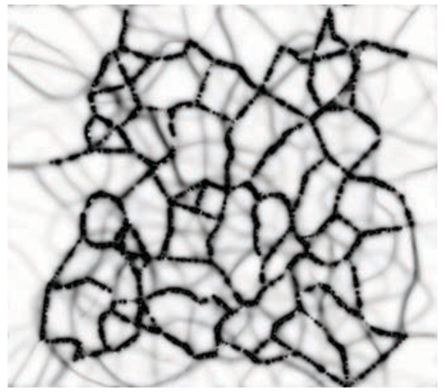
Steering: 0.5
Pheromone: 0.5
Separation: 0.3
Speed: 3

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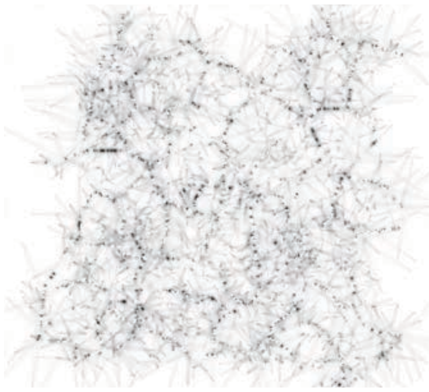
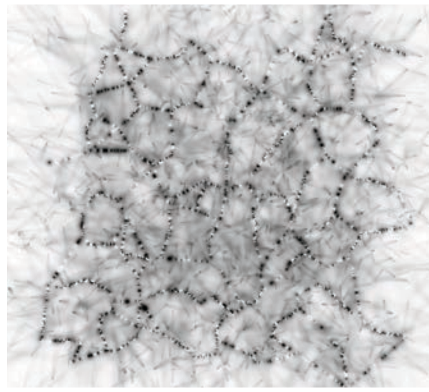
Speed: 3

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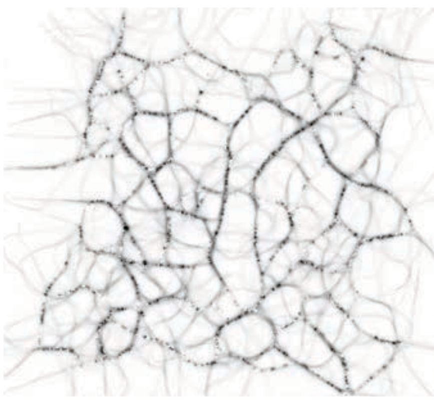
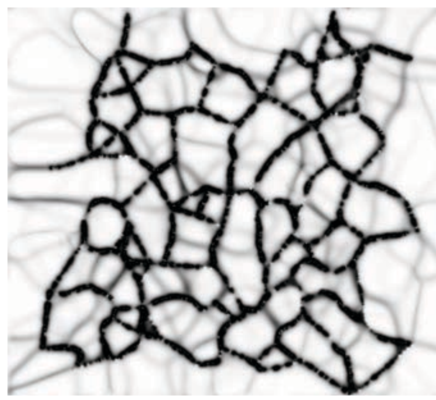

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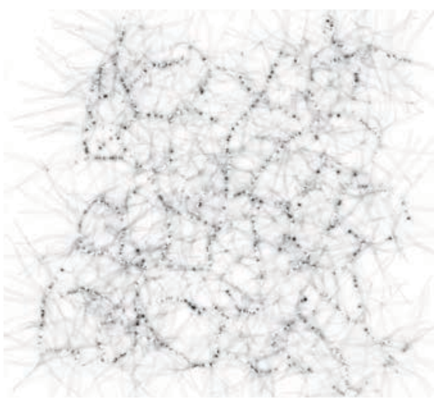
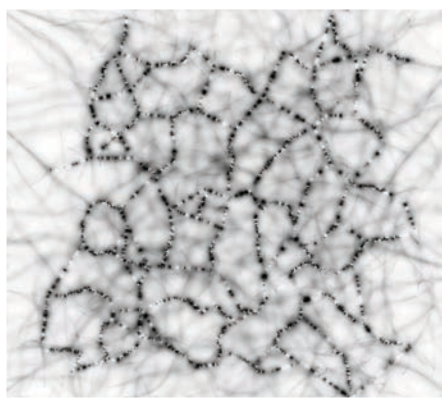
Separation: 0.3
Speed: 3

Frame: 50 | Frame: 200

S.E 5
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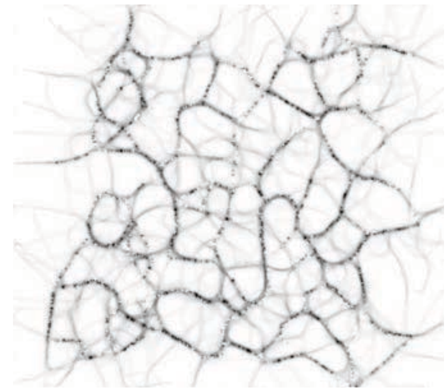
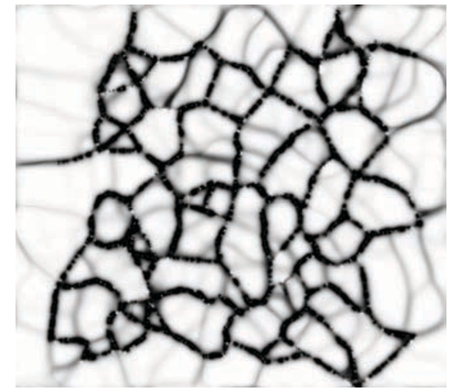
Steering: 1.5
Pheromone: 0.5
Separation: 0.3
Speed: 3

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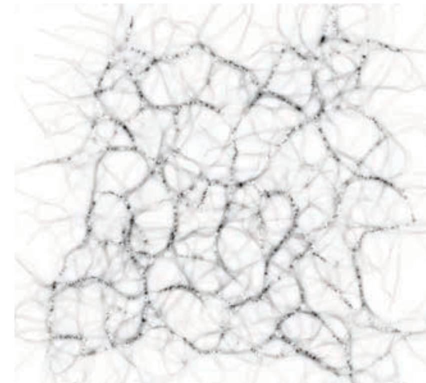
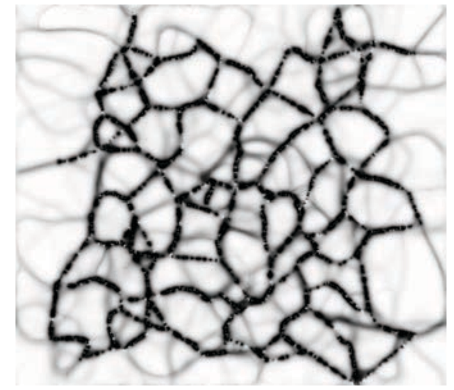
Pheromone: 0.5
Separation: 0.7
Speed: 3

S.E 7
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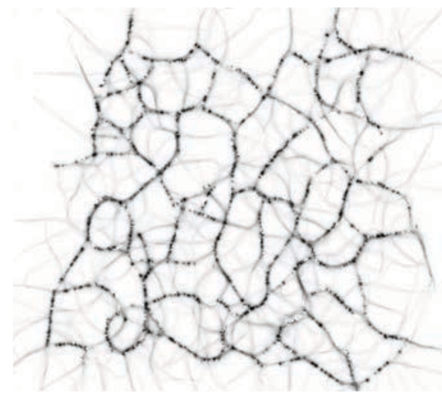
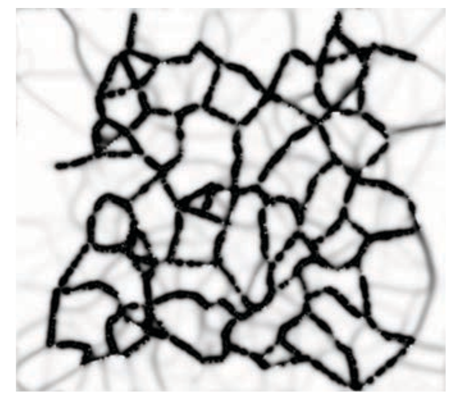
Pheromone: 0.5
Separation: 0.5
Speed: 3

S.E 8
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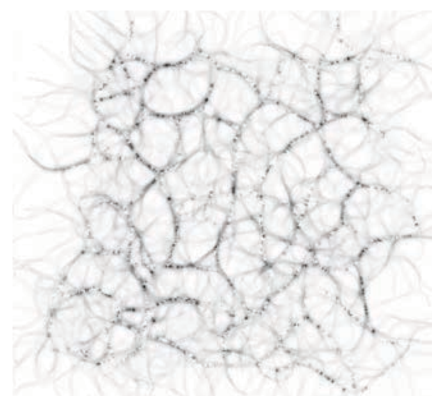
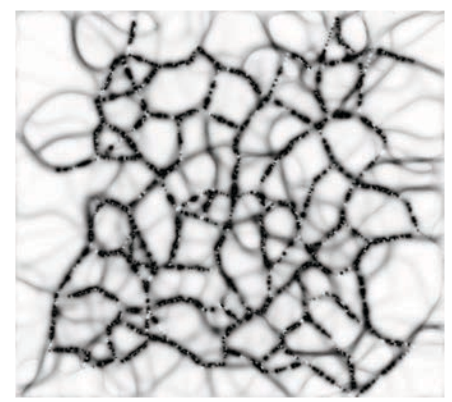
Pheromone: 0.5
Separation: 1
Speed: 3

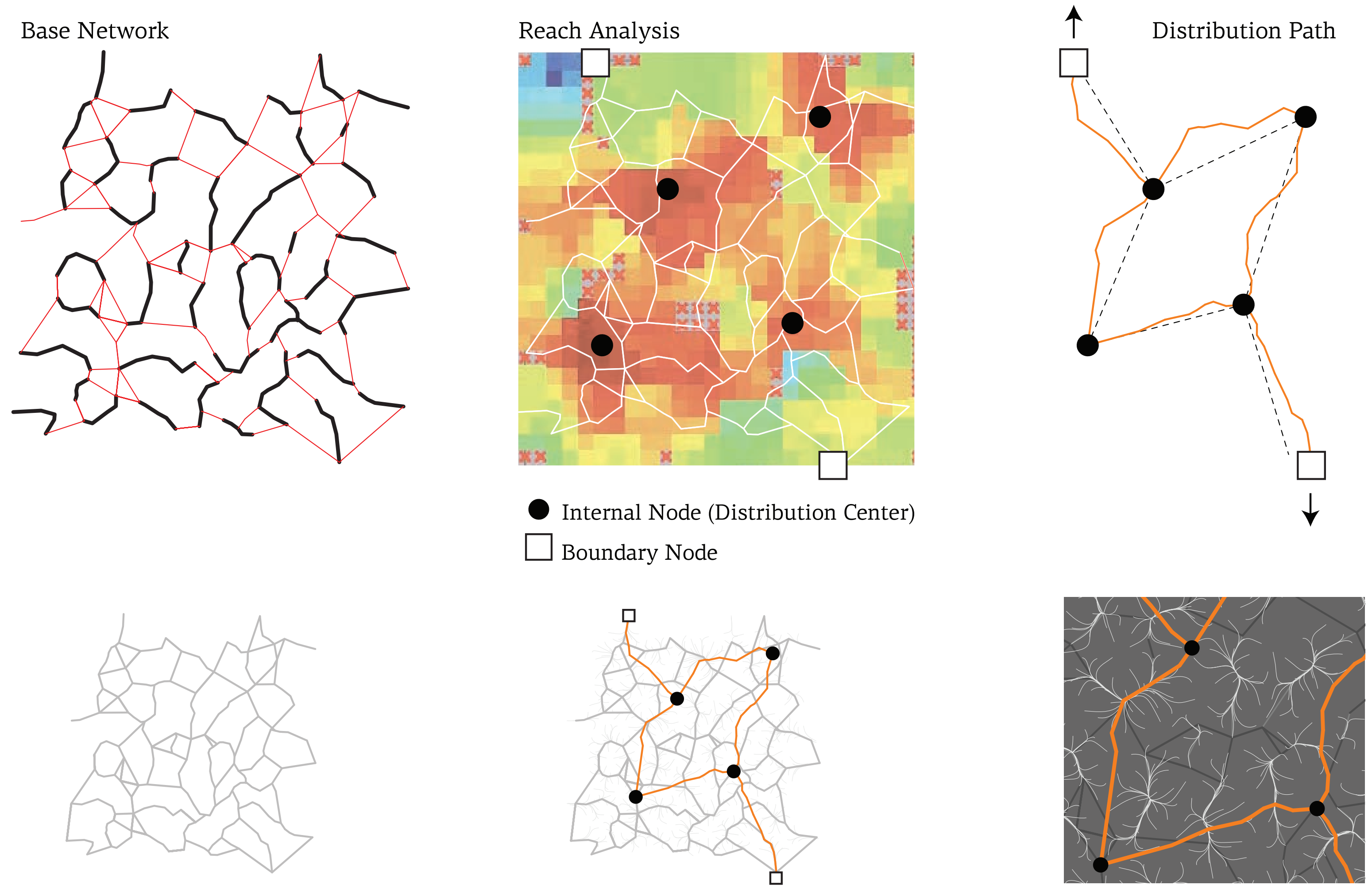
4.2.4 Distribution Path Evaluation

The movement canal network has been created taking into account the logistics of moving products, workers and residents in the unique aquatic environment of the Mesopotamian marshes. The paths have been hierarchically classified according to their expected usage judging by the principle nodes that they accommodate (distribution centres, processing centres, residential islands, productive islands, etc). Thus the canals differ in width (from a few meters to 30m wide) and in depth (from 0.6m to 3m deep) allowing usage for different kinds of boats (see *5.1.4 Logistics Landscapes*). The primary and secondary canals have been selected using an almost top down approach, because they facilitate the products movements that should be as efficient as possible, while the tertiary canals are mainly emergent, bottom-up and reinforced by use (as described before).

After connecting the main paths of the residential clusters with each other (using the already mentioned agent based simulations), the resulting networks were evaluated and ranked using network analysis softwares (integration analysis).

The following step was to position the distribution centres. The distribution centres were placed along the most integrated parts of the network, ensuring that they can be easily reached by as many parts of the network as possible. Local and regional parameters as the position of the distribution centre in relation to the neighbouring productive uses and its proximity to "densely" populated residential clusters further informed the positioning of the centres. After that, the distribution centres were connected to each other (primary canal - distribution path). The canals created were drawn following the existing base network, being within a small deviation from the "optimal" straight connections. Furthermore, the main distribution paths were also drawn in a way that leaves the main productive areas uninterrupted and therefore some connections between them were discarded.

For graphic representation and explanatory reasons the above-described process is shown on the next page using a generic square as a reference "plot", in the same way as in the "residential clusters generation" diagrams.



4.2 Networks

4.2.5 Site Network and Program Distribution

The earlier mentioned techniques for generating networks were applied to the selected site. The area of the site was calculated to fit the total area of production which is needed to sustain the adjacent town Chibayish, while keeping enough natural marsh to retain its wild character. Each type of production is represented as; a circle with a fixed radius. These circles are used as inputs for circle packing algorithm that distributes the different productive functions across the site. Through the use genetic algorithms, the circle packing is optimised to achieve a desirable configuration.

The script was set to optimise for the shortest pipe network that would distribute the desalinised input water to each productive area. This water is assumed to be pumped up from the sea.

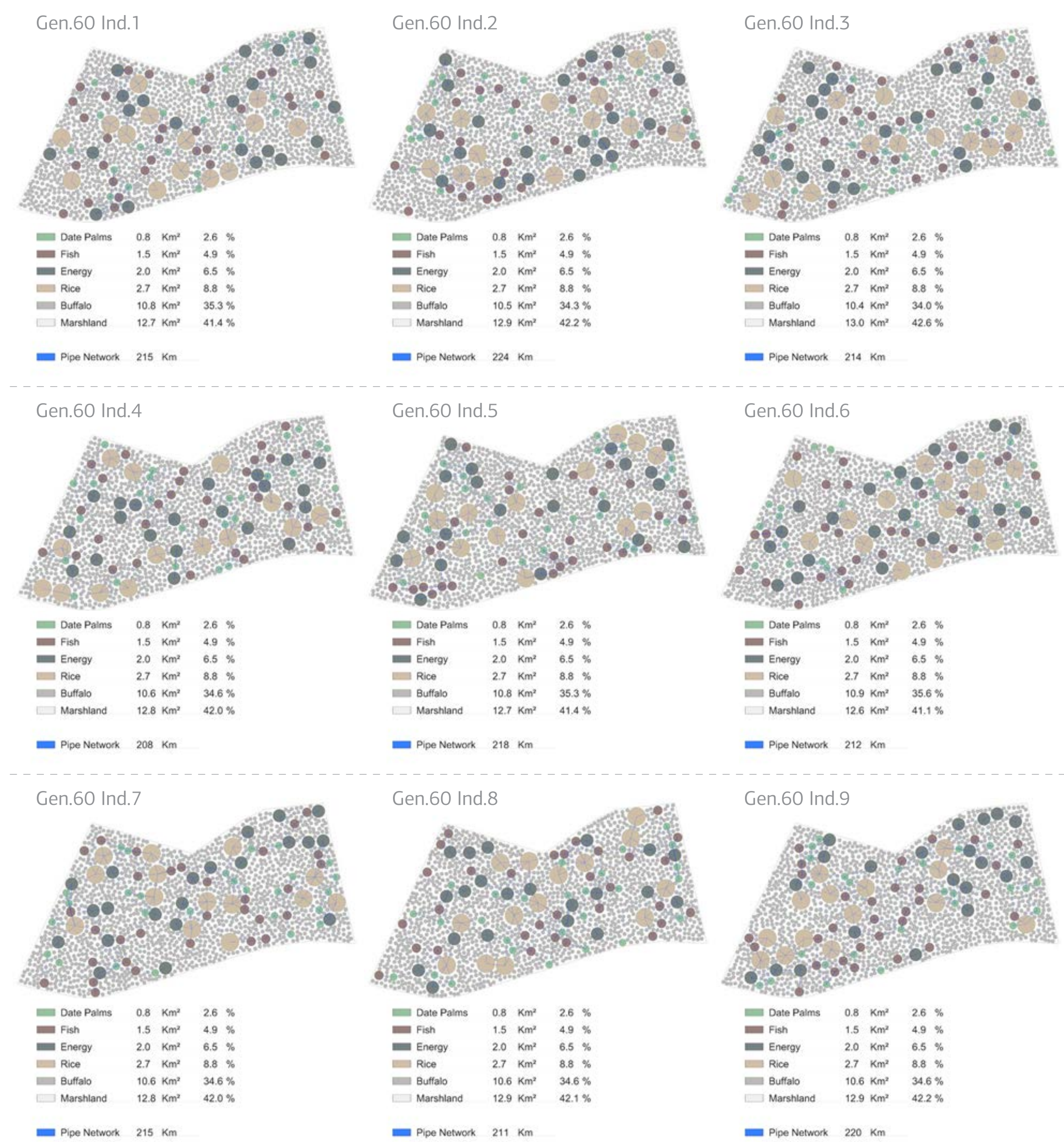
At the same time, the algorithm is set to optimise for the highest number of beneficial relationships between productive zones(see *4.1.3 Synergies*). This was measured through counting the number of connections achieved between products that benefit from interacting with each other. The algorithm evaluates these connections through a proximity reach set within a set radius. Additionally, the algorithm searches for a solution that maintains the set target area for each individual product.

Having completed the land distribution with different circles containing different productive activities, different intensities were assigned to the circles, according to the intensity of the productive activity that is taking place there. This was then used to generate the residential clusters through a magnetic field simulation(see *4.2.2 Generation of Base Network*).

When the residential cluster had been generated, a network could be found through connecting the central paths of the clusters through an agent simulation of coordinated behaviour(see *4.2.3 Generation of Integrated Network*). The networks were then evaluated through integration using Space Syntax.

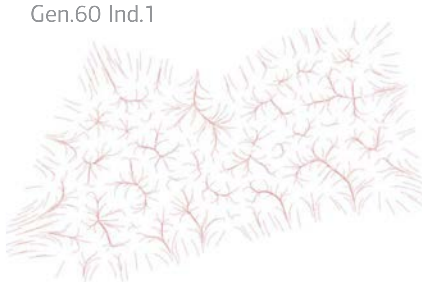
In order to find the location of the distribution centres a reach analysis was conducted using Urban Network Analysis toolbox. The outcomes were evaluated in search of the highest average reach index of the whole site.

When having generated the network and the location of the distribution centres, the main distribution paths could be defined. The canals following these paths would have to be wider and deeper in order to be able to fit the larger ships and traffic of export, creating a hierarchy in the network. These paths were evaluated through calculating the deviation from the virtual straight path from the distribution centres to the canals connecting to the Euphrates river.



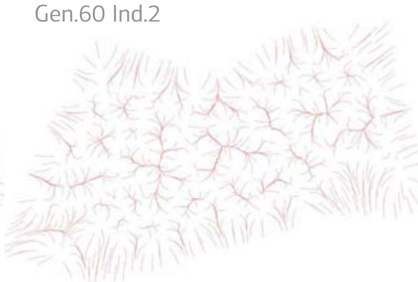
4.2 Networks

Gen.60 Ind.1



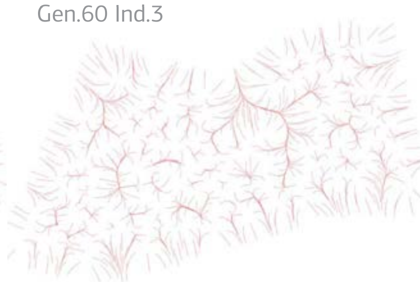
Cluster Count: 29

Gen.60 Ind.2



Cluster Count: 24

Gen.60 Ind.3

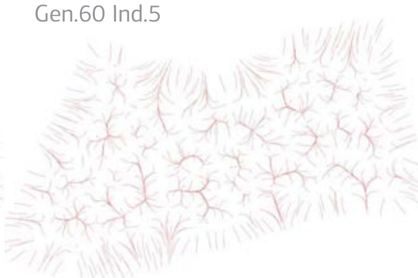


Cluster Count: 39

Gen.60 Ind.4

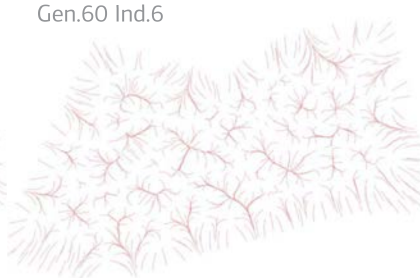
Cluster Count: 34

Gen.60 Ind.5



Cluster Count: 33

Gen.60 Ind.6



Cluster Count: 27

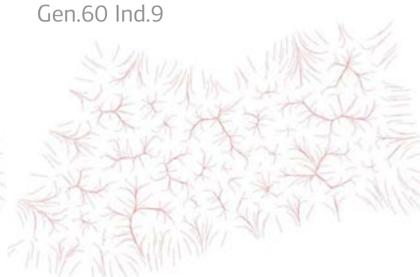
Gen.60 Ind.7

Cluster Count: 28

Gen.60 Ind.8

Cluster Count: 40

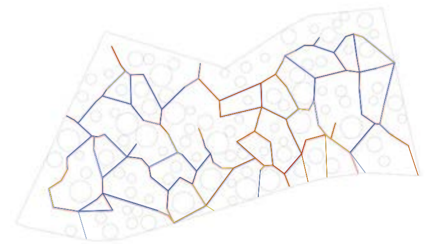
Gen.60 Ind.9



Cluster Count: 35

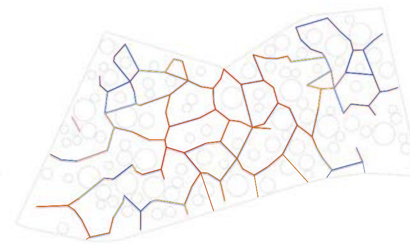
The residential clusters were generated through a magnetic field simulation. The paths from the residential nodes were pushed out from the production areas and forced to connect, creating clusters with a central path.

Gen.60 Ind.1



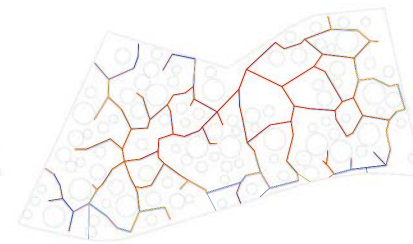
HH Integration: 0.0439

Gen.60 Ind.2



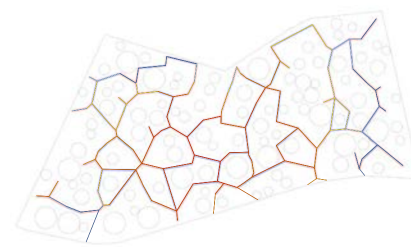
HH Integration: 0.0919

Gen.60 Ind.3



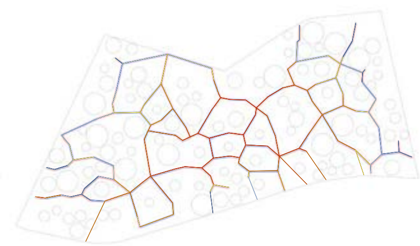
HH Integration: 0.1326

Gen.60 Ind.4



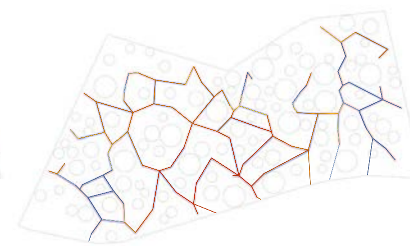
HH Integration: 0.1014

Gen.60 Ind.5



HH Integration: 0.0945

Gen.60 Ind.6

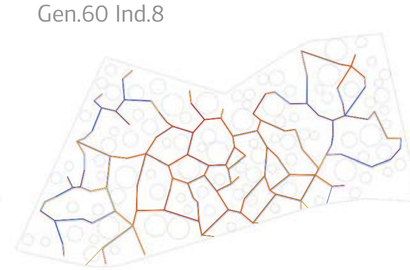


HH Integration: 0.0821

Gen.60 Ind.7

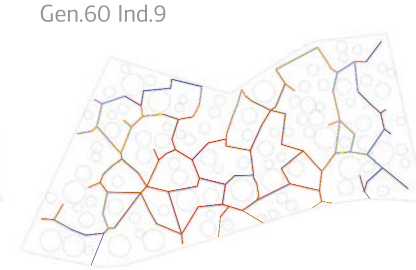
HH Integration: 0.0325

Gen.60 Ind.8



HH Integration: 0.0579

Gen.60 Ind.9

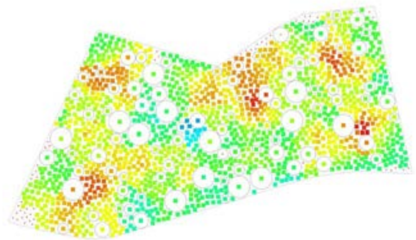


HH Integration: 0.0726

The network was generated by finding connections between the central paths of the residential clusters. The connection were generated through an agent based simulation of coordinated behaviour

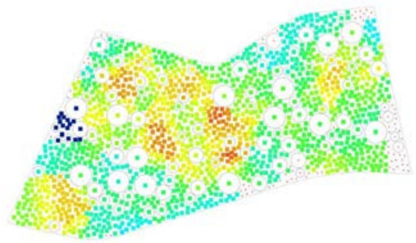
4.2 Networks

Gen.60 Ind.1



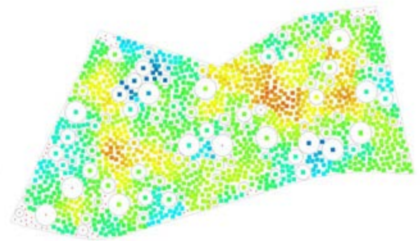
Average Reach: 78
D.C. Count: 5

Gen.60 Ind.2



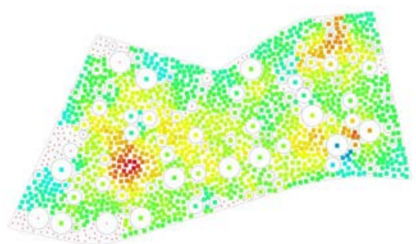
Average Reach: 67
D.C. Count: 3

Gen.60 Ind.3



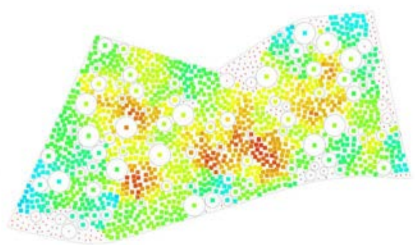
Average Reach: 69
D.C. Count: 3

Gen.60 Ind.4



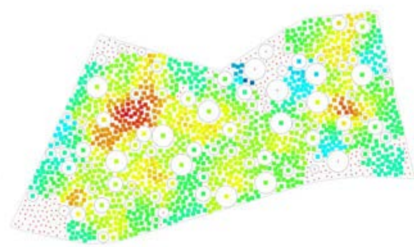
Average Reach: 68
D.C. Count: 3

Gen.60 Ind.5



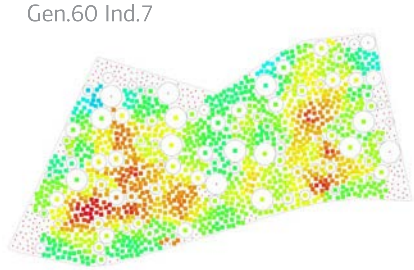
Average Reach: 69
D.C. Count: 4

Gen.60 Ind.6



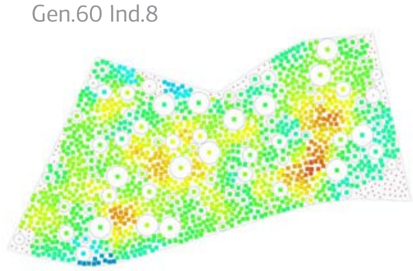
Average Reach: 65
D.C. Count: 2

Gen.60 Ind.7



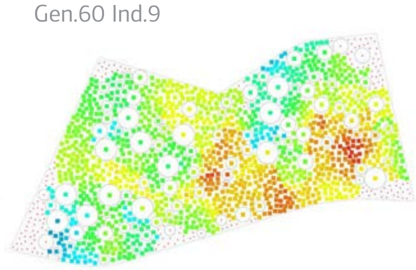
Average Reach: 70
D.C. Count: 4

Gen.60 Ind.8



Average Reach: 66
D.C. Count: 2

Gen.60 Ind.9



Average Reach: 68
D.C. Count: 2

Urban Network Analysis toolbox was used to find the location of the distribution centres and evaluate the outcome through the average reach index

Gen.60 Ind.1

Deviation Path: 0.67

Gen.60 Ind.2

Deviation Path: 0.69

Gen.60 Ind.3

Deviation Path: 0.71

Gen.60 Ind.4

Deviation Path: 0.73

Gen.60 Ind.5

Deviation Path: 0.74

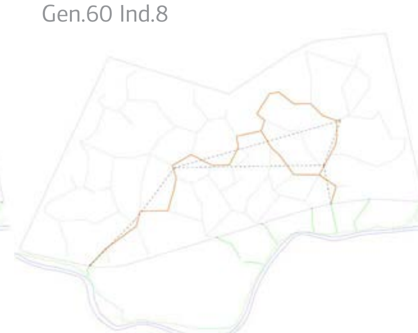
Gen.60 Ind.6

Deviation Path: 0.80

Gen.60 Ind.7

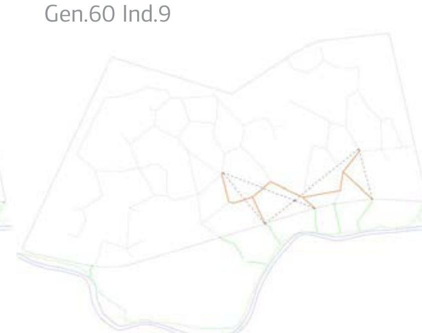
Deviation Path: 0.52

Gen.60 Ind.8



Deviation Path: 0.65

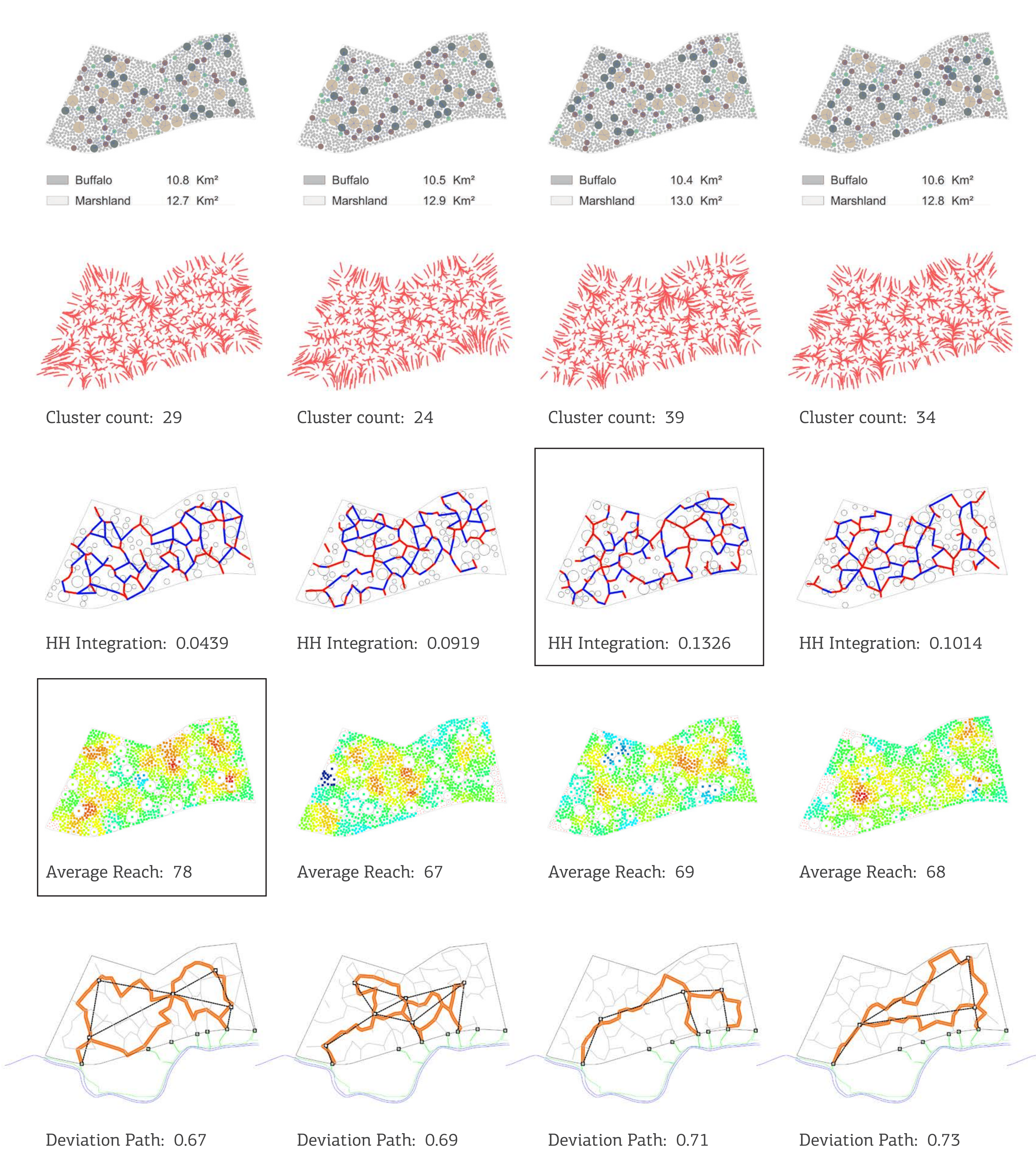
Gen.60 Ind.9

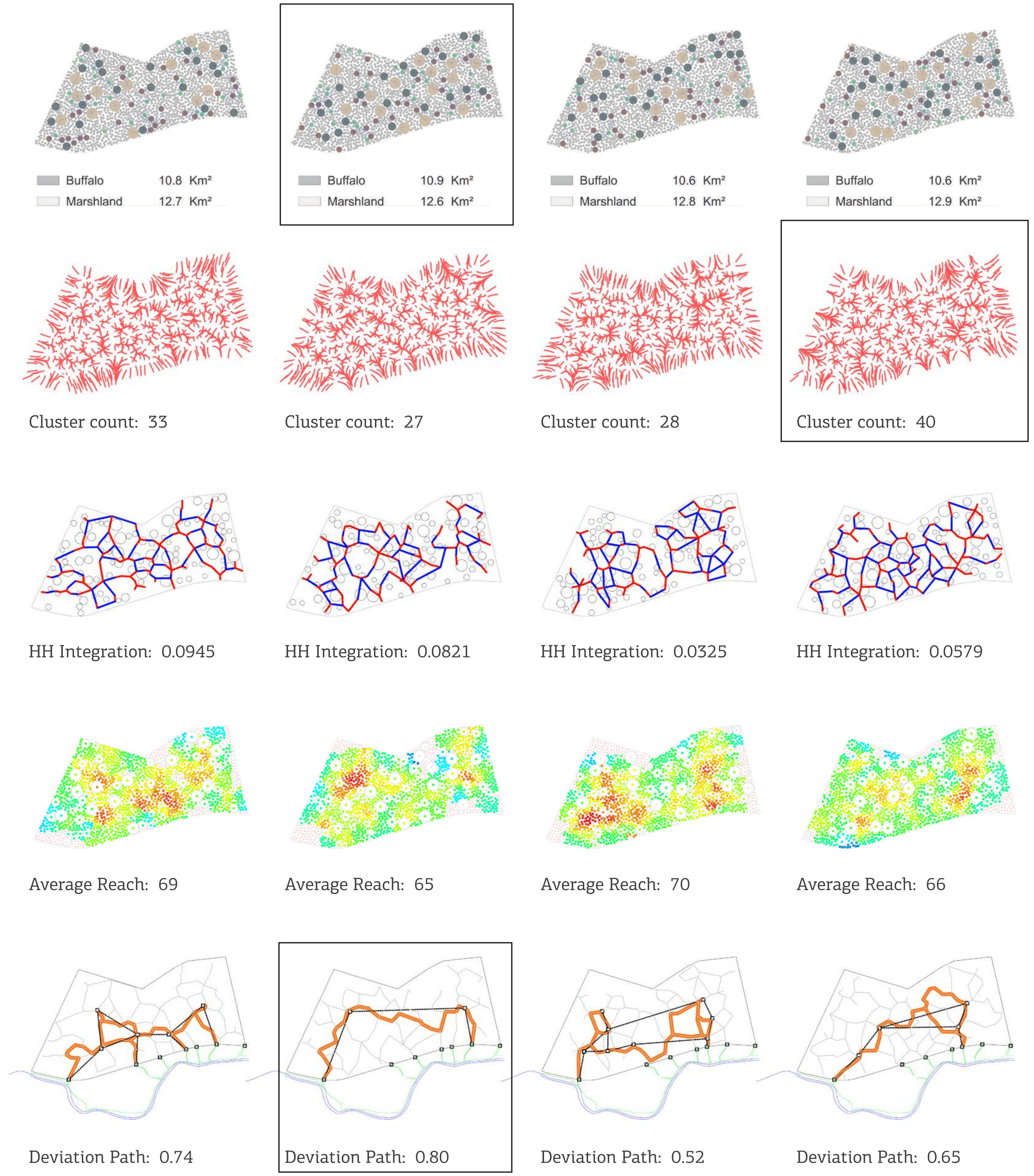


Deviation Path: 0.72

The distribution paths were defined through finding the shortest path from the distribution centres to the existing canals connecting to the Euphrates river. They were evaluated in search for the least deviation to the virtual straight path.

4.2 Networks


Buffalo 10.8 Km²
Marshland 12.7 Km²
Buffalo 10.5 Km²
Marshland 12.9 Km²
Buffalo 10.4 Km²
Marshland 13.0 Km²
Buffalo 10.6 Km²
Marshland 12.8 Km²
Cluster count: 29
Cluster count: 24
Cluster count: 39
Cluster count: 34
HH Integration: 0.0439
HH Integration: 0.0919
HH Integration: 0.1326
HH Integration: 0.1014
Average Reach: 78
Average Reach: 67
Average Reach: 69
Average Reach: 68
Deviation Path: 0.67
Deviation Path: 0.69
Deviation Path: 0.71
Deviation Path: 0.73


Buffalo 10.8 Km²
Marshland 12.7 Km²
Buffalo 10.9 Km²
Marshland 12.6 Km²
Buffalo 10.6 Km²
Marshland 12.8 Km²
Buffalo 10.6 Km²
Marshland 12.9 Km²
Cluster count: 33
Cluster count: 27
Cluster count: 28
Cluster count: 40
HH Integration: 0.0945
HH Integration: 0.0821
HH Integration: 0.0325
HH Integration: 0.0579
Average Reach: 69
Average Reach: 65
Average Reach: 70
Average Reach: 66
Deviation Path: 0.74
Deviation Path: 0.80
Deviation Path: 0.52
Deviation Path: 0.65

5.0 Design Proposal
5.1 Design Proposal

5.1 Design Proposal

5.1.1 Design Outcome

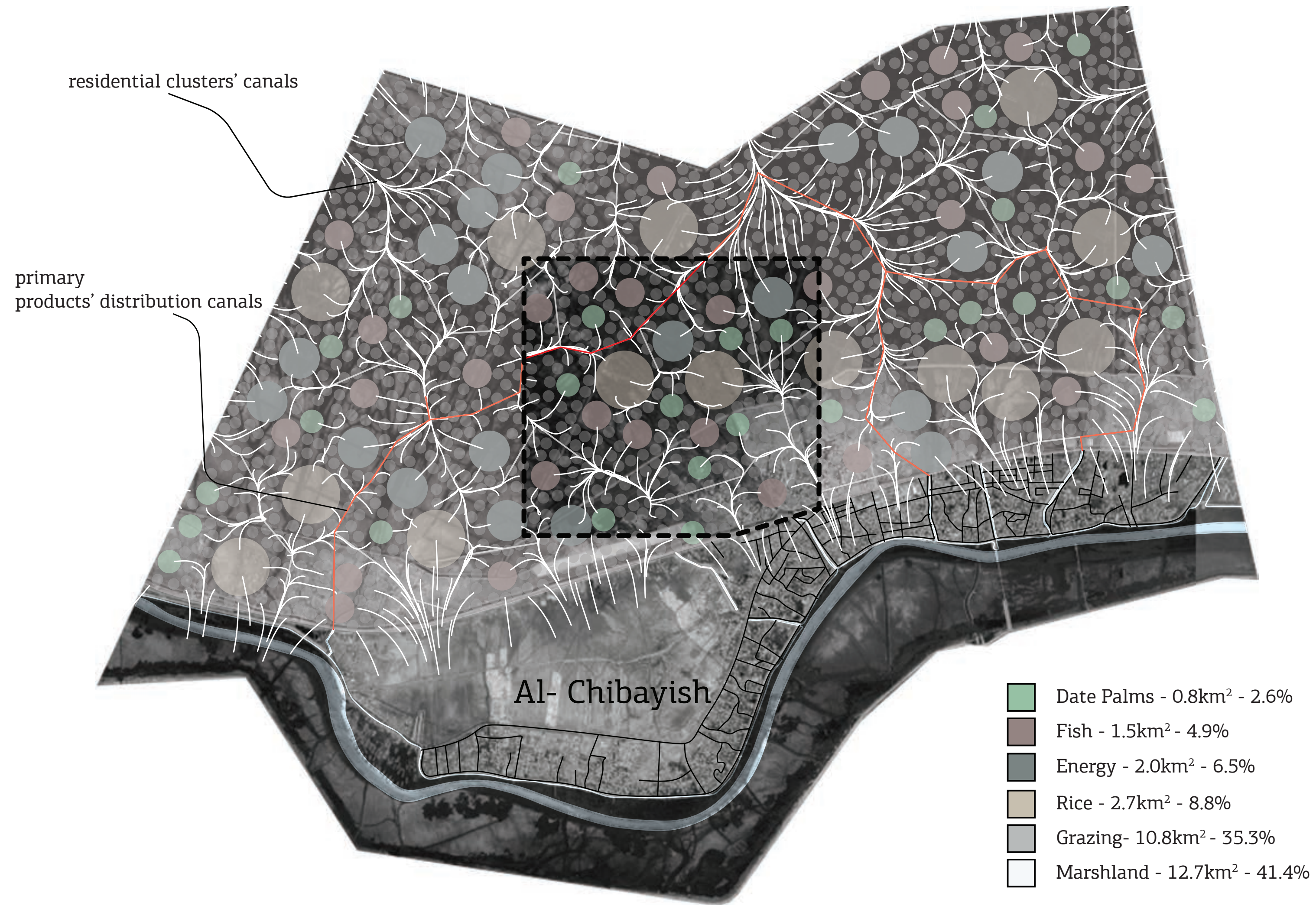
After analysing, comparing and ranking all the individuals generated through the program distribution phase the solution that best responded to all the criteria presented before was selected and further designed. Some of the criteria were conflicting and there was no solution that was the fittest according to all the criteria. Therefore the selected solution was the one that responded the best to all the criteria on average and in relation with the existing context of the city of Chibaysh and it's existing main canals-water inlets. The selected individual solution contained the best integrated network, a big amount of residential clusters, high average reach and the deviation of the main distribution path was within the limits.

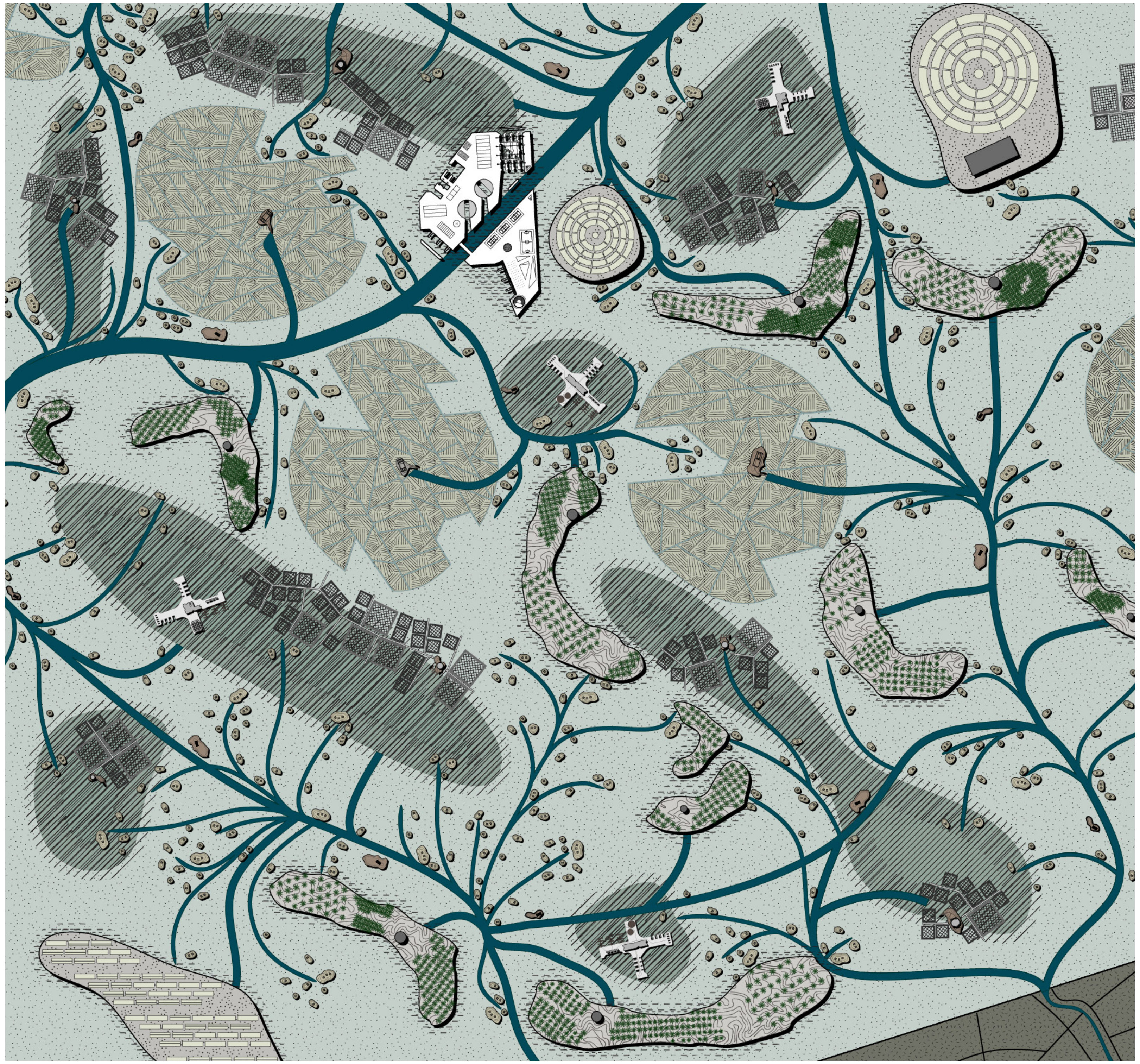
The expected amount of production fitted in the selected plot exceeds the current consumption needs of the inhabitants of Chibaysh plus the new inhabitants needed to work/live in the marsh area itself. To design a more elaborated version of this plan we further zoomed in, choosing a 3km*3km patch, which includes all the different features found in the biggest plot.

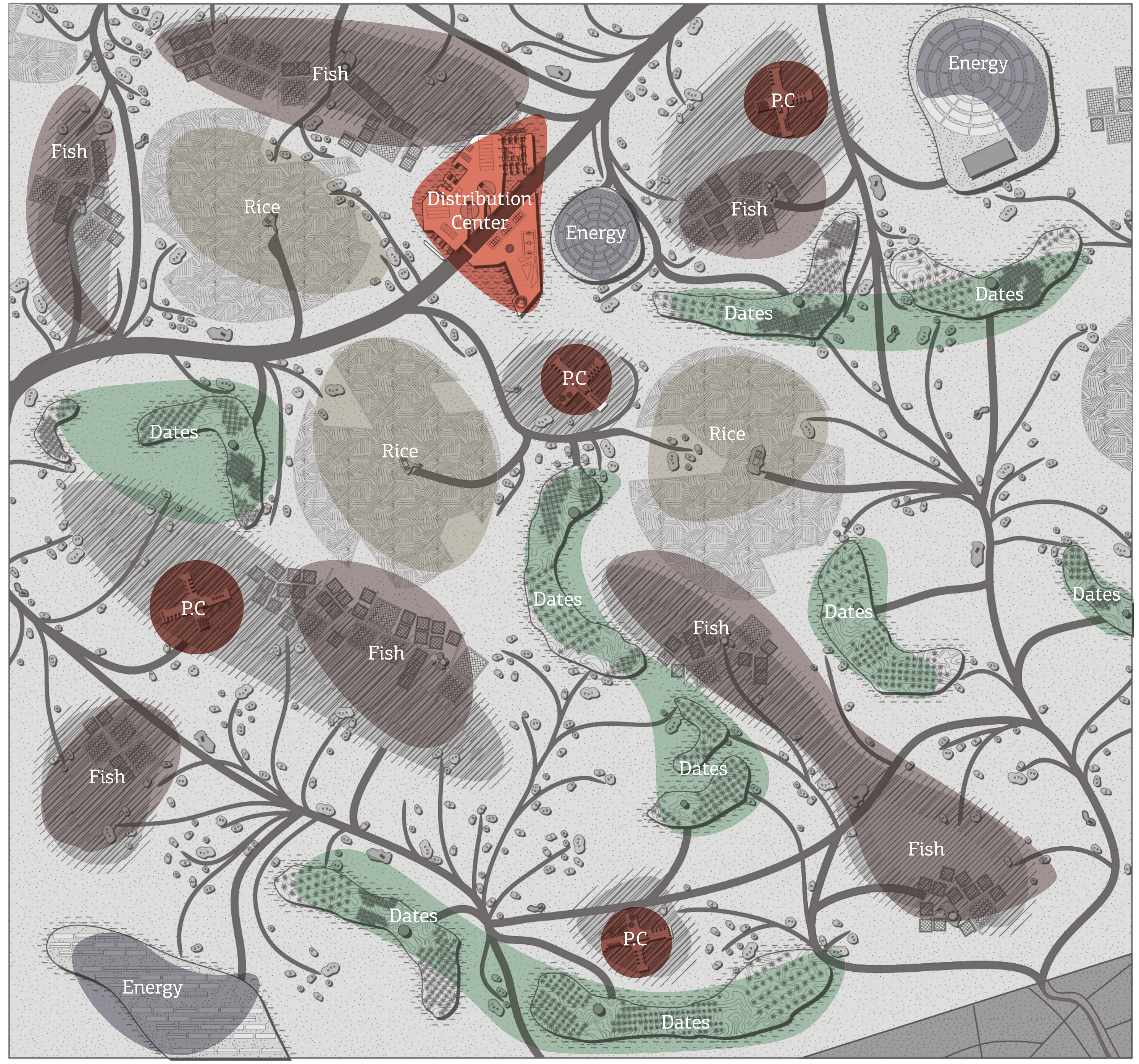
The 3km*3km plot, marked out on the previous page, has been further designed and contains most of the different residential, production and infrastructural typologies that were explored throughout this project. First of all, the water canals vary in width and length, depending on the ships that use them. The primary canal is 30m wide and several meters deep. This canal is designed to fit several medium to big cargo ships and many more smaller ones and it connects the distribution centres to each other and to the Euphrates river. The secondary canals are around 15m wide and connect all the water tanks - collection points with the processing centres and the main canal. The tertiary canals are branching out from the secondary canals and their width and depth are dependent on their usage. The busier the canal, the wider and deeper it becomes (see *4.2.4 Networks, Emergent paths*). The residential islands' clusters are formed along the tertiary paths. Furthermore, the residential islands can range from islands with a single family house, a multi-family house to bigger islands with several residential units and small stables for their water buffaloes or poultry.

The outline of the various productive zones has been deformed - the circle that was used to signify the area is no more readable - based on the local interactions between the different productive or residential zones. The water tanks, however, remained on the centre of the circles used before, in order to ensure the controlled distribution of water for agricultural reasons or for the periodical "flushing", done to clean the soil from the various dissolved solids. Moreover, the islands used for dates production have acquired this elongated shapes in order to provide land connections between different residential clusters. By doing so, they could host various social activities and provide a terrain for social interaction, harnessing the shadows of the palm trees and their proximity to various residential clusters.

The distribution centre acts as the logistics centre of a broader area. It is the place where various processed or raw products are gathered to be sent away to the rest of the country through Euphrates. It is also the input gate for those products that are not available in the marshes and are being imported or exchanged. The processing centres are the intermediate nodes between the collection points - water tanks - and the distribution centres. Each product is served by a different processing centre (PC), in order to maximise the efficiency of the production. The frequency of use differs significantly between different processing centres. The fish processing centre can be used daily while the rice pc is used twice per year, the dates pc once a year, etc. The frequency of use depends on how many harvest is each product giving per year. Thus, in order to utilise and inhabit the infrastructure throughout the year, the pieces of built infrastructure that are land intensive but necessary for only short periods of time are being "charged" with another, social function (schools, health centres, markets, communal houses, etc), which they carry for the rest of the year.







Palm trees	Rice
Energy	Processing Center
Fish	Distribution Center

5.1 Design Proposal

5.1.2 Infrastructure as Architecture

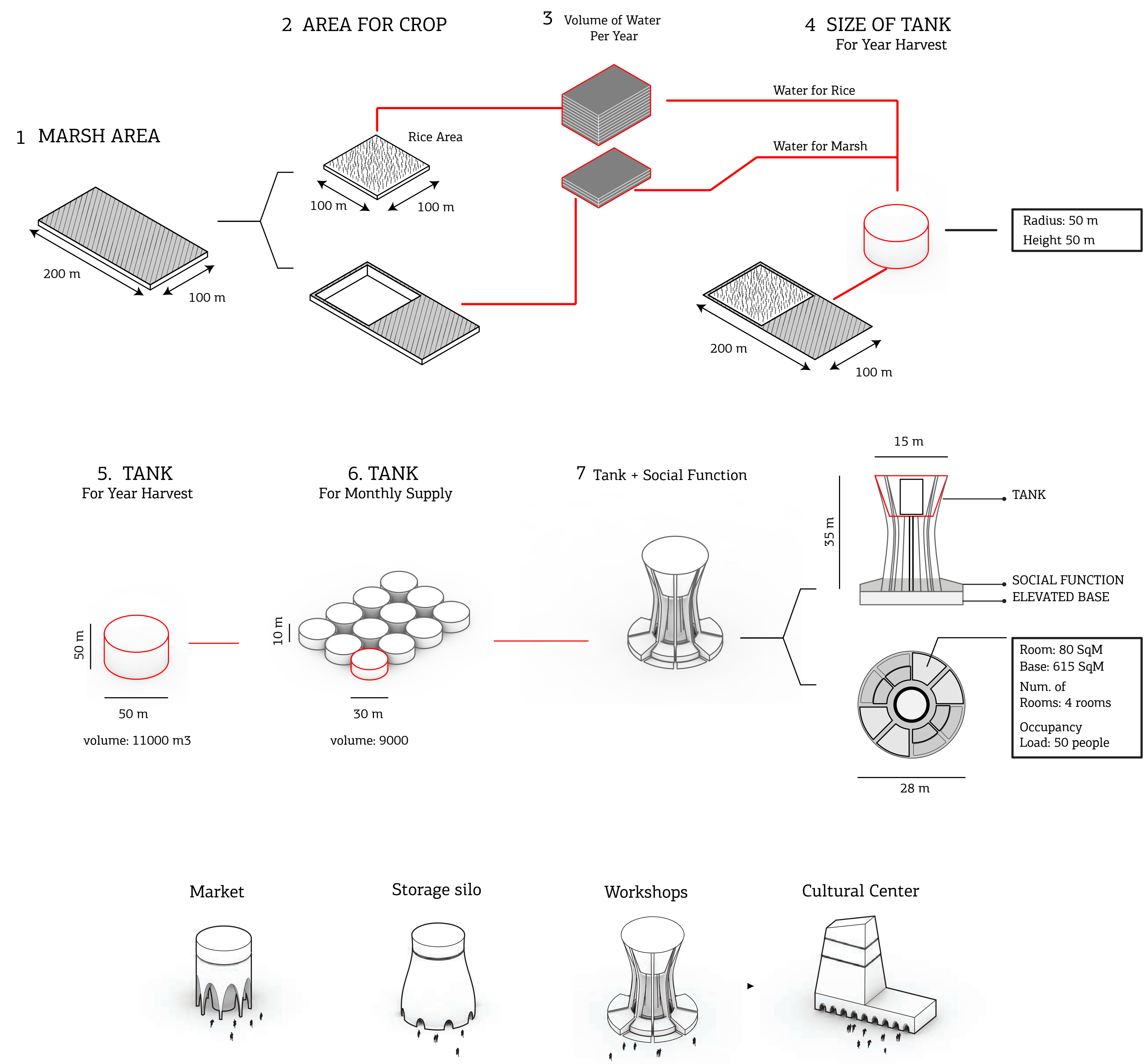
The series of images of industrial structures that photograhers Bernd and Hilla Becher's put together in their work "typologies" suggest a space of possibility for design and calls attention to everyday buildings that are often ignored and unacknowledged by the design professions. Water tanks, silos, factories and processing facilities of different shapes are arrayed on a grid allowing the viewer to focus on the little details that make them unique and different. Despite the enormous importance that these buildings have in supporting human activities, the planning of infrastructure has been relegated to the engineering professions with very little input from architects and design professionals. Perhaps the shift of interest away from infrastructure coincides with the loss of interest in the countryside where most of these buildings and their related functions take place. This has not been always the case, the visionary work of Claude Nicolas Ledoux, the house for the waterworks managers (maison des directeurs de la loue) is evidence of a time when architects were invested in the design of infrastructure as an architecture that could take on multiple forms and serve various purposes.

As the main infrastructural element and backbone of the project, the water tank fulfills three main functions. For its ecological function tank can store and supply fresh water to the marshes facilitating the movement of water throughout the ecosystem. For its economic function, the tank controls and regulates the amount and time at which water is supplied to the various productive areas. For its social function, the tank provides a space for human occupation which can take on a variety of uses relative to its location within the network and its size.

The size of the tank is dictated by calculating the volume of water required for a year supply of water to the marshes and the productive areas. The diagram on the right shows the process of sizing the tanks and the variables involved in the calculations. In this example, a sample area was selected to illustrate the process. The water demand requirements for the marsh and rice production are calculated to obtain the volume needed to contain the water for a year supply. Because the size obtained would typically be very large to be built, the volume is divided by twelve to provide a monthly supply bringing down the size of the building to a working planning dimensions. In this case, the planning depth of the base of the building is close to 10 meters from envelope to core providing a space about 600 SqM, which could hold an occupancy load of 50 people. This building could be used as a workshop space or learning center to serve a community of 300 people.

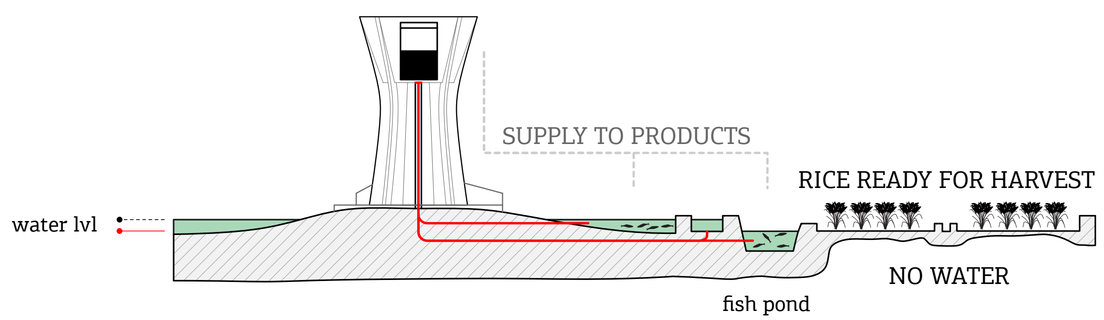
- (tvs) tank volume size
- (x) marsh area
- (y) marsh depth
- (z) product area
- (pwr) product water req.
- (t) months

$$\text{tvs} = \frac{((x * y) - (z*y))+(pwr*z))}{t}$$

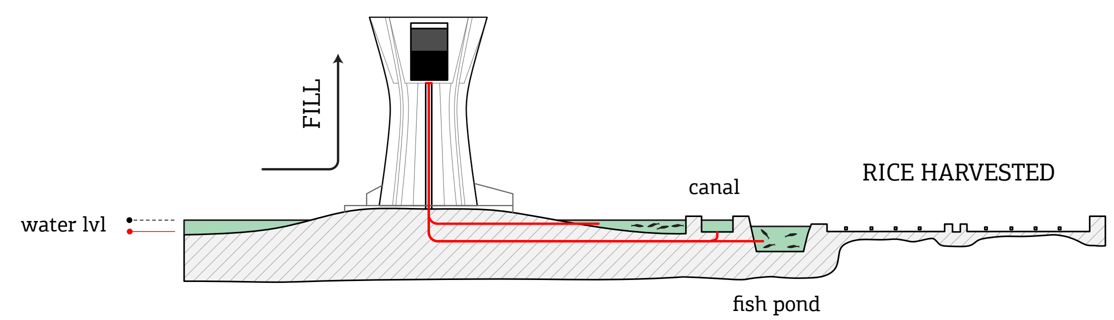


5.1 Design Proposal

As described earlier in this book, the water tank fulfills three main functions. [1] Provide water to the marshes. [2] Supply water to products. And [3] provide space for a social function such as a school or learning center. The following diagrams illustrate the relation between the tank, the marsh and the productive zones during a harvest season.

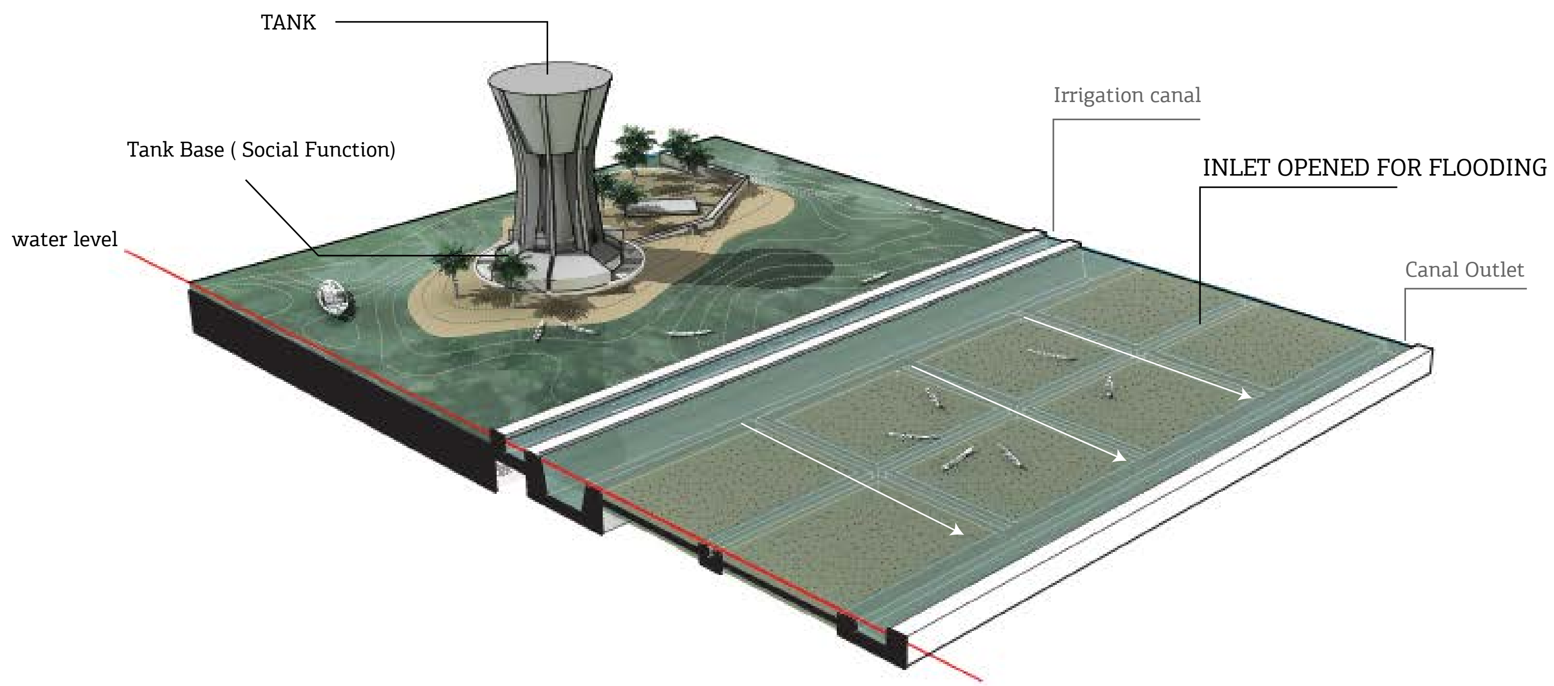


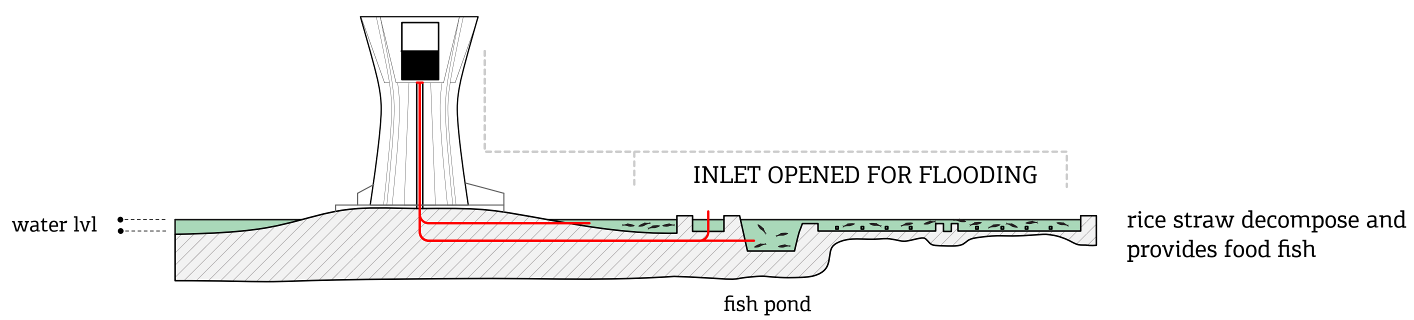
1. During this time of the year rice is ready to be harvested. At this point, water is no longer being supplied to the rice fields. Water is stored in the tank and in the marshes.



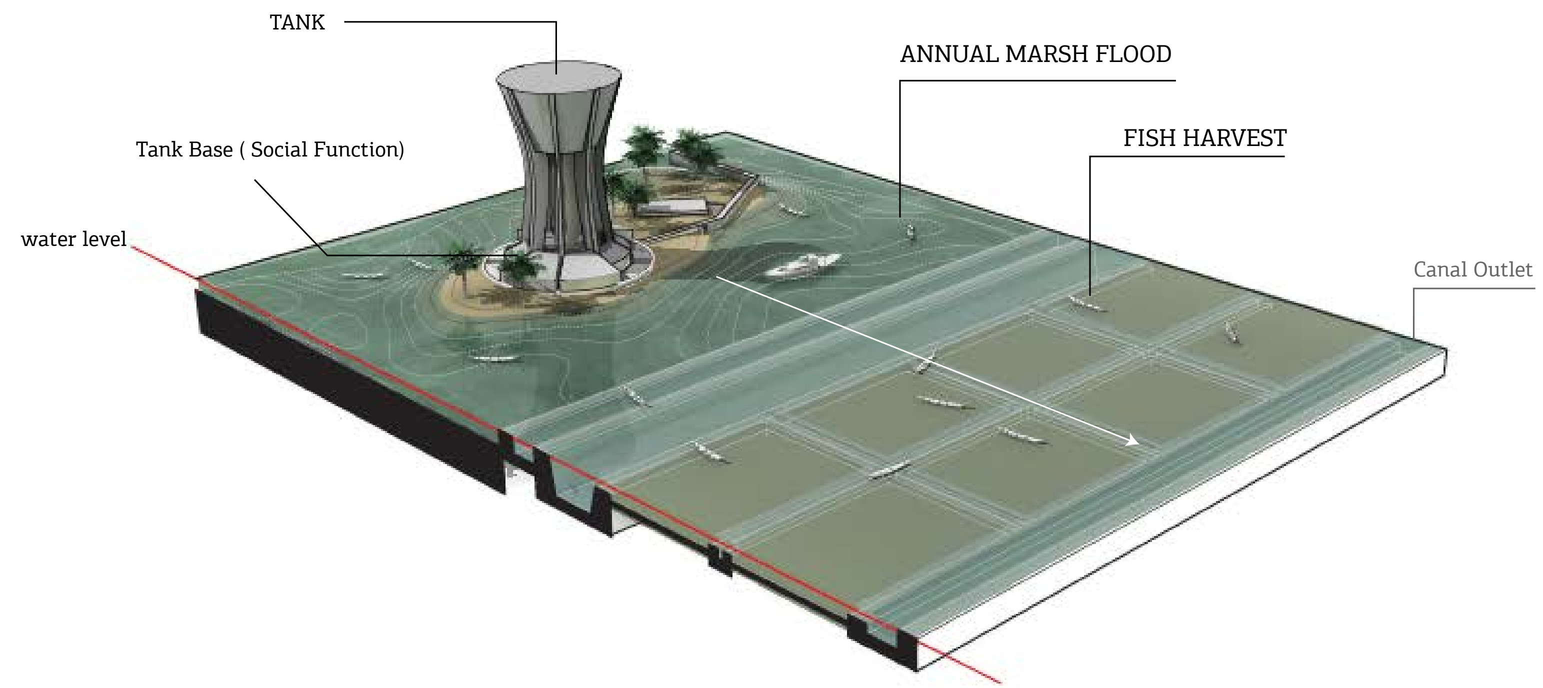
At this point the rice produce has been collected and moved to the collection center. There is no water in the rice fields and rice straw is left to decompose. Water keeps accumulating in the tank and stored in the marshes.

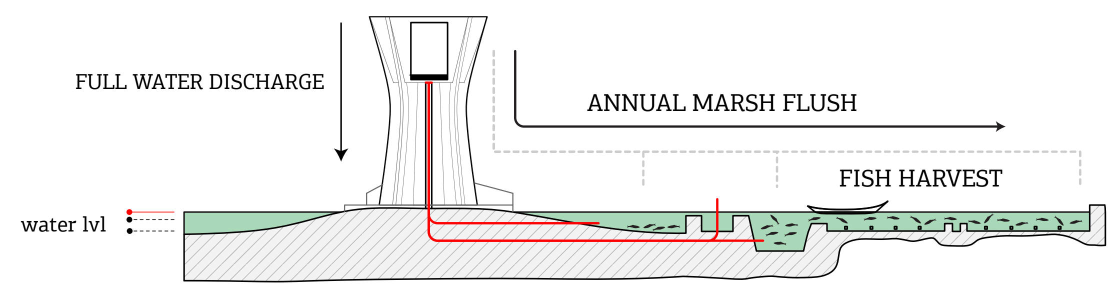
5.1 Design Proposal





A couple weeks after, the inlet of water is opened for the first flooding. The level of water rises and fish can now move from the fish ponds to the rice fields. Decomposed rice straw lying on the soil of the field provides food for fish and other animals.





Finally water is fully discharge from the tank simulating the annual spring flood. Fish can be first harvested from the productive zones and when the water level rises wild fish can move into the fields for a second fish harvest.

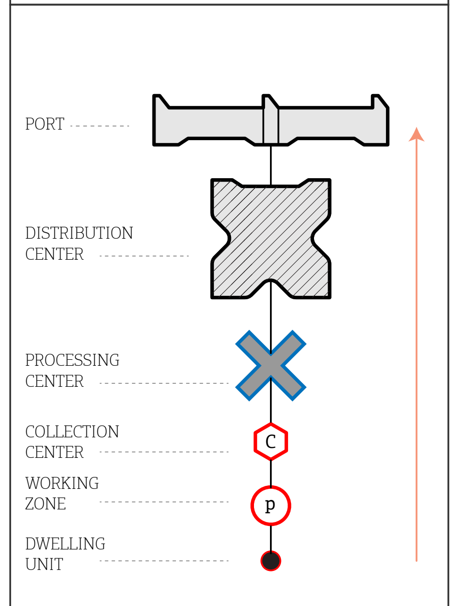
5.1 Design Proposal

5.1.3 *Logistics Landscapes*

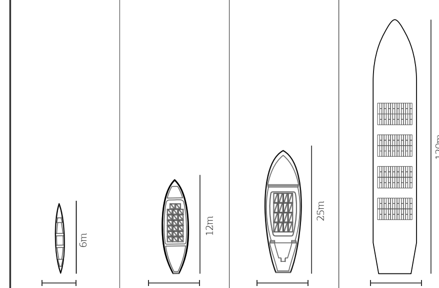
The entire global industrial economy can be understood as a network of industrial processes though which resources are extracted and transformed into goods and commodities to meet the needs of human society. The intensification of demand for consumer goods due to urbanisation has generated the emergence of complex distribution networks and logistics landscapes. Susan Synder and Alex Wall, in their essay "Emerging Landscapes of Movement and Logistics" offer a clear argument for the increasing role of logistics in shaping and reordering the spatial conditions of the global economy. Wall's essay notes that "the organisation of movement, infrastructure and new industrial ensembles has traditionally been at the fringes of design". However, he argues that distribution networks are precipitating new urban assembles and could become the basis for the design of new settlements.

A distribution network is composed of multiple nodes where resources are extracted, refined and synthesised throughout various production stages, moved through logistical and commercial routes and then consumed by end users. Distribution networks are not homogeneous, instead they organise hierarchically at multiple levels generating hubs where activity concentrates. Hubs are nodes that are particularly important within the network because of the number of connections they hold and amount of movement of people, goods and information that passes through them. With this in mind, a network was developed to bring together the different elements of the project and organise the movement of people throughout the site. Different nodes create different amounts of movement and establish different flows throughout the site. The basic structure of nodes starts at the dwelling unit which holds around 2 to 5 people. From a dwelling unit, a worker would move into a productive zone to work on a particular produce. The product would be collected by the worker and move to a collection centre. At the collection centre, the produce is packed into boxes or containers to be moved in bulk to the processes sing centre. At the processing centre, workers would take the raw product and processes it for human consumption. The final output would be packed in larger containers to be moved to the distribution centre. At the distribution centre, multiple products and workers come together to sell and buy their products. The collection centre, processing centre and distribution centre provide additional social functions, such as health, recreation, culture and learning facilities. These functions are distributed according to the position and weight (amount of connections) particular to each node. Despite the hierarchical order set up by the design, the network is scale free and is able to grow and contract over-time. A scale free network has a high degree of heterogeneous distribution and randomness. As described in previous sections, this type of networks can be described by a "power law" distribution; there are few important nodes with many connections and a "fat tale" of nodes with very fewer connections.

DISTRIBUTION NODES



TRANSPORT VESSELS

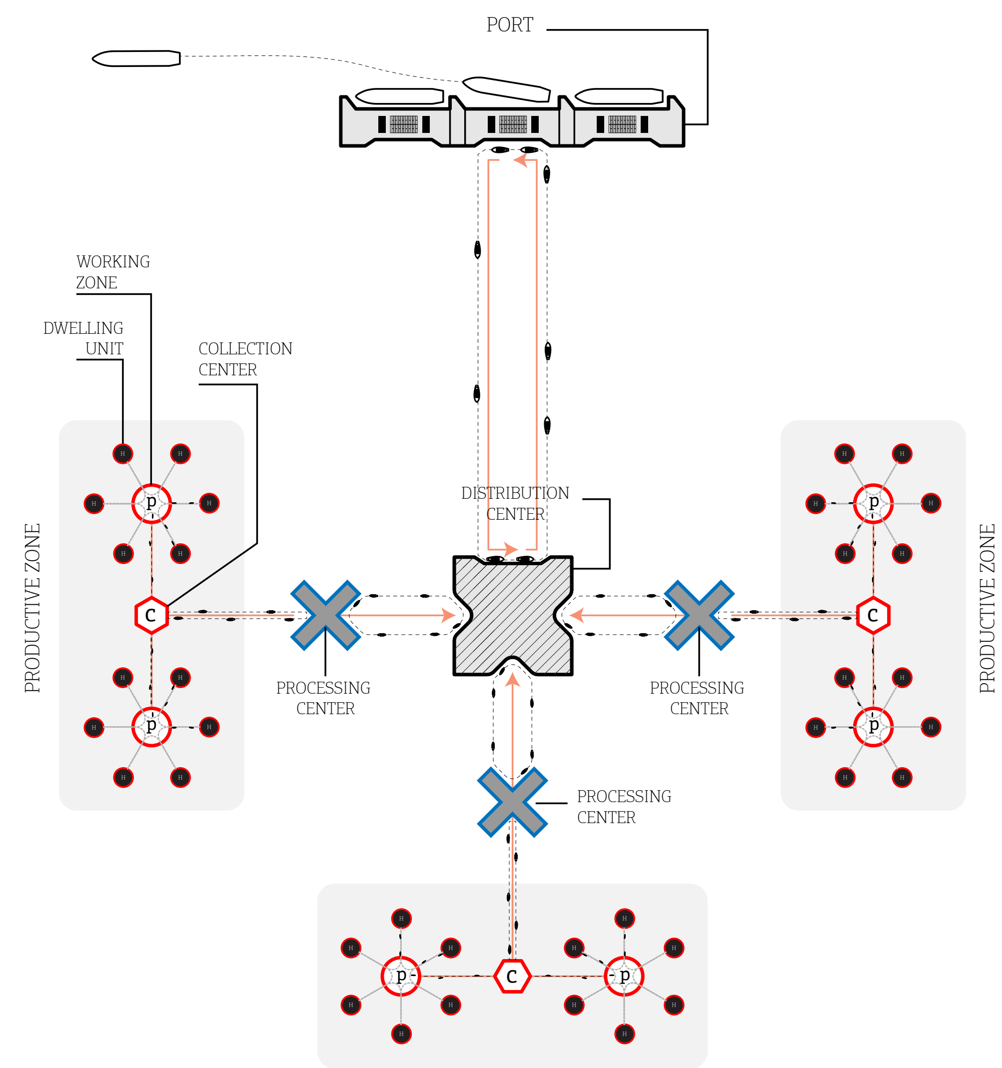


MASHOOF	SMALL CARGO	MEDIUM CARGO	LARGE CARGO
0.8 m	3.4 m	7.5 m	15 m
DRAUGHT0: 20 cm	DRAUGHT: 100 cm	DRAUGHT: 200 cm	DRAUGHT: 600 cm

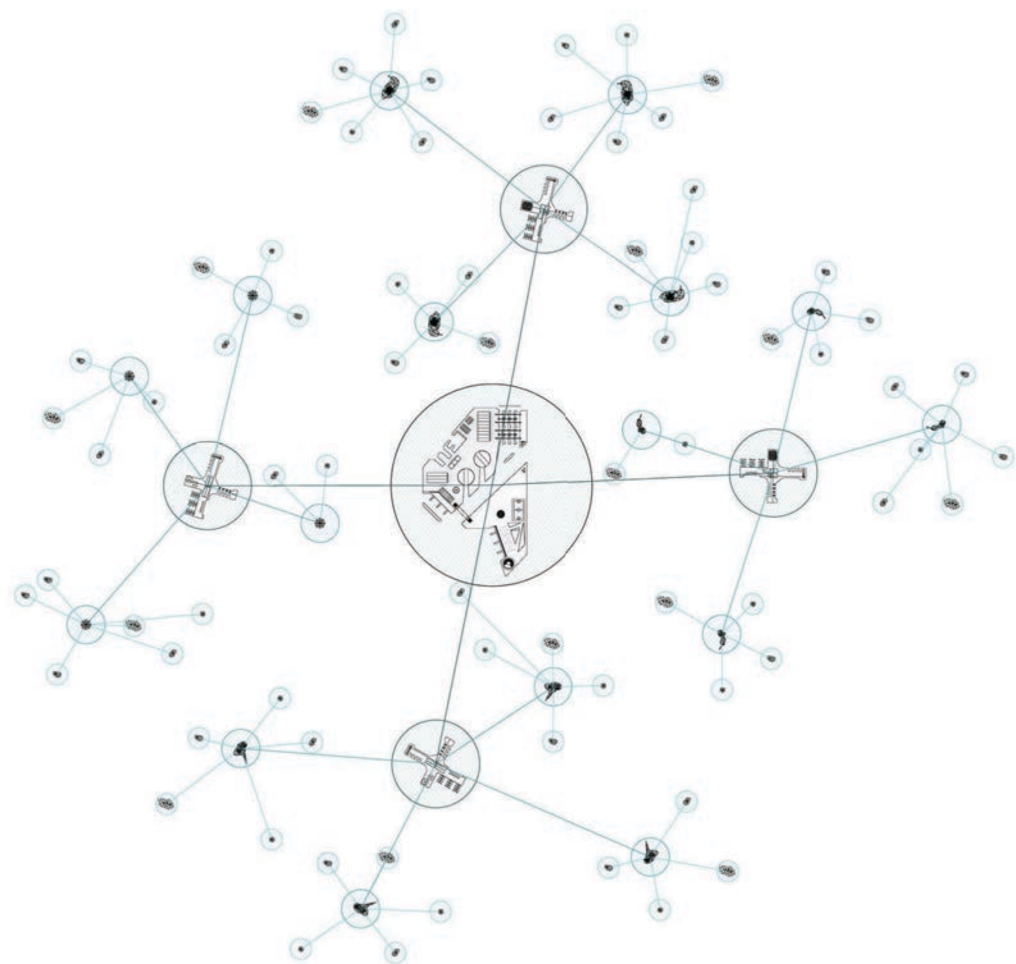
CANAL SIZE

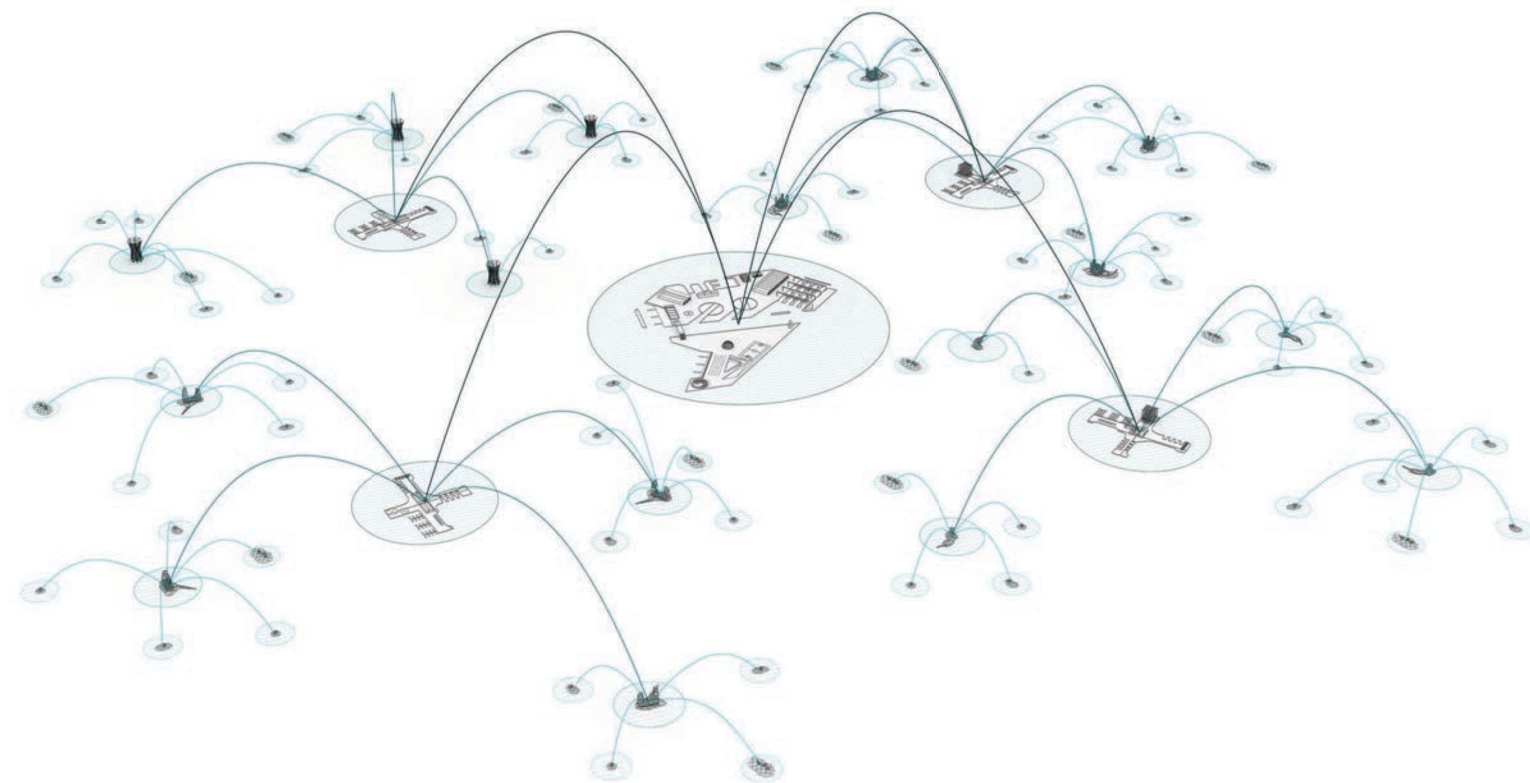
TERTIARY PATH:	SECONDARY PATH	PRIMARY PATH	EUPHRATES RIVER
5 m	15 m	30 m	250 m

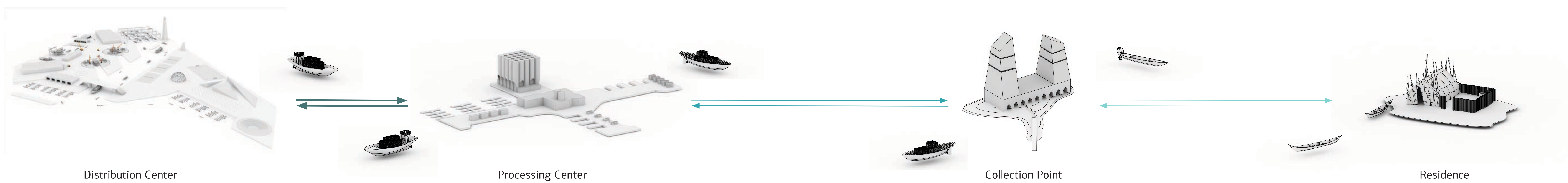
DISTRIBUTION NETWORK



Hierachical Distribution Network







Distribution Center

Processing Center

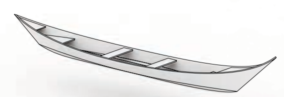
Collection Point

Residence

5.1 *Design Proposal*

5.1.4 Typologies

Tonnage: 5 m³

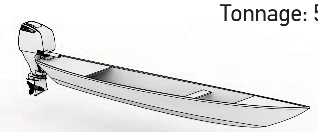


The Mashoof is a small draft boat used by locals to easily navigate through the shallow waters of the marshes

Mashoof
Residential Network

The Mashoofs are used as a pleasure craft as well as collecting products and transporting them to a collection point. They are the only boats that are fit to use the thirtary network

Tonnage: 5 m³

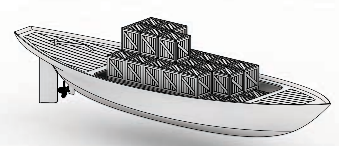


The modern Mashoof has a similar design to the traditional one, but is equiped with an outboard engine.

Motor driven Mashoof
Residential/Thirtiary Network

The width and depth of the secondary network is defined by the dimensions of the small cargo ship

Tonnage: 50 m³

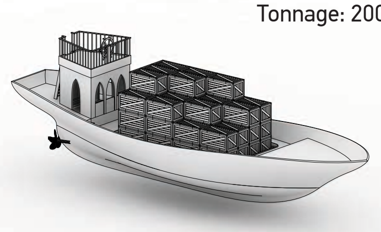


The small cargo ship is used to transport products from the collection point to the processing centre and then further to the distribution centre

Small Cargo Ship
Secondary Network

"Tonnage" specifically refers to a calculation of the volume or cargo volume of a ship

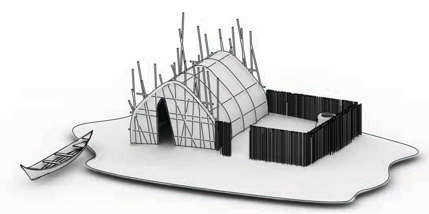
Tonnage: 200 m³



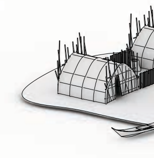
The large cargo ship is used to export products from the distribution centre to Chibayish and out to the harbour on the Euphrates

The width and depth of the primary network is defined by the dimensions of the large cargo ship

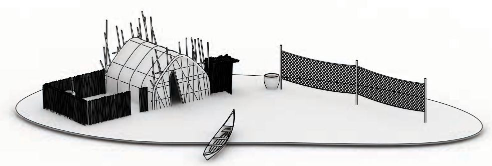
Large Cargo Ship
Primary Network



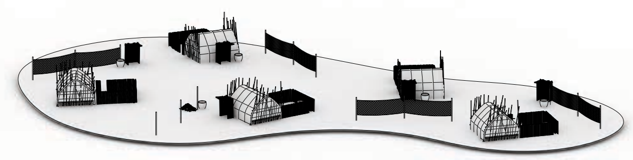
Single Unit Island - Residential



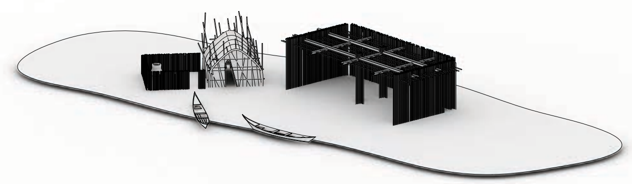
Multi Unit Island - Residential



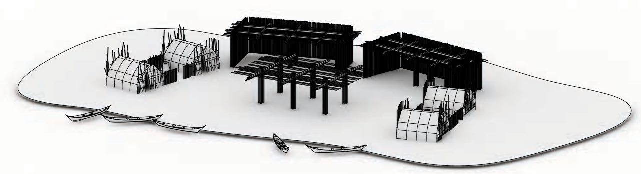
Single Unit Island - Fish



Multi Unit Island - Fish

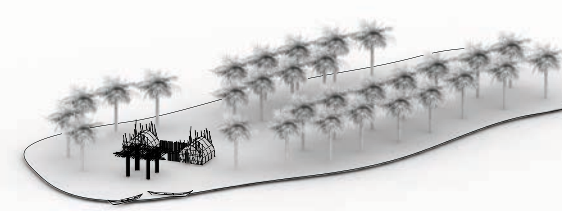


Single Unit Island - Buffalo



Multi Unit Island - Buffalo

Single Unit Island - Date Palms

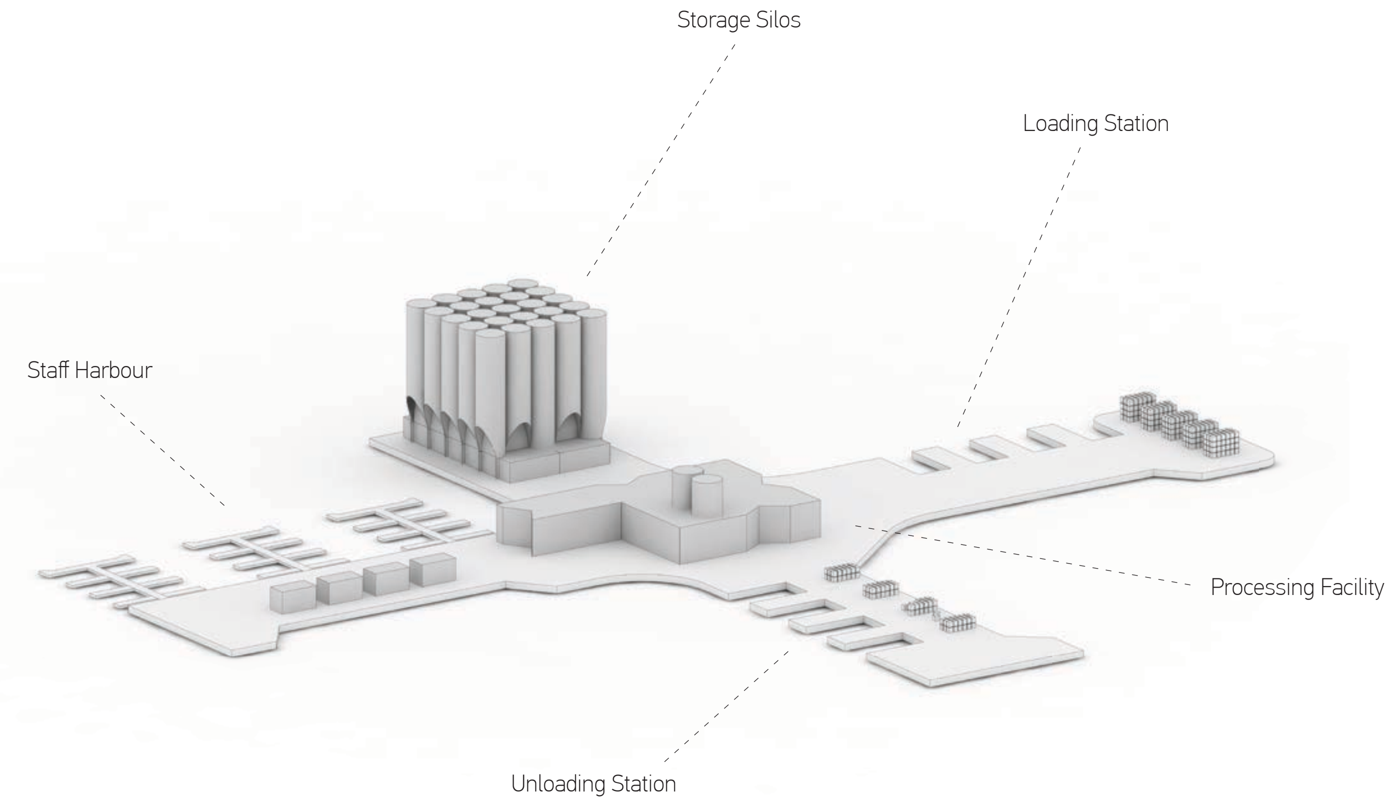


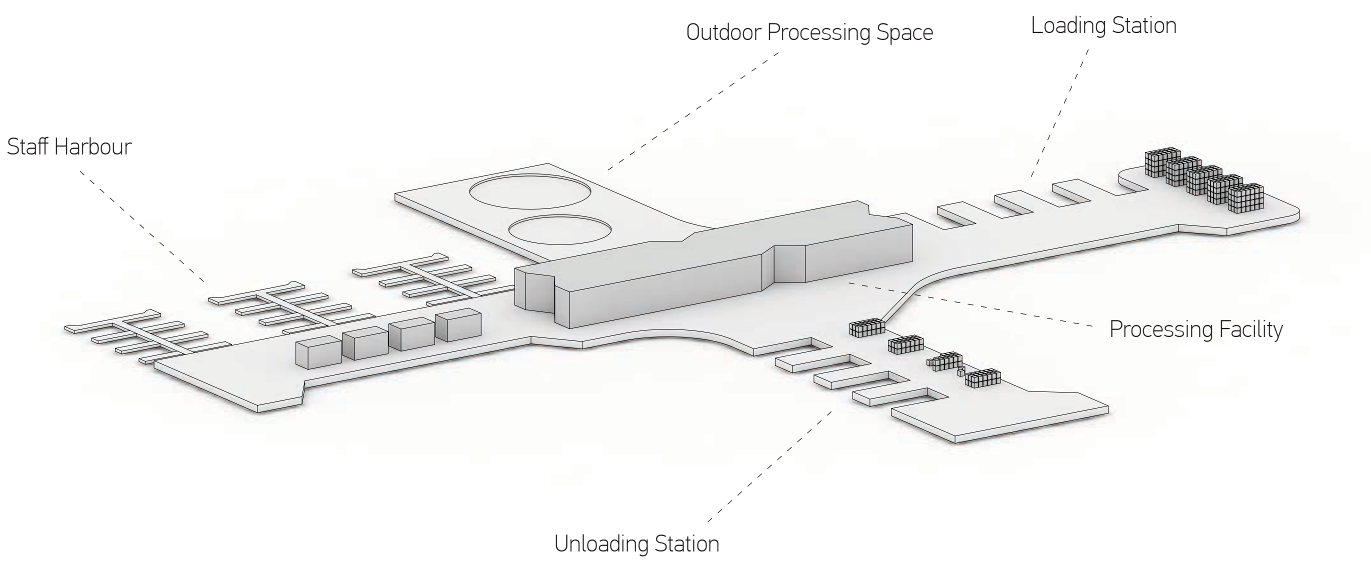
Multi Unit Island - Date Palms

There are two types of configurations that can be used when modifying the landscape to inhabit wetlands. The original vernacular islands of the Mesopotamian Marshlands were constructed as an archipelago of multiple small islands. The islands were constructed with the intention to provide enough space for one family to live there with their reed house and a few buffaloes. The other option is to construct larger islands that would be populated by multiple families.

These islands are then modified and designed specifically to support the needs of the residents occupation.

5.1 Design Proposal





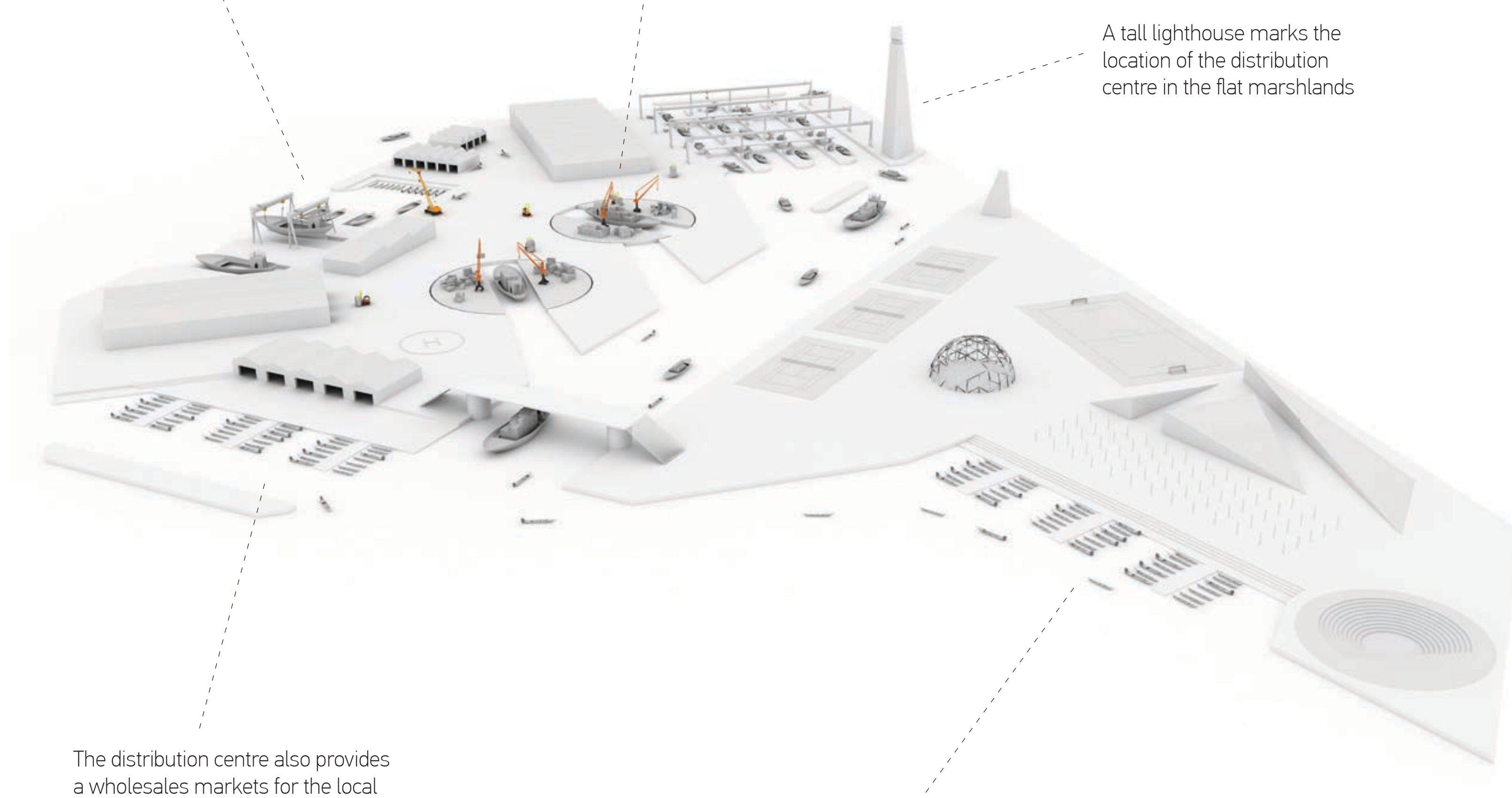
The processing centres would be connected to the distribution centres through the secondary distribution network. Each type of production has its own processing centre, where the products go through all stages of processing before it gets packaged and shipped of to the distribution centre.

After being processed, all different products are shipped to the distribution centre. Here the products are stored and then exported. It is also the receiving point for all the import to the marshes. This island would also serve as the main node of the area providing different necessary functions such as shipyards and wholesales markets as well as social functions like theatres and leisure centres.

The large cargo ships have rotating loading stations because their deep hull and large turn radius do not allow them to do such maneuvers in the dredged canals

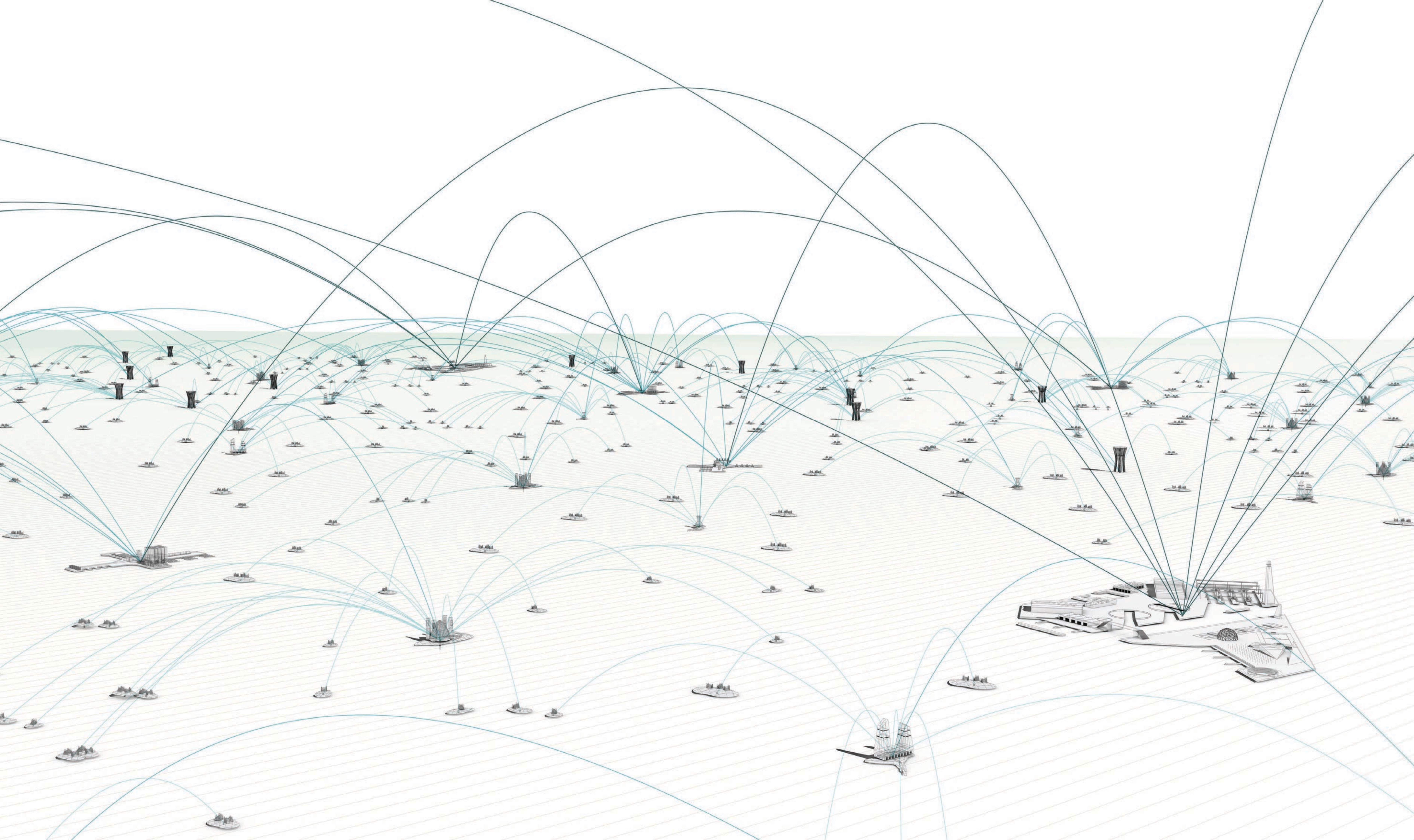
As all transport is happens by boat the presence of a shipyard is of high importance

A tall lighthouse marks the location of the distribution centre in the flat marshlands



The distribution centre also provides a wholesales markets for the local retailers

The distribution centre island also serves as a main node for social functions which are accessible through a guest harbour



6.0 Conclusions

6.1 Conclusions

6.1 *Conclusions*

Conclusions and Limitations

The scope of research of this work aimed at interrogating the urban question and presenting a more comprehensive view on urbanisation. Urbanisation is understood as a totalising condition that has taken over the entire surface of the earth. The goal of the project was to address the transformations that are occurring in the countryside as a result of urbanisation. This work also aimed to touch upon a number of issues that are being discussed in current debates of architectural and urban design. The increasing interest in landscape urbanism, resource management, sustainability, the expansion of cities and the role of infrastructure and the countryside in supporting human societies.

This project presents a framework for the re-occupation of the marshlands of Mesopotamia. Historically this site has been altered and transformed in many ways. Mesopotamia continues to be a land in state of constant transition. It was in this land between the Tigris and Euphrates where humans began to transform large territories into productive land to meet the needs of human societies. The site is linked to the history of urbanisation as a support landscape that has for centuries sustained the development of human society. From the early days of agriculture to the current presence of the oil extraction industry, the land of Mesopotamia has been defined by its operational character. In searching for alternative models of human occupation, this work looked at various historical precedents of vernacular architecture as well as the work of other architects who were invested in establishing a connection between urban growth and the countryside.

This work also attempted to bring forward ideas from the emerging body of knowledge that is often referred to as the "science of complexity". This work moves away from traditional modes of practice which rely on static and stable states. Instead, this work attempted to develop an approach to urban design informed by the concepts of network thinking, evolution theory, complex systems and ecology. To this end, advanced computation was a central aspect to the explorations. Computer models and simulations were utilised to coordinate and analyse large sets of data involved in the design.

The design experiments aimed at producing a model of function distribution for different productive activities [rice, dates, buffalo, energy and fish]. These were distributed by using a custom circle packing algorithm in combination with a magnetic field algorithm that would create clusters of units for human habitation in between the productive zones. The design options would be evaluated according to target levels of production for which a certain amount of area for each product would need to be satisfied. The distribution patterns generated by the algorithm would later be analysed through network analysis. A network based model would evaluate the movement of products and people across the site of intervention and rate them according to network evaluation indices such as reach, accessibility and integration.

Results

The custom circle packing algorithm developed in this project was successful in offering a technique for semi-random distribution. Contrary to other computation methods for random distribution such as Cellular Automata, where patterns simply evolve from initial seeds without any desired goal, the custom circle packing algorithm used in this project allows users to gain a higher level of control over areas by granting the user the opportunity to input specific numeric values(weights) for the radius of the circles. Because of this the search algorithm (Genetic Algorithm) was able to optimise target areas and distribute them in accordance to desired adjacencies across the site while keeping the total areas close to the target.

The use of the magnetic field algorithm was successful in offering a solution for clustering a random distribution of elements based on basic rules of distance, direction and avoidance. Magnetic fields allow the designer to assign charges (weights) and cluster elements in relation to a force of attraction and repulsion. They generate convergence points that cannot be anticipated and can only be generated by the computer. This method proved efficient to establish some degree of order and structure to what otherwise is a random distribution of elements. The magnetic charge introduces a force, or intensive difference, that prompts the elements to self-organise into clusters. The algorithm provides a lot of flexibility as values can be updated and re-instantiated in relation to changes in the productive areas.

The marshes offered a unique environment for testing Agent Based Simulation. Unlike cities where infrastructure is costly, fixed and highly engineered, the infrastructure of the marshes is "soft", movement happens through shallow canals created by boat and animal movement. As in any other aquatic environment movement is not prescribed. In this context the use of Agent Based Simulations provides a more accurate picture of the movement that would occur in reality. The experiments were successful in generating multiple possible scenarios for network configurations with more or less similar results.

One major limitation for evaluating the work was the difficulty to assign numeric values to the interaction between products and simulate the complex behaviour that occurs in natural environments. Using ecological processes as design drivers is an area that deserves further exploration. However, in many cases, this knowledge lies outside the scope of the designer. Serious research in this area requires the participation of multiple disciplines with experts in various fields. Another limitation was posed by the scale of intervention of the project. Most of the efforts went into establishing a clear strategy at the macro-scale which outlined the basis for developing specific areas of the project at the scale of architecture. Due to time limitations, only one case was explored at this scale. An area of rice and fish production was selected to understand the relationship between the tank and the productive zone throughout a harvest season. Further exploration will look at further developing key areas of the project at the architectural scale. The design of the various typologies that make up the project was restricted to basic schematic design. The development of residential units based on vernacular construction systems and locally material sourced materials suggests an intriguing area of future research. Parallel to this, further exploration on the development of infrastructure should also be considered. The tank typologies which are central to the project should be further investigated. Finally, further exploration on networks should take place to respond to changes in the development of typologies at the architectural scale.

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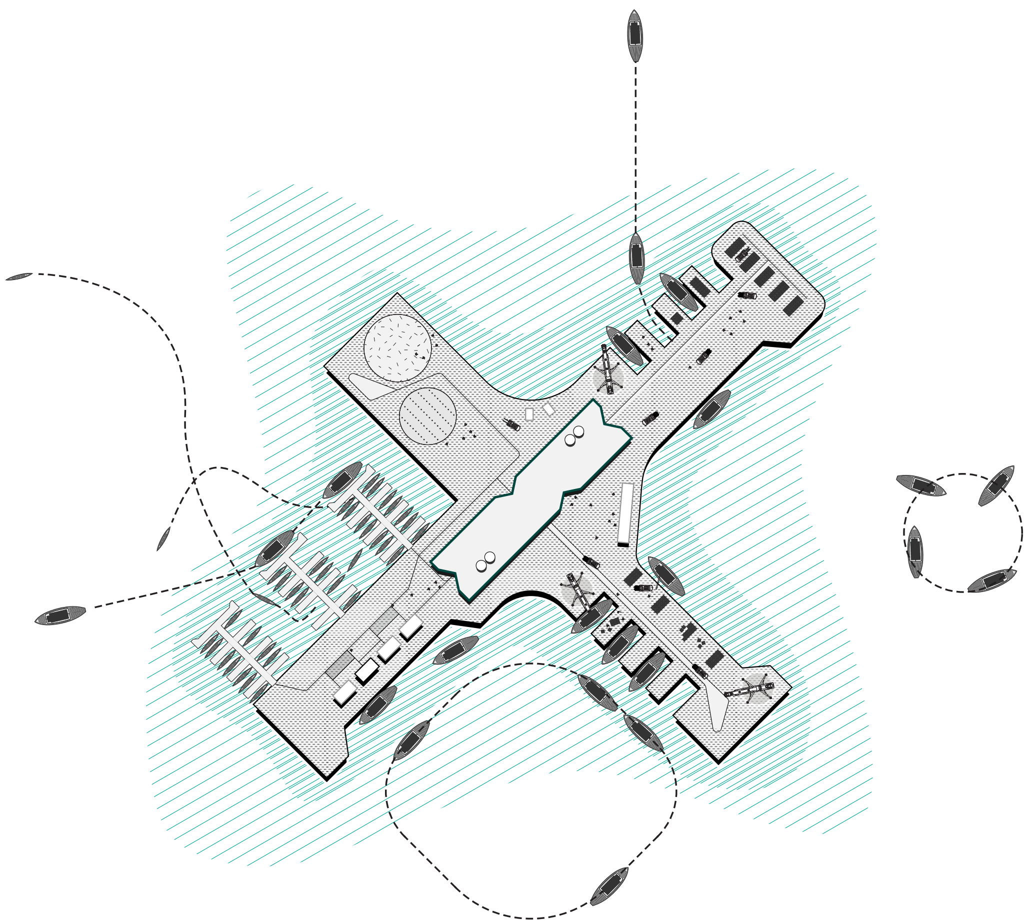

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