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Titre : An ecosystem under pressure : the case of Marano and Grado lagoons

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RÉSUMÉ

Lagoons are crucial environments for the world's biodiversity. They are home to a rich ecosystem that lives at the interface between sea and land. This fragile equilibrium is endangered by threats linked to human activity and climate change. The Marano and Grado lagoons are an example of this fight for wetland survival. In this work, we analyze the current organisation of the region, rooted in its history, that led to a neglected lagoon. We then identify the threats and propose a plan for a renewed lagoon. It copes with the climatic and pollution threats, promotes the development of aquaculture and establishes a new relationship between man and the lagoon.

MOTS-CLEFS

Changement climatique, Gestion de l'eau, Zone humide, Lagune, Biodiversité, Dépollution, Aquaculture

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Exemple de traduction :

Version originale :

Les ailes étendues je plane au-dessus de l’eau miroitante les lagunes de Marano et Grado. Sous le soleil du matin, elle scintille. Sa transparence me permet de voir tout ce qui s’y passe, révélant toute la beauté de sa diversité.

Cette lagune est ma maison, c’est ici que je suis né et où j’ai donné vie à mes petits, dans des zones, calmes proche de l’eau. Je partage ce riche environnement avec des nuées d’oiseaux. On trouve de la bonne nourriture ici, avec beaucoup de poissons et d’amphibiens que je vois nager rapidement dans les eaux claires.

Mais j’ai peur pour mon paradis. Je vois les choses changer. J’ai de plus en plus de mal à pêcher, les poissons sont de moins en moins nombreux, ils meurent. L’eau devient trouble et verte. A chaque tempête je crains pour ma vie et celle de mes petits. Je n’arrive plus à m’orienter, les cycles naturels sont bouleversés et je ne sais plus quand je dois migrer.

Mon coeur se serre face à ces changements, et j’espère que nous pourrons préserver ce sanctuaire pour les générations futures.

Version traduite :

With outstretched wings, I glide over the shimmering water of the Marano and Grado lagoons. In the morning sun, it sparkles. Its transparency reveals everything that happens below the surface, in all the beauty of its diversity.

The lagoon is my homeland, this is where I was born and where I gave birth to my offspring, in quiet areas close to the waters. I share this rich environment with flocks of other birds. We find good food here, with so many fishes and amphibians that I can see swiftly swimming in the clear waters.

The pink flamingos have returned from their southern winter travel, like every year at this season. They cluster in tight groups close to the shore and I like flying over them just for the view.

But I worry about the future of my paradise. I see things changing. I’m finding it harder and harder to fish, the fishes are less and less abundant, they’re dying. The water is getting murky and green. With every storm, I fear for my life and those of my little ones. I can’t orientate myself anymore, the natural cycles are disrupted and I no longer know when I should migrate.

My heart hurts at these changes, and I pray that we can preserve this sanctuary for future generations.

Exemple de reformulation :

Version originale :

The IPCC has developed 4 scenarios showing the probable paths of climate change between now and 2100. These are the RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios. The RCP2.6 scenario is the most optimistic, predicting a sea-level rise of 0.43 m by 2100, with an uncertainty range of 0.29 m to 0.59 m. This would mean an increase of 4 to 9 mm per year until 2100. The RCP8.5 scenario, the worst case, sees an rise of 0.84 m, with a larger range of uncertainty from 0.61 m to 1.10 m. This means a water level rise of 15 mm per year until 2100 (IPCC AR5, 2014).

The RCP2.6 scenario means a loss of salt-fresh water ratio. The Lagoon, which is currently made up of 70% freshwater, would experience a change to more marine conditions. This change would lead to the phenomenon of the “salt wedge”, where salt water would penetrate more deeply into the soil, impacting freshwater quality. The result would be increased soil salinization, which would be bad for agriculture, as plants are sensitive to high levels of salt in the soil, which can affect their growth and yield. Increased salinity in agricultural soils can also make land less ideal for cultivation.

The RCP8.5 scenario predicts a sea-level rise of between 0.61 and 1.10 m, with major consequences for the Marano and Grado lagoons.

The coastal barriers that surround and protect the lagoon would be submerged. This would transform the lagoon into a bay, leading to its disappearance. Ecosystems would see their habitats disappear. Some species would be able to move to other areas where they could develop. But other less mobile or non-mobile species would find themselves in conditions to which they are not adapted, and would eventually die.

Version reformulée :

4 scenarios have been established by the IPCC reflecting the likely trajectories of climate change by 2100. These are RCP2.6, RCP4.5, RCP6.0 and RCP8.5, with RCP2.6 being the most optimistic scenario, predicting a sea-level rise of 0.43 m by 2100, with an uncertainty range of 0.29 m to 0.59 m. This would mean an increase of 4 to 9 mm per year until 2100. Scenario RCP8.5, the most unfavourable, envisages an increase of 0.84 m, with a wider range of uncertainty from 0.61 m to 1.10 m. This means a rise in water levels of 15mm per year until 2100 (IPCC AR5, 2014).

The RCP2.6 scenario implies a loss of balance between salt and fresh water. Currently composed of 70% freshwater, the lagoon would undergo a shift towards more marine conditions. This change would lead to an increase in the « salt-water wedge » phenomenon, where salt water penetrates deeper into the land soils and affects freshwater quality. As a result, this would lead to increased soil salinization, which would be damaging for agriculture, as plants are sensitive to high levels of salt in the soil, which can affect growth and yield. Increased salinity in agricultural soils can also render land unfit for cultivation.

The RCP8.5 scenario predicts a sea-level rise of between 0.61 and 1.10 m, with serious impacts for the Marano and Grado lagoons.

The coastal barriers that enclose and protect the lagoon would be submerged for the most part. This would tend to turn the lagoon into a bay, leading to its disappearance. Ecosystems would see their habitats disappear. Some mobile species could move to other areas favourable to their development. But other less or non-mobile species would then find themselves in conditions to which they are not adapted and would eventually perish.



**AN ECOSYSTEM UNDER PRESSURE : THE CASE OF
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«Wetlands are vital for human survival. They are among the world's most productive environments; cradles of biological diversity that provide the water and productivity upon which countless species of plants and animals depend for survival» (RAMSAR)



Fig. 1 «Landscape of the lagoon» PERCO, 2004

« Wetland ecosystem services far exceed those of terrestrial ecosystems. They provide critical food supplies including rice and freshwater and coastal fish, and fresh water, fibre and fuel. » (Gardner, 2018)



Fig. 2 «Landscape of the lagoon » PERCO, 2004

« On a global scale, wetlands represent only about 5-8% of the earth's surface, but contain some 30% of the total soil carbon pool, with peatlands and coastal wetlands being particularly important for carbon storage. » (Robertson, 2022)



Fig. 3 « Landscape of the lagoon » PERCO, 2004

« The lagoon is an area of salt or brackish water separated from the sea by low sandbanks or a similar barrier » (Oxford English Dictionary)



Fig. 4 «Landscape of the lagoon» PERCO, 2004

Lagoons : life sources and nurseries



Fig. 5 « Landscape of the lagoon » PERCO, 2004

1 INTRODUCTION

With outstretched wings, I glide over the shimmering water of the Marano and Grado lagoons. In the morning sun, it sparkles. Its transparency reveals everything that happens below the surface, in all the beauty of its diversity.

The lagoon is my homeland, this is where I was born and where I gave birth to my offspring, in quiet areas close to the waters. I share this rich environment with flocks of other birds. We find good food here, with so many fishes and amphibians that I can see swiftly swimming in the clear waters.

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2 THE LAGOON FRAGILE ENVIRONMENT

In this chapter, we explore the importance of lagoons by considering the different roles they play from different perspectives. We then focus the Marano and Grado lagoons, to understand their geographical and morphological contexts.

2.1 Wetlands

In the current context of climate changes, water, essential to life, is one of the most affected natural resources. These changes are disturbing the ecological balance, particularly in vulnerable ecosystems such as wetlands.

Wetlands are crucial ecosystems, contributing to 40% of the world's biodiversity. But, their importance goes beyond biodiversity. They act as hydrological buffers, facilitating water storage and purification, flood control, and barrier against storm surges and seashore erosion. They offer crucial habitat for a variety of species, including birds, fish, and endangered species (wetlands.org).

Wetlands present a variety of morphologies, including peatlands, mangroves, lakes, swamps, floodplains, mudflats, salt marshes and lagoons (wetlands.org). For instance, peatlands behave like sponges, absorbing excess water during floods and releasing it during droughts, and mangroves play an essential role in water purification, filtering out pollutants.

2.2 Lagoons

In this work, we will focus on lagoons. They constitute a major wetland, because lagoons contain a wide variety of morphologies influenced by the vagaries of sea and rivers behaviours. They include mudflats, salt marshes, flood plains, etc...

The lagoon is defined as a shallow surface of water located at the boundary between the continental and maritime zones, separated from the latter by a strip of sand (called a «dido») and in which there are openings to the sea, making the lagoon a tide-influenced area. It is a spread-out frontier between two environments that merge together in this all-important transition zone: the land and the sea.

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Upstream factors such as freshwater coming from inland through water courses influence the lagoon, making it a brackish water area. This salty/fresh water mix is especially favourable to the growth of a rich plankton life, initial link in the ecosystem chain.

The lagoon morphologies are shaped by these water flows of variable amplitude, and particularly the sea tides (average amplitude 65 cm and maximum amplitude 105 cm) (Fontolan, 2010).

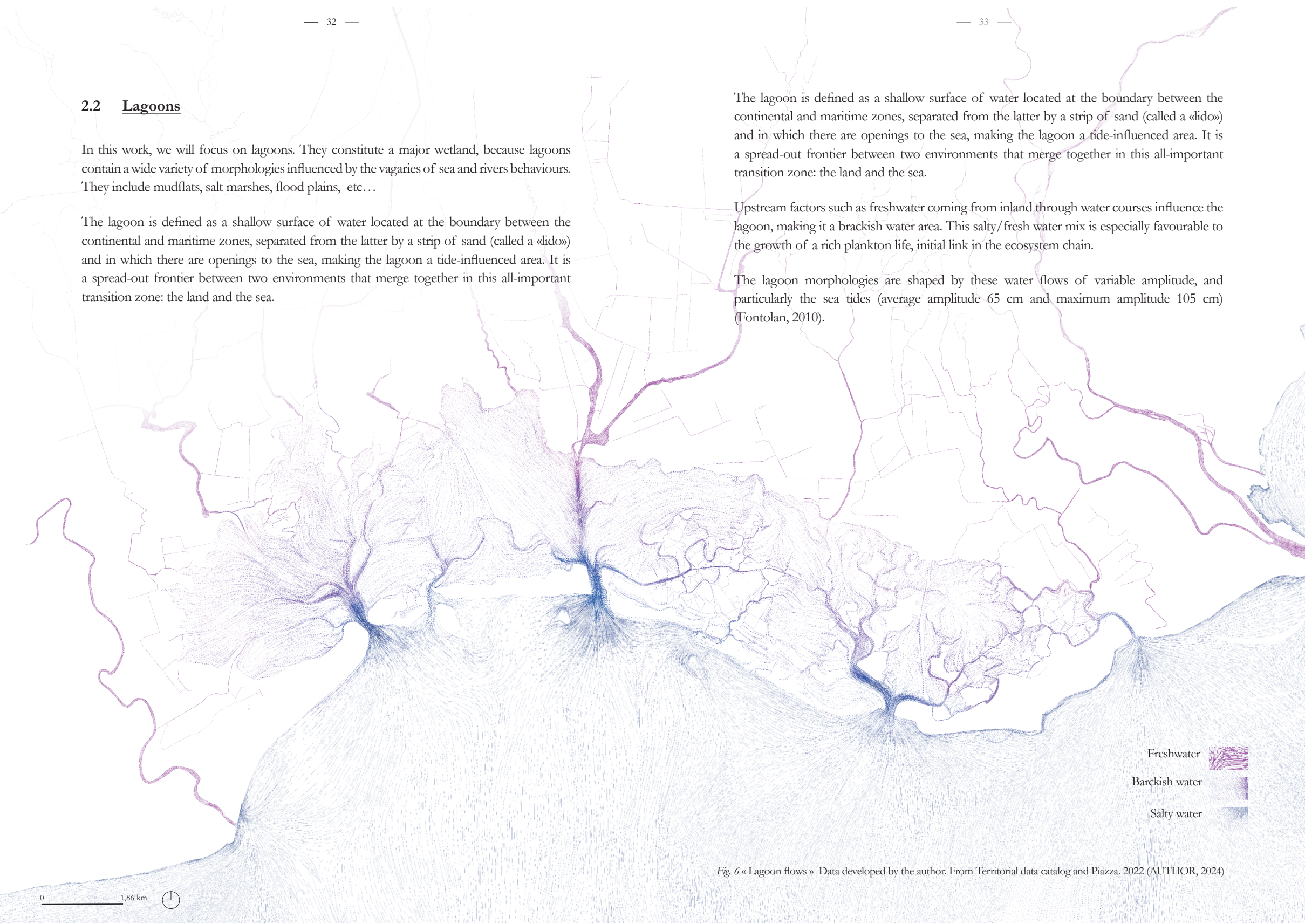


Fig. 6 « Lagoon flows » Data developed by the author. From Territorial data catalog and Piazza. 2022 (AUTHOR, 2024)

The lagoon environment can be divided into 3 zones, depending on the water level:

The first zone includes land that lies above the average high tide level. This includes salt marshes¹, islands, coastal strips (lido) and coasts.

The second is defined by the areas between the mean high and low tide levels, such as secondary channels², mudflats and barenes³.

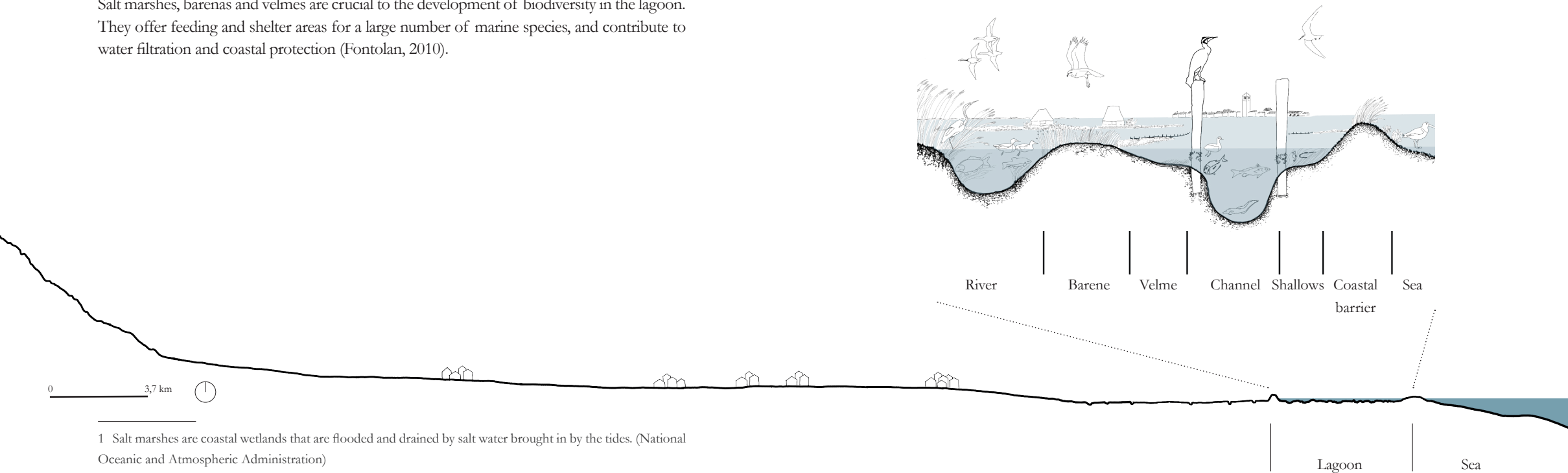
The last covers what is mostly underwater, below the average low tide level. It contains the main channels, which can be as deep as 10m, the lagoon mouths and the velmes⁴ (ARPA, 2023).

Salt marshes, barenas and velmes are crucial to the development of biodiversity in the lagoon. They offer feeding and shelter areas for a large number of marine species, and contribute to water filtration and coastal protection (Fontolan, 2010).

2.3 Lagoons as nursery areas

Thanks to this diversity, and the shallowness of their waters, lagoons are extremely favourable environments for the development of a rich biological environment. The most important element is the variety of seagrass, which can grow if water is clear with ample sunlight at the proximity of the water surface. Fishes breed in these seagrass 'fields' and young fishes spend their early age hidden from larger predators in this habitat. Seagrass itself contributes to the water purification by trapping sediments and removing pollutants from the water.

Micro-organisms like zoo- and phyto-plancton, algae and bacteria also develop there, serving as feeding sources to many species of fishes and shellfishes (crustaceans and mollusks). Above the surface, more than 300 species of birds benefit from this extensive feeding area (Cosolo, 2015).



1 Salt marshes are coastal wetlands that are flooded and drained by salt water brought in by the tides. (National Oceanic and Atmospheric Administration)

2 The channels refer to the waterways or passages within the lagoon. They are natural or man-made routes that traverse the lagoon and facilitate navigation for boats and other vessels.

3 Sandbanks or mudflats that emerge at low tide. These areas can be important habitats for the lagoon's flora and fauna.

4 Velmes are distinctive sedimentary formations found in lagoons. They are accumulations of organic substances and sediments that generally form in the calm, shallow parts of lagoons, often near the shores or estuaries of rivers.



Fig. 8 Views of the lagoon

2.4 Northern Adriatic context

The Marano and Grado lagoons are the cases studied. They are part of a series of wetlands, including lagoons and brackish water basins, stretching from Ravenna to Monfalcone in the Friuli Venezia Giulia region, the Grado lagoon being the most easterly.

Over time, some lagoons have tended to close due to sediment accumulation, while others have become areas of ecological or economic importance. The most renowned part of this network is the Venice lagoon, whose destiny has been strongly influenced by human activity. In contrast, the Marano and Grado lagoons are relatively more natural. Most of these lagoons have traditionally been used for fishing, and today attract tourists thanks to their ecological environment. Over centuries, they have lived different destinies. But what will be their future fate ?



Fig. 9 « Location of the Northern Adriatic and the Marano and Grado lagoons » (AUTHOR, 2024)



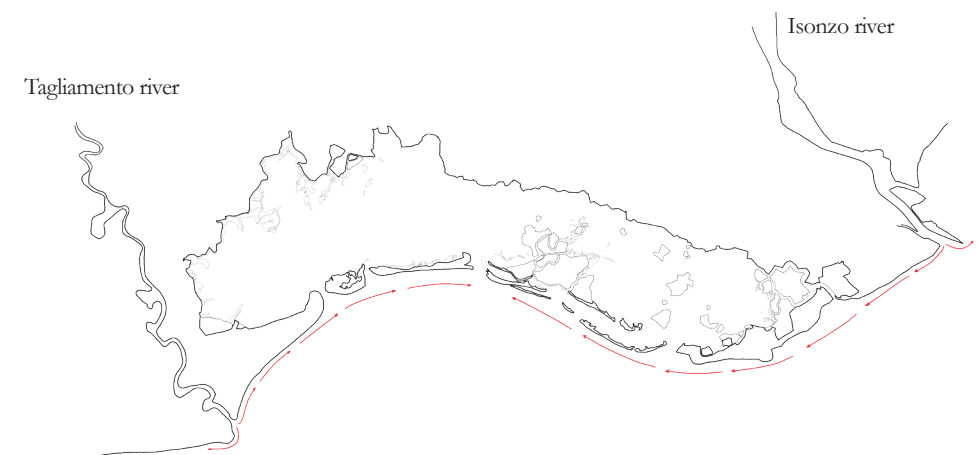
Fig. 10 « Northern Adriatic wetlands » From Sbarigia. 2023. (AUTHOR, 2024)

2.5 Genesis of the lagoon

The Marano and Grado lagoons and the wetlands of the northern Adriatic have been formed 6000 to 5000 years ago. Therefore, they are relatively recent on the geological time scale. At that time, sea levels were rising dramatically, leading to the flooding of the alluvial plains⁵ (ARPA, 2023). Another factor making the formation of a lagoon possible is the presence of two abundant sources of sediments that will define the sides of the lagoon. For the Marano and Grado lagoons, these sources are the Tagliamento and Isonzo rivers.

Another factor making the formation of a lagoon possible is the presence of two abundant sources of sediments that will serve as material for the sides of the lagoon. For the Marano and Grado lagoons, these sources are the Tagliamento and Isonzo rivers. The sediments coming from these streams have been progressively transported along the shoreline by a longshore drift current. The accumulation of these sediments gives rise to a «sand arrow»⁶ (Paskoff, 2010).

This landscape is dynamic and constantly changing, due to the influence of tides, river movements and sediment supply. Sand is continuously moving with the longitudinal transport. However, the mouths of the Marano and Grado lagoons have been stabilized, but some of the coastal barriers remain mobile and subject to erosion due to the movements of the tides (Piazza, 2022).

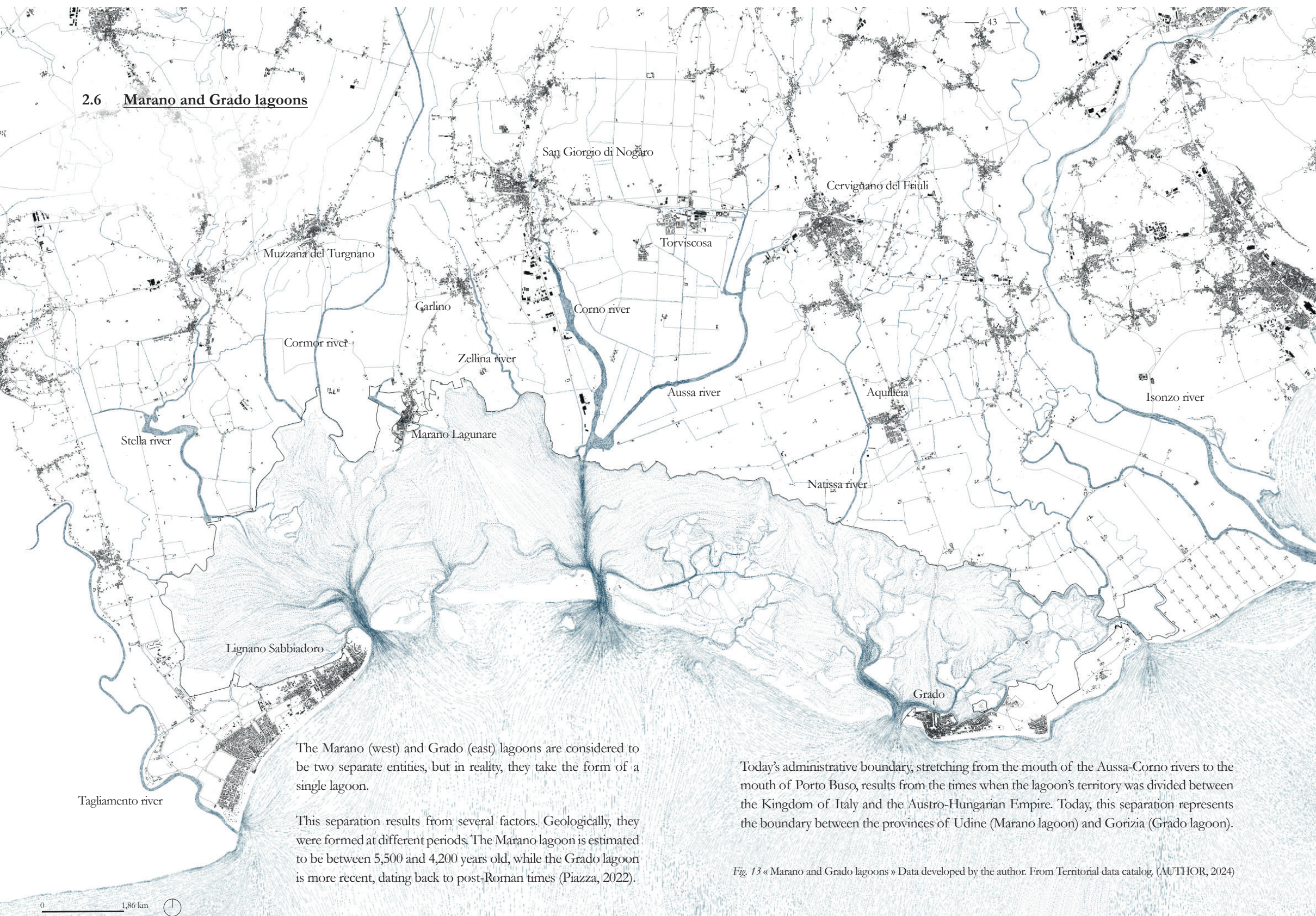


⁵ An alluvial plain is an area of flat or slightly sloping land adjacent to a watercourse, such as a river.

⁶ According to the Gilbert 1885 theory supported by Fisher 1968

Fig. 12 « Lagoon formation » Data developed by the author. From Territorial catalog and Piazza, 2022. (AUTHOR, 2024)

2.6 Marano and Grado lagoons



The Marano (west) and Grado (east) lagoons are considered to be two separate entities, but in reality, they take the form of a single lagoon.

This separation results from several factors. Geologically, they were formed at different periods. The Marano lagoon is estimated to be between 5,500 and 4,200 years old, while the Grado lagoon is more recent, dating back to post-Roman times (Piazza, 2022).

Today's administrative boundary, stretching from the mouth of the Ausa-Corno rivers to the mouth of Porto Buso, results from the times when the lagoon's territory was divided between the Kingdom of Italy and the Austro-Hungarian Empire. Today, this separation represents the boundary between the provinces of Udine (Marano lagoon) and Gorizia (Grado lagoon).

Fig. 13 « Marano and Grado lagoons » Data developed by the author. From Territorial data catalog. (AUTHOR, 2024)

Morphologically, the two lagoons also differ from one another. The Marano lagoon is deeper, while the Grado lagoon is shallower and features a greater diversity of islands, salt marshes, barenes and velmes.

The total surface area of the combined lagoons is 160 km² (32 km long and 5 km wide), making it the second largest lagoon in Italy. Its watershed covers an area of 1880 km², delivering freshwater to the lagoon (Barbanti, 2011).

There are 6 rivers discharging into the lagoon with a total flow of 84m³/sec (ARPA, 2005). Saltwater is supplied by the 6 outlets to the sea, which act as hydraulic regulators. The balance of freshwater and saltwater in the Marano lagoon is 70-80% of freshwater, whereas the Grado lagoon has a higher salinity since only one river flows into it (Barbanti, 2011). Moreover, the lagoon salinity is variable depending on the zone, time of day and tide amplitude with a gradient from the rivers to the sea. This creates into a varied eco-system depending on the life species affinity or intolerance to salt. It is another factor of the fragile equilibrium that can be drastically affected by climate variations.

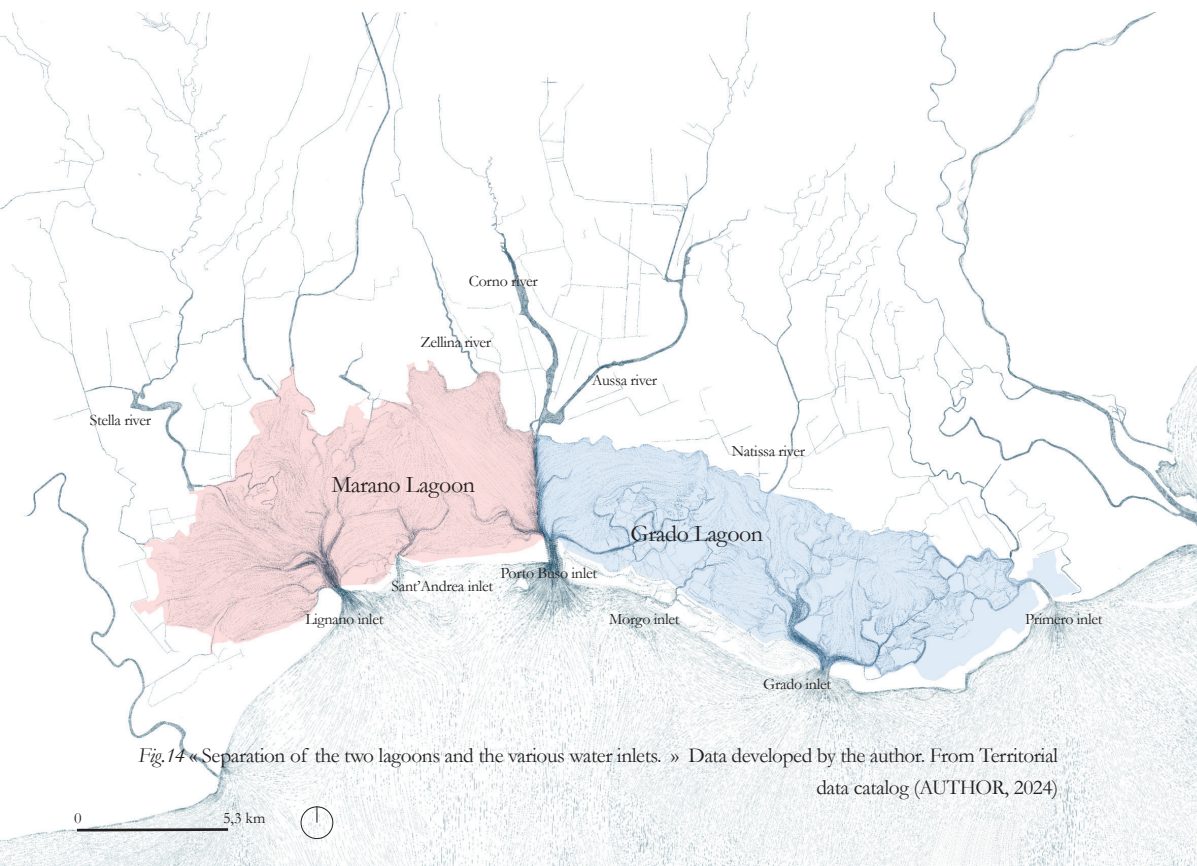


Fig. 14 « Separation of the two lagoons and the various water inlets. » Data developed by the author. From Territorial data catalog (AUTHOR, 2024)



Fig. 15 « Lagoon watershed » Data developed by the author. From Territorial data catalog (AUTHOR, 2024)

3 HISTORY OF THE RELATIONSHIP BETWEEN MAN AND THE LAGOON

The relationship between man and the lagoon has evolved considerably over time. An analysis of this evolution is essential to understand the origins of the current threats endangering the lagoon.

3.1 Traditional life in the lagoon

Until the end of the Second World War, a population of traditional fishermen lived closely linked to the lagoon. It provided their only resource. People lived very precariously off the lagoon. They settled in huts called «casones» in the middle of the lagoon, isolated from the outside world, ignored and neglected by the society. They had no access to drinkable water and lived from fishing exclusively, in almost complete autarky. They therefore developed their own fishing techniques, lifestyles and traditions, which today are a heritage to be preserved. (Museo della pesca e della civiltà lagunare)



Fig. 16 « Ancient traditional life in the lagoon » (Museo della pesca e della civiltà lagunare)

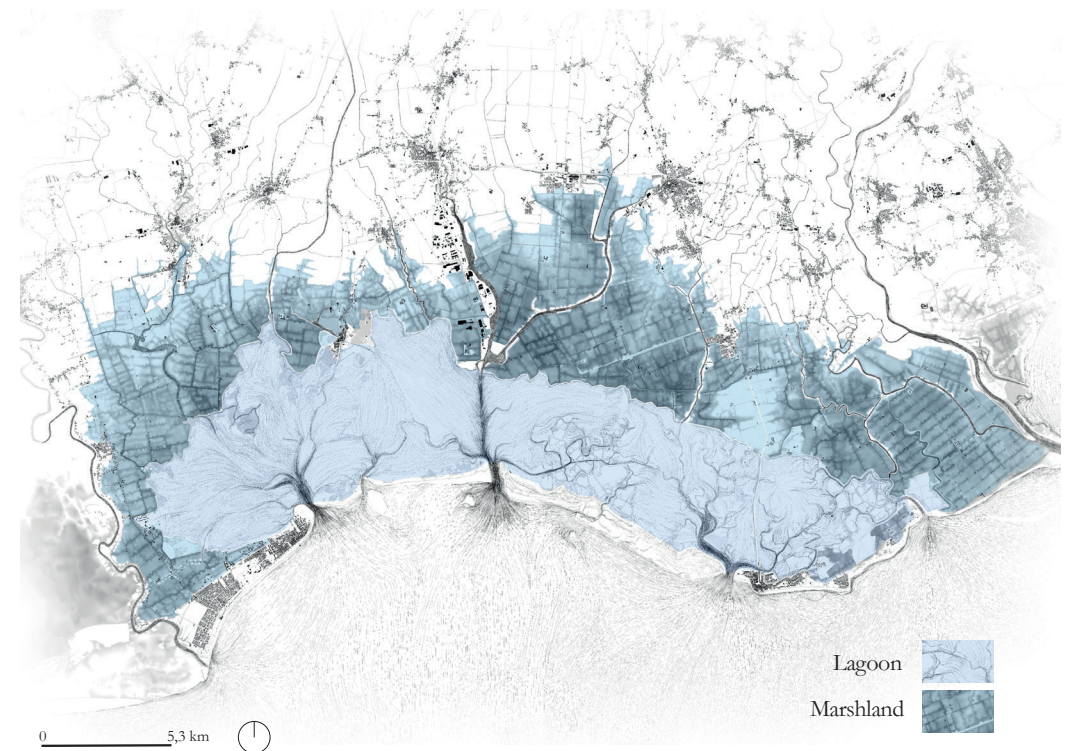
3.2 Transformation of the territory

Before the 1930's, the Upper Adriatic wetlands covered 764,000 hectares (Cosolo, 2015). In less than a century, they were subjected to enormous land reclamation works that totally reshaped the landscape, with the aim of developing the economy in this underdeveloped region. Only 75 000 hectares of wetlands still remain.

These works were part of the Fascist policy of the time, which aimed to support and develop an Italian autarkic commercial independence. This involved increasing agricultural yields and developing industry (Felcher, 2020). These transformations consisted in land reclamation, land reorganization, hydraulic works and the birth of “founding towns” such as Torviscosa.

Reclaimed land, gained on the lagoon and marshlands, is located on average between 1m and 3m below sea level, making continuous drainage pumping necessary. At the time, this land was marshland, unsuitable for cultivation and prone to diseases such as paludism spread by mosquitoes.

Before this work, only 49,000 hectares out of the 70,000 hectares of the Friulian plain were cultivated, the rest being marshland, fishing grounds and sandbanks (Cosolo, 2015).



Mountains

Plains

Lagoon until the 1920s

Sea

Fig. 17 « Former shape of the lagoon » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

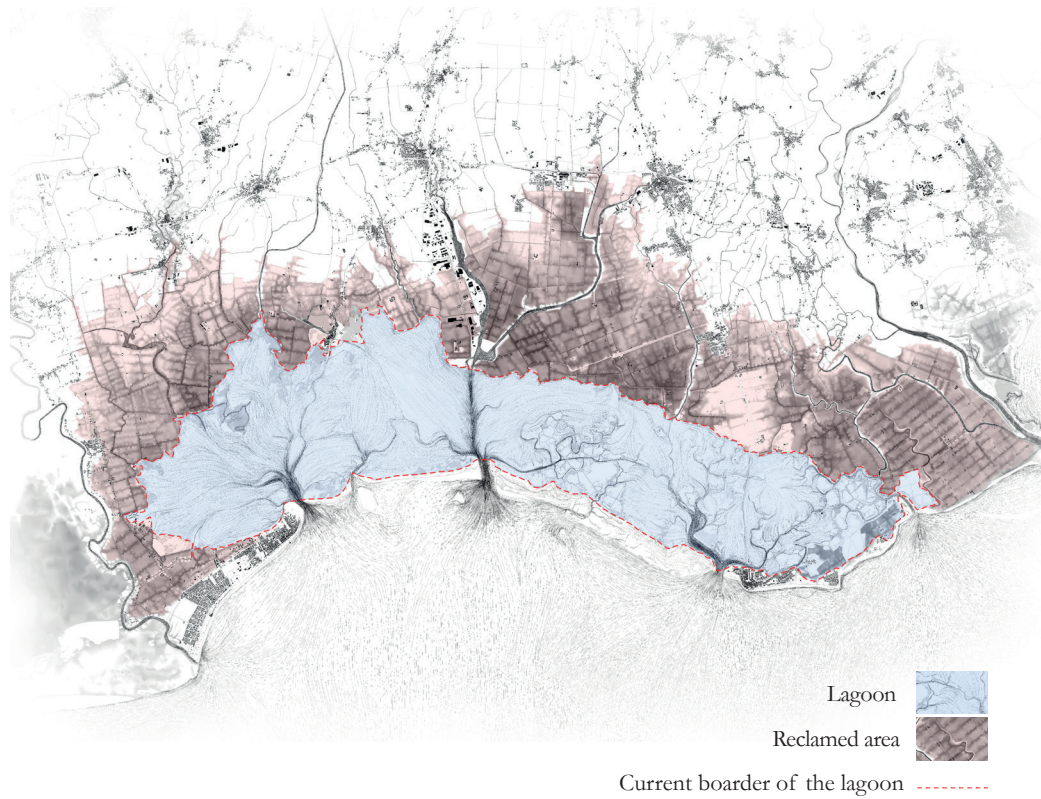


Fig.18 « Current shape of the lagoon » Data developed by the author. From Territorial data catalog and Tarquini, 2023.
(AUTHOR, 2024)



3.2.1 The case of Torviscosa

The story of the town of Torviscosa is a perfect illustration of this transformation. And it helps to understand the purpose of these reclamation projects.

Torviscosa is a «Città di fondazione⁷» founded by Mussolini in 1937. It represents an example of Fascist urban planning linked to «Fascist reclamation». The city was built in the center of marshlands in the process of reclamation. Its development grew up around the SNIA viscosa factory, which produced textile fibers from the cellulose of giant cane cultivated in the reclaimed fields. This was a substitute for foreign-produced synthetic polymers, important to the economic independence (autarky) of Italy.

The concept of reclamation, in the Italian Fascist context, was not only limited to hydraulic engineering and land development initiatives but was also embedded in a broader ideology. These initiatives were designed to reinforce state power and promote Fascist ideals of progress and modernization. They responded to the need to eliminate social tensions, by creating jobs and fertile land, while reinforcing the regime's control over the local population.

This model city was the direct result of the Fascist vision of radical territorial transformation, both economically prosperous and politically in line with the regime's doctrine.



⁷ A «città di fondazione» was a new town founded under Mussolini's Fascist regime, designed as a model of urban planning and social organization.

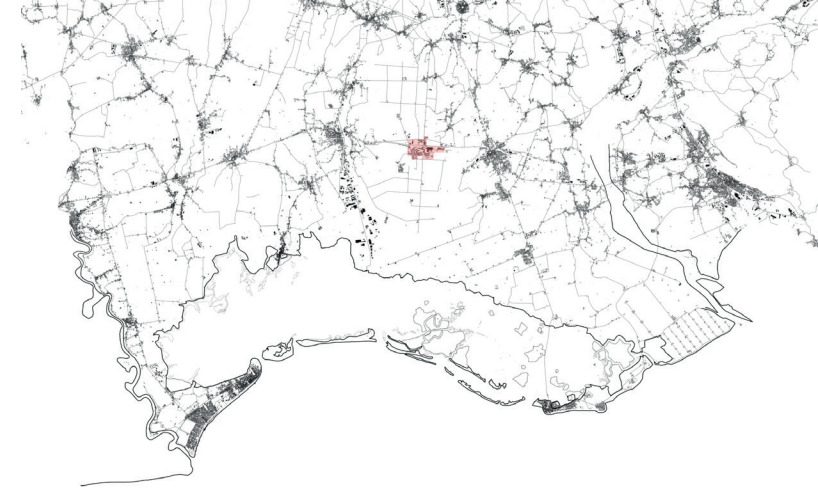


Fig. 20 « Torviscosa » (Torviscosa museum)

3.3 Hydraulic machinery

This work of land reclamation is known in Italian as «bonifica», from the Latin «bonum facere», meaning «to render (the land) good».

To reach this goal, the historical «consorzi di bonifica» have been revived. These consortiums had been in place since Roman times and were responsible for managing water-related infrastructures.

Today, these organizations, with public legal status and structured as associations, supervise the management and maintenance of rehabilitation projects. They also oversee the efforts of private individuals in areas undergoing restoration and receive funds from private sources (Perez, 2018). The entity responsible for the lower Friuli plains is the «consorzio di bonifica pianura friulana».

Land reclamation has become possible thanks to the implementation of various works such as hydraulic infrastructures, land redevelopment projects and the design of new roads to ensure flawless functionality. It is therefore part of large-scale operations requiring the re-examination and reshaping of a significant part of the territory.

The first phase involved building 65 kilometers of dikes (called « argine ») along rivers and lagoons to control water levels and prevent flooding. These structures were erected at an average height of 3 meters above the average water level of the lagoon, making them prominent features of the landscape. These dikes were also erected along watercourses to contain runoff and stabilize the river network.

The creation of dikes goes hand in hand with the digging of canals as part of an irrigation and drainage network. These canals are designed to bring and drain water from farmland in a controlled way, allowing the water to circulate only within their boundaries. They also collect and deliver the water to pumps, where it is discharged back into the lagoon and river water levels.

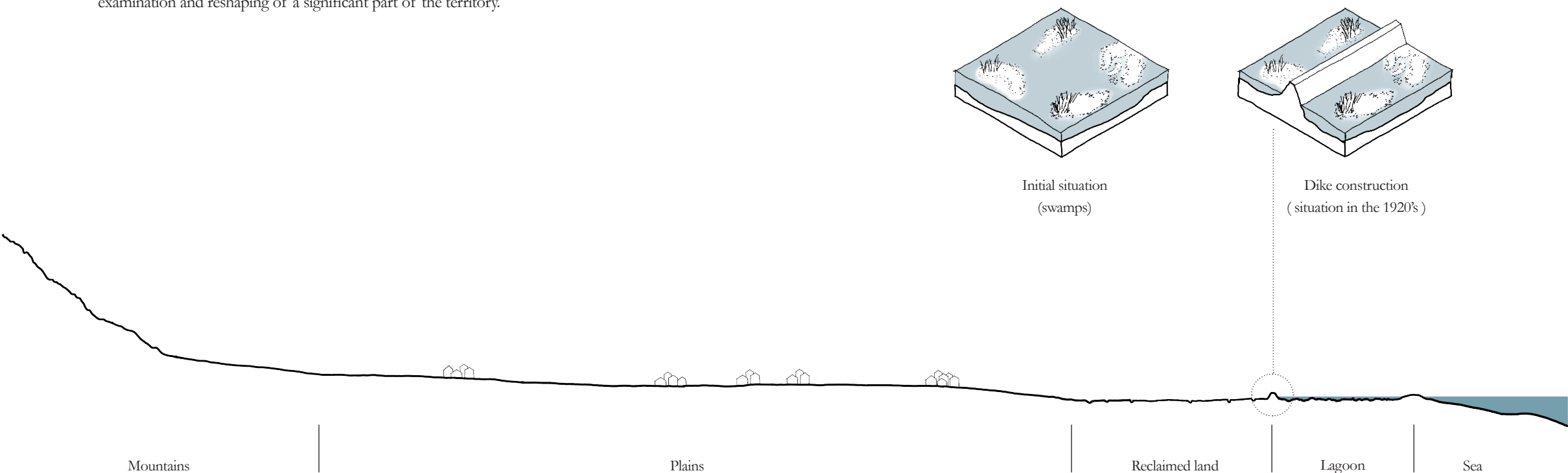


Fig. 21 « Dikes elevation » From Marin, 2021. (AUTHOR, 2024)

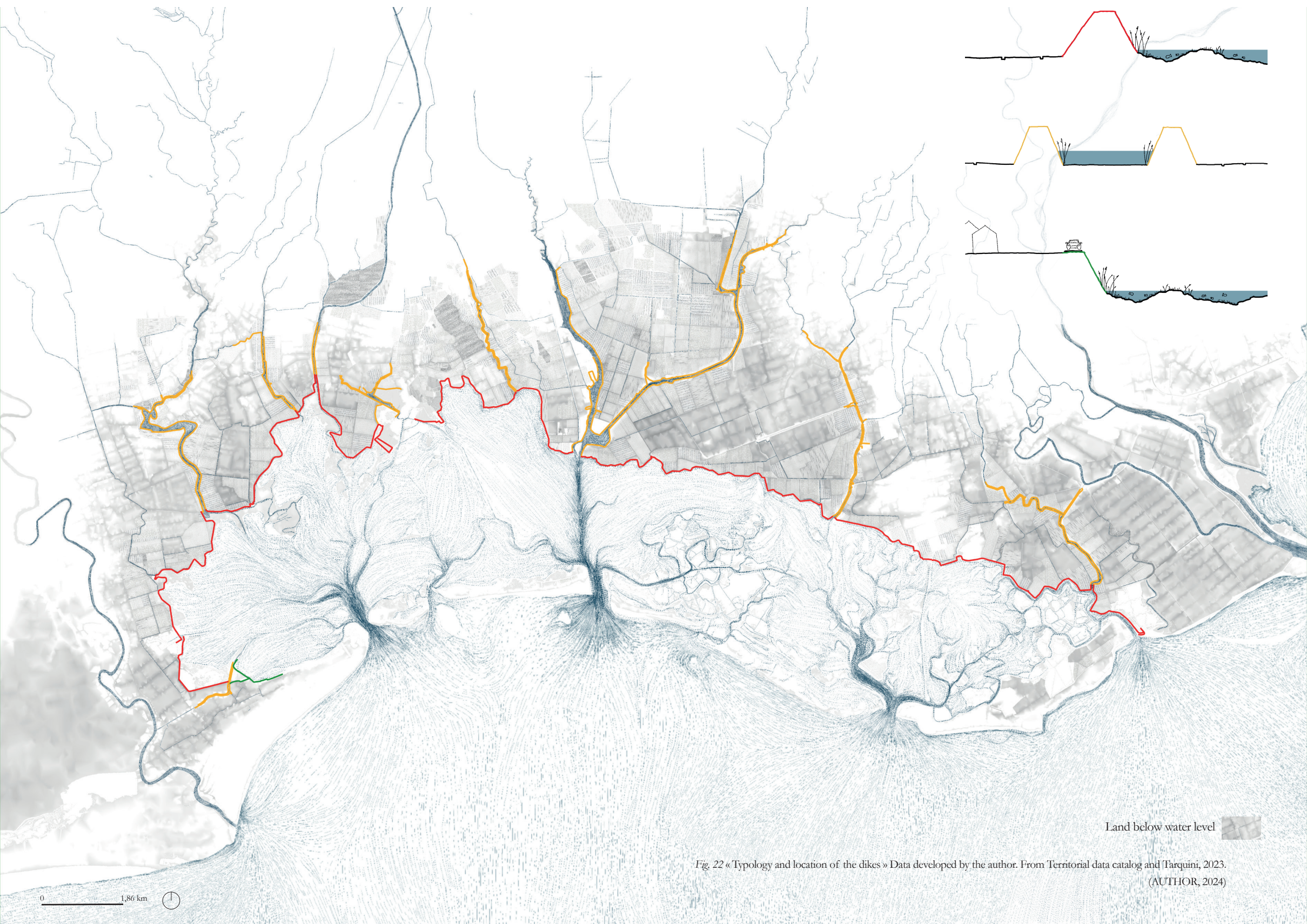
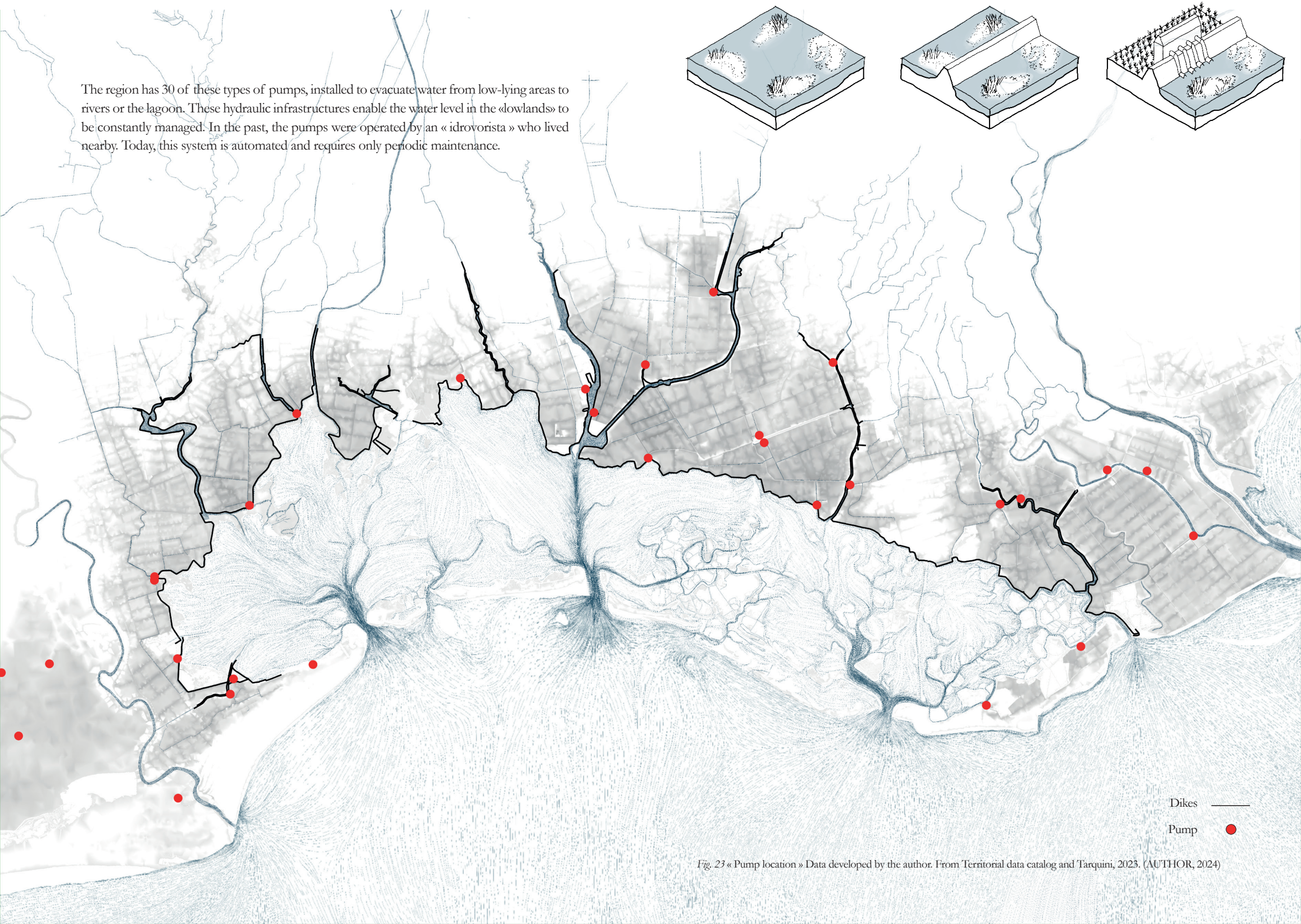
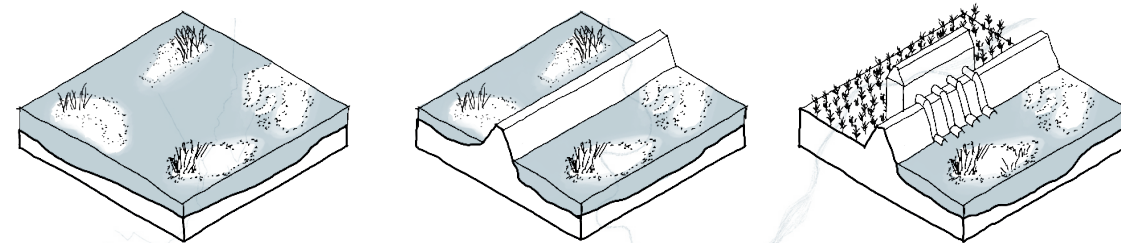


Fig. 22 « Typology and location of the dikes » Data developed by the author. From Territorial data catalog and Tarquini, 2023.
(AUTHOR, 2024)

The region has 30 of these types of pumps, installed to evacuate water from low-lying areas to rivers or the lagoon. These hydraulic infrastructures enable the water level in the «dowlands» to be constantly managed. In the past, the pumps were operated by an «idrovorista» who lived nearby. Today, this system is automated and requires only periodic maintenance.



Dikes —
Pump ●

Fig. 23 « Pump location » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

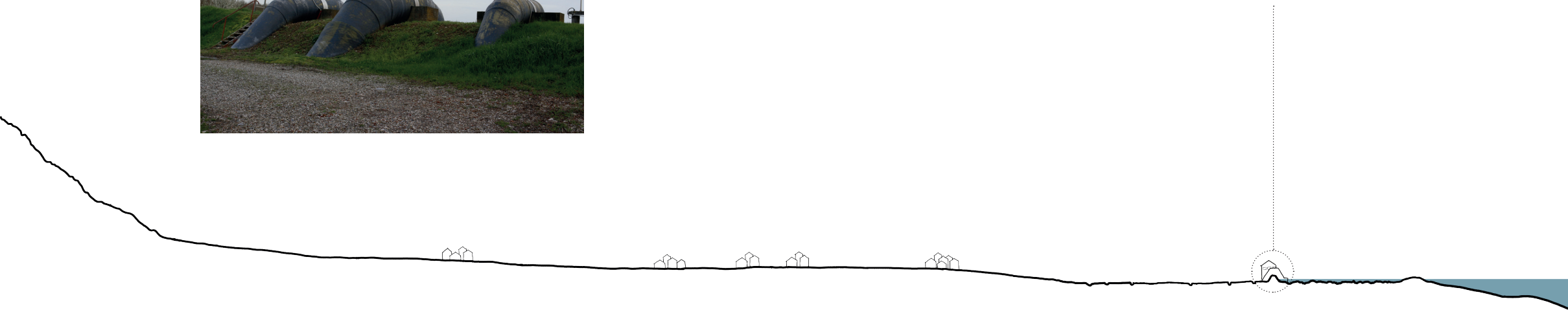
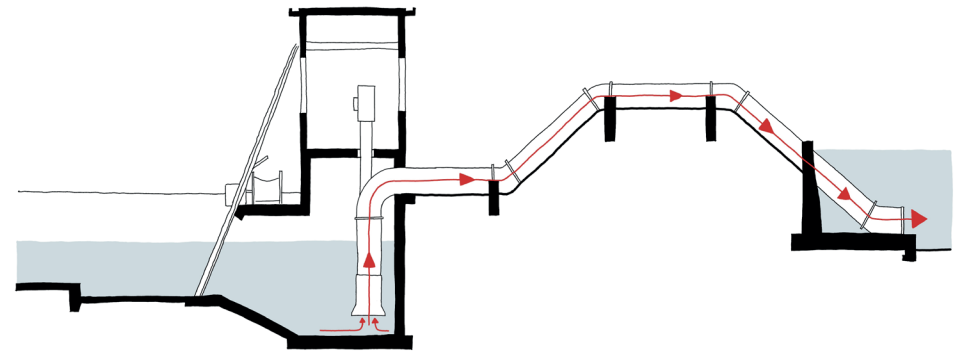
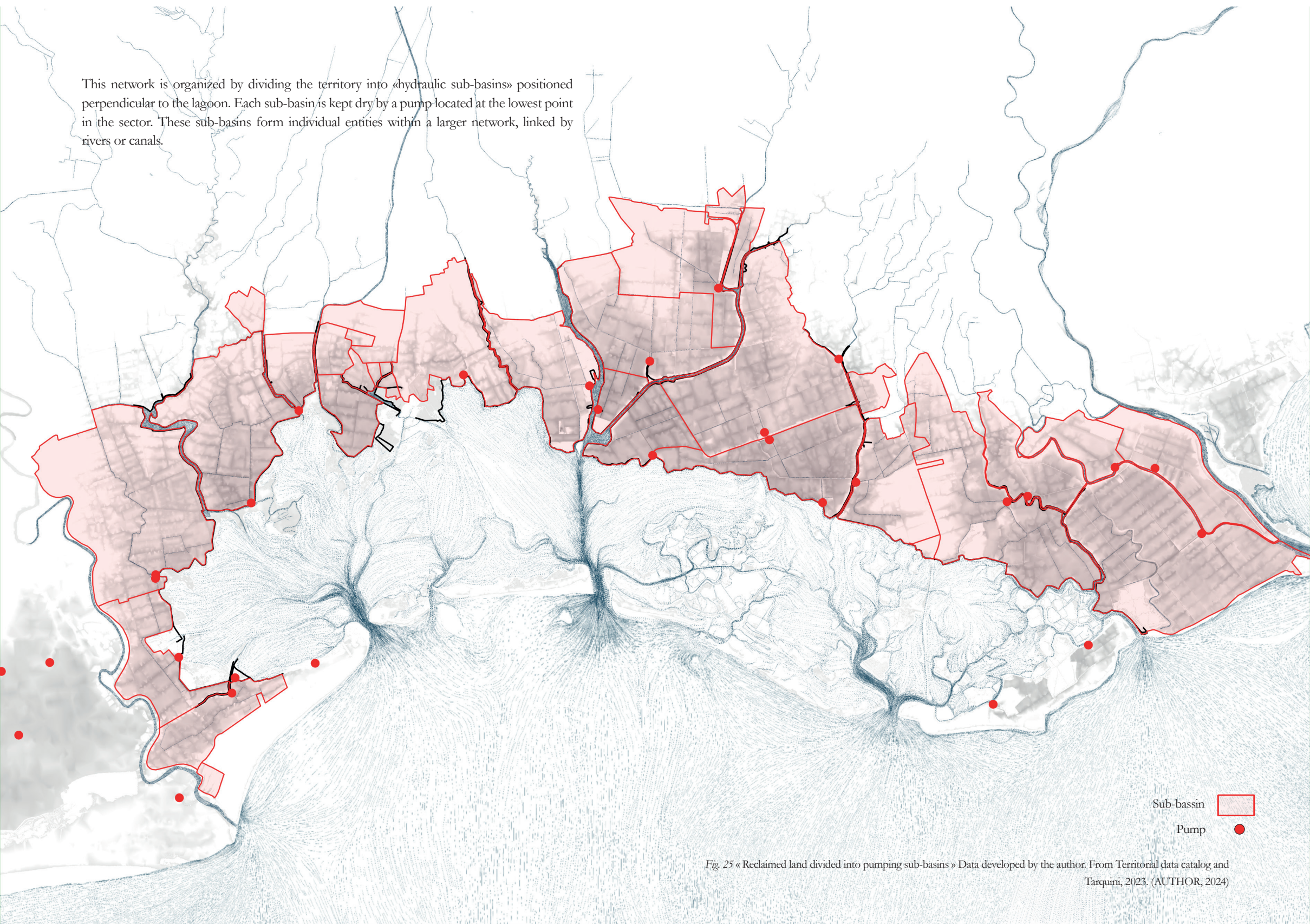


Fig. 24 « Pumping station » From ANBI Veneto, 2018. (AUTHOR, 2024)

This network is organized by dividing the territory into «hydraulic sub-basins» positioned perpendicular to the lagoon. Each sub-basin is kept dry by a pump located at the lowest point in the sector. These sub-basins form individual entities within a larger network, linked by rivers or canals.



Sub-bassin 
Pump 

Fig. 25 « Reclaimed land divided into pumping sub-basins » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

On the scale of one of these basins, we can better understand how this system works.

Let's take the « Famula » sub-basin to analyze it in more depth. It covers an area of around 13 km².

This sub-basin contains a series of canals of varying sizes. Very fine canals crisscross the fields to drain them (1). They then flow into slightly larger, deeper canals at the edges of the fields, from which water is drawn for irrigation (2). The last type of canal is the collector canal (3). Wider and deeper, they collect all the water and convey it to the pumps (4) before being discharged into the lagoon or the water courses (5).

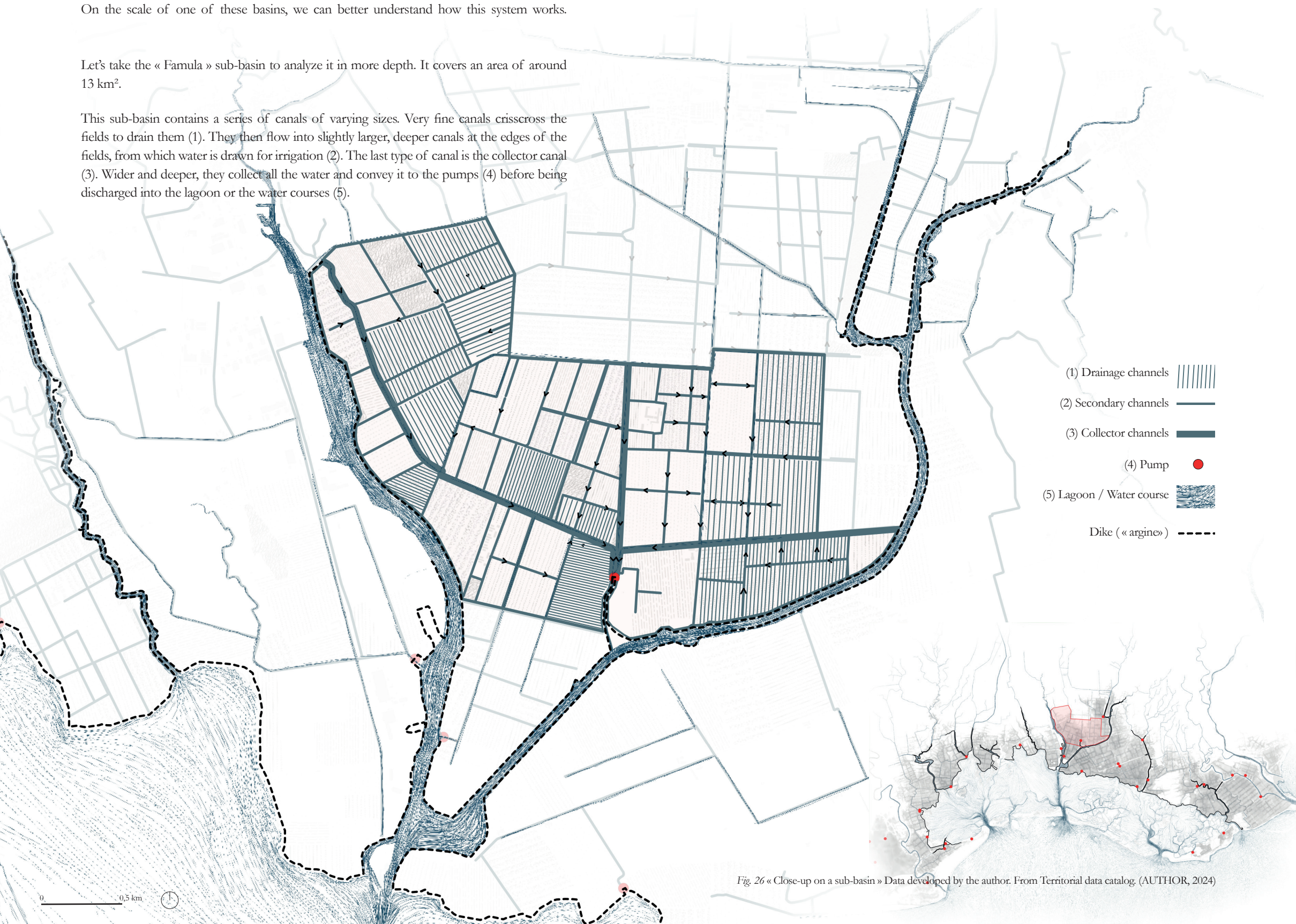


Fig. 26 « Close-up on a sub-basin » Data developed by the author. From Territorial data catalog. (AUTHOR, 2024)

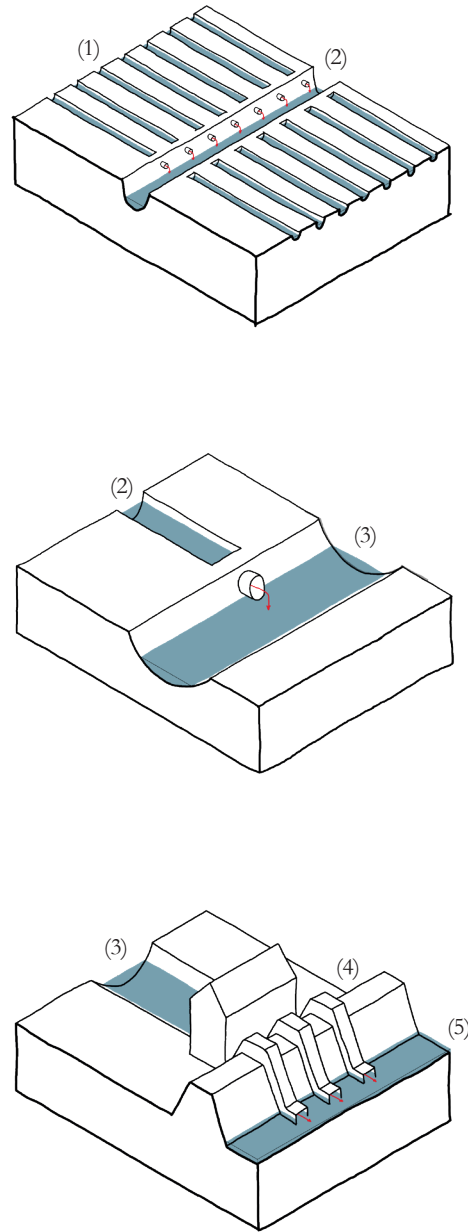


Fig. 27 « Water trail through reclaimed land » (AUTHOR, 2024)

Throughout this network, man constantly manages the flow of water. Between the various canals are valves, small pumps, pipes, and other mechanisms that control the inflow and outflow of water as required.



Fig. 28 The various elements found on the water trail

3.4 Industries and the sewage system

Until the 1950s, the region was mainly dependent on agriculture. It wasn't until the 1970s that the regional economy really began to evolve again, with the establishment of new industries, the development of tourism and the adoption of innovative agricultural techniques such as the abundant use of fertilizers.

Agriculture was no longer the only source of income. Factory work offered an attractive alternative, providing a regular income. This led to the coexistence of factory work and agricultural activities. Moreover, the low cost of labor favored this transition.

Today, the Aussa-Corno industrial zone is one of the region's most important industrial hubs. Several types of industry have established themselves here, including manufacturing industry, chemical industry, energy industry, construction industry and, until the 2000s, a large number of leather tanneries have been an environmental disaster. The fact that the industrial zone is located near the mouth of the Aussa-Corno rivers and the lagoon has raised many questions about the discharge of pollutants into the water and soil.



In 1987, a project was proposed for a water treatment plant in the area. The aim was to maintain the lagoon's ecosystems.

A second hydraulic system was then installed, but focusing this time on collecting polluted waters from industrial and domestic uses. A large water treatment plant, operated by the company CAFC was installed in San Giorgio di Nogaro. It is the largest in the region.



Fig. 29 Aussa-Corno industrial zone

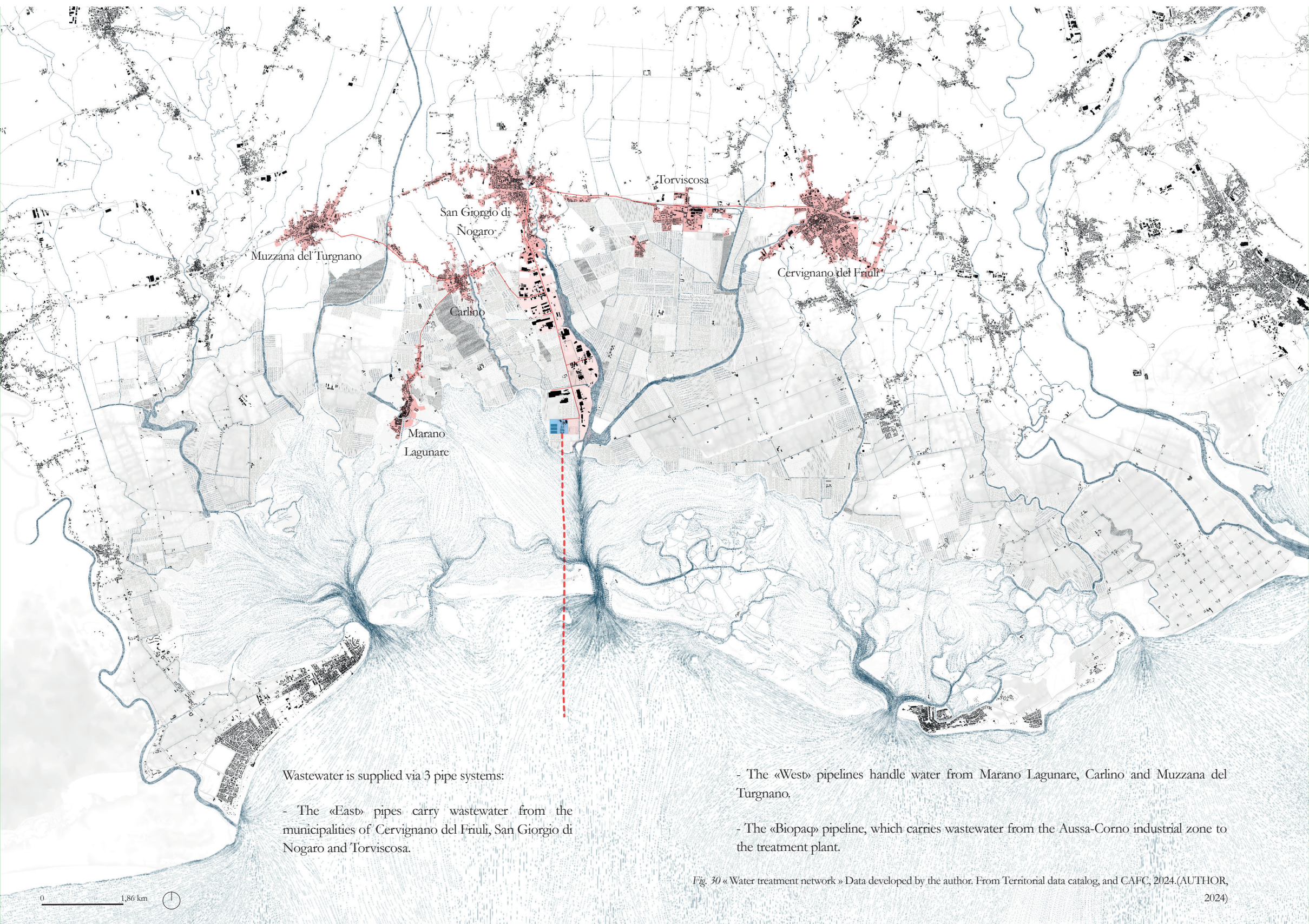


Fig. 30 «Water treatment network» Data developed by the author. From Territorial data catalog, and CAFC, 2024.(AUTHOR, 2024)

Once it arrives in the treatment plant, 3 lifting pumps bring 83,000m³ of wastewater per day into the basins.

It then undergoes various cleaning steps.

- The first is physical, with several «sedimentation» phases in which thick and medium sediment settles to the bottom of the basins, while oils and greases rises to the surface before being redirected to other systems.

- The second phase is known as «chemical». It involves the use of active mud made up of micro-organisms that digest the nitrates (resulting from the oxidation of ammonia by air injection) present in the water, before releasing them in the form of nitrogen gas, which evaporates.

After these various stages, the water is purified and can be discharged into the open sea 13 km from the plant via a Trans lagoon pipeline (7 km from the lido).

3.5 A neglected lagoon, behind the dikes wall

It is clear from the above that the past history of this wetland region has been more dictated by economical factors than by a genuine interest in the ecological value of this fragile and rich environment. It was almost considered a nuisance or at best an irrelevant part of the national territory.

The local authorities seemed intent on making a break with the past, putting the lagoon on the background or even neglecting it. Over time, it became almost exclusively a tourist attraction, lacking the attention and care needed to preserve its fragile ecosystem and historical significance. This disregard for the lagoon reflects a wider tendency to sacrifice natural wealth in the name of economic progress and urban development. Despite the development of a certain form of eco-tourism, this situation has largely persisted to the present day, as demonstrated by the proposed installation of an ultra-polluting steelworks alongside the lagoon.

This denial is also evident in the shape of the site itself. In order to protect the reclaimed land from the water, which is seen as a source of income, massive dikes several meters high were erected, creating a formal separation from the lagoon. This artificial division not only creates a physical separation, but also an economic, social and environmental one.

Nowadays, we don't even realize that on the other side of this «wall», a rich biodiversity exists.



Fig. 31 Demonstration against the construction of a steel factory near the lagoon

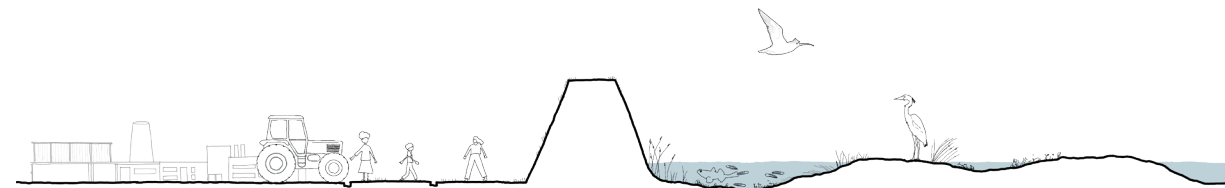


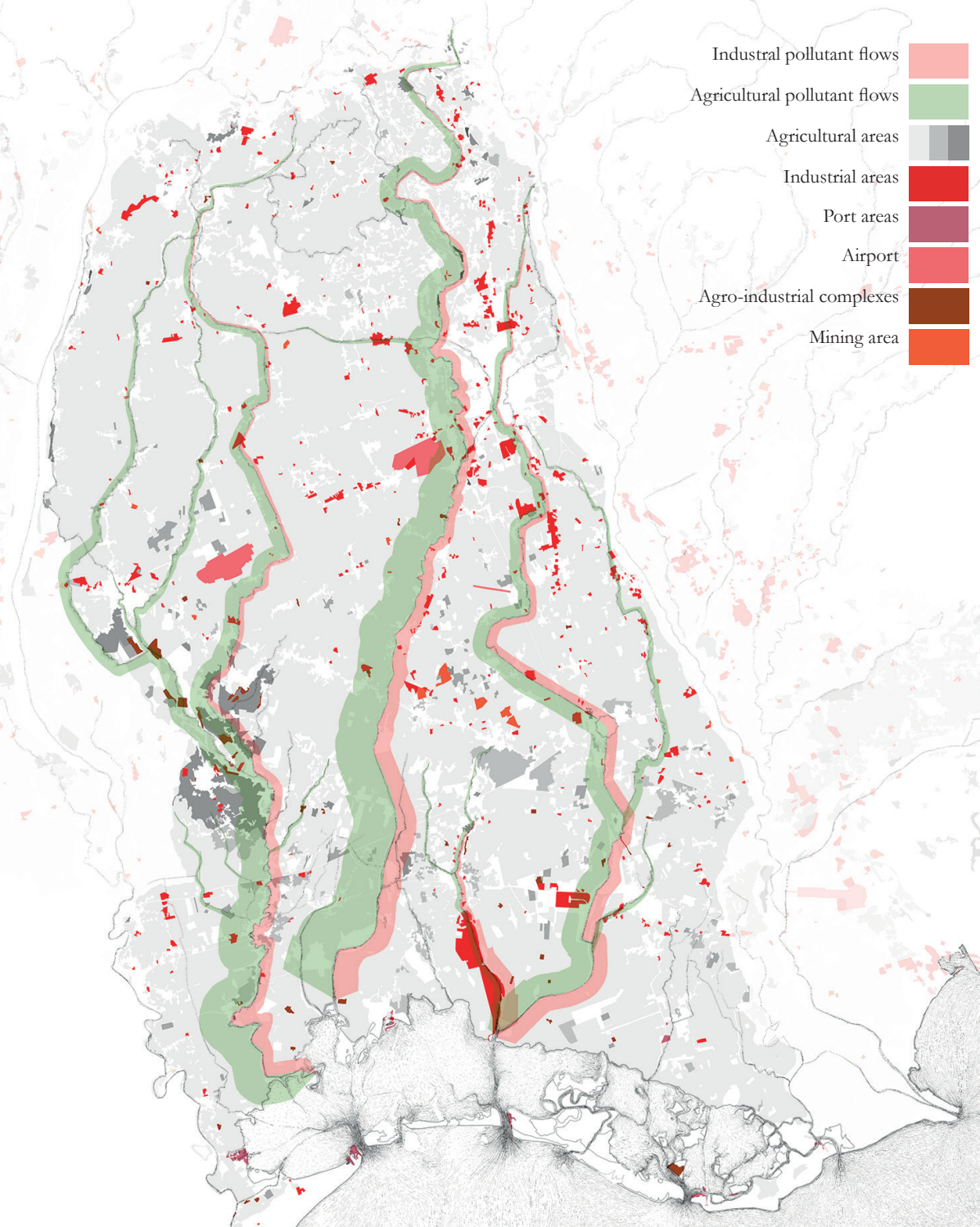
Fig. 32 Highlighting the distinct environments separated by dikes

4 AN ENDANGERED ENVIRONMENT

As an interface between the mainland and the sea, the lagoon represents a delicate and sensitive ecosystem. Its shallow depth makes it one of the most vulnerable coastal zones to environmental disturbances. Even the slightest change can disrupt its equilibrium with devastating consequences, threatening its very survival.

In our rapidly changing world, the lagoon is in the front line when it comes to being vulnerable to these changes. In this chapter, we analyze the various threats to the lagoon. To better understand these threats, we have divided them into two categories: those coming from upstream, generally of anthropogenic origin, and those coming from downstream, typically from the sea, including those linked to climate change. In our analysis, we consider the entire tributary basin.

4.1 Upstream threats :



4.1.1 Agricultural pollution

The threat of pollution mainly arises from field run-off and agricultural activities. Indeed, 76% of the lagoon's watershed is covered by fields of corn, beet, cereals, sunflowers, etc., which are generally cultivated by intensive farming. Agriculture is the region's leading economic activity, since it was strongly developed during the Fascist era as an economic development plan. Until today, agricultural areas are still expanding (and using fertilizers, herbicides and pesticides without moderation) to meet the growing demand for food.

According to the Ramsar Convention, agricultural land and pasture have increased from 27.2% to 46.5% of total surface area, while the extent of natural wetlands has declined by 35% over the last 100 years. They represent a diffuse source of contamination, polluting the soil, groundwater, river sediments and the lagoon. This is why part of the lagoon is included in the list of contaminated sites of national importance SNI (Brabanti, 2011).

The Wetlands Convention identifies agriculture and its use of chemicals as the main cause of wetland loss.

Today, we can clearly see the consequences. Water bodies are covered with a green filter due to the abundance of nutrients such as phosphorus and nitrogen. Aquatic vegetation then quickly spreads to cover the water's surface, stopping the supply of CO₂ essential for organisms living below the water's surface and resulting in areas devoid of aquatic life. This phenomenon is known as eutrophication.

Fig. 33 « The threat of industrial and agricultural pollution » Data developed by the author. From Territorial data catalog. (AUTHOR, 2024)

These nutrients find their way into the lagoon via the hydraulic network. In fact, the fields are drained by a series of canals, flowing into larger ones before arriving in streams or directly into the lagoon via the pumping system that keeps the land dry. There is no known filtration system at this level.



Fig. 34 Eutrophication

4.1.2 Industrial pollution

As we saw previously, the region is host several major industrial centers, including the Aussa-Corno area, which is close to the lagoon. Concerned about their lagoon, the inhabitants decided to install a wastewater treatment plant. Since then, the concentration of industrial pollutants has decreased considerably. But as can be seen in the graph below, there are still some signs of the past industrial activity, since there is still a small concentration of heavy metals, PFAS, ... That's the reason why it's important to note that there may still be potential leaks (in the water treatment network), leading to small quantities of industrial pollutants entering the lagoon.

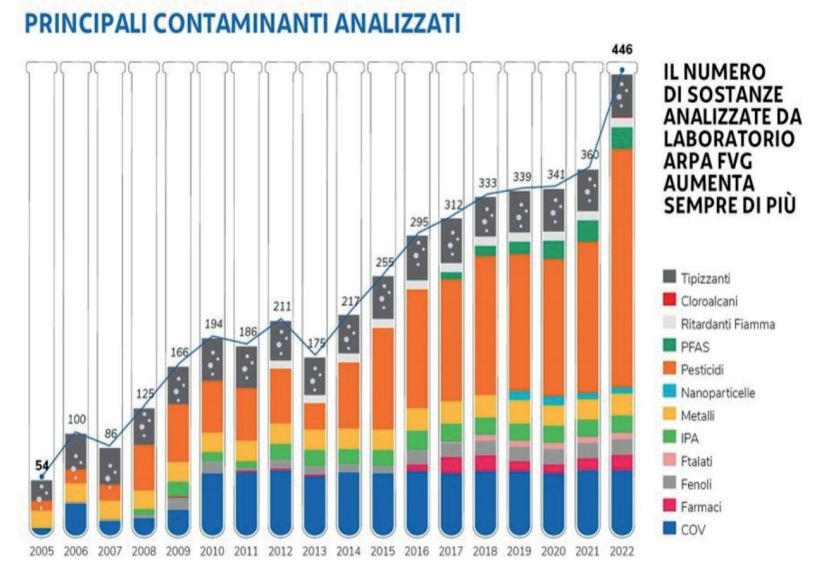
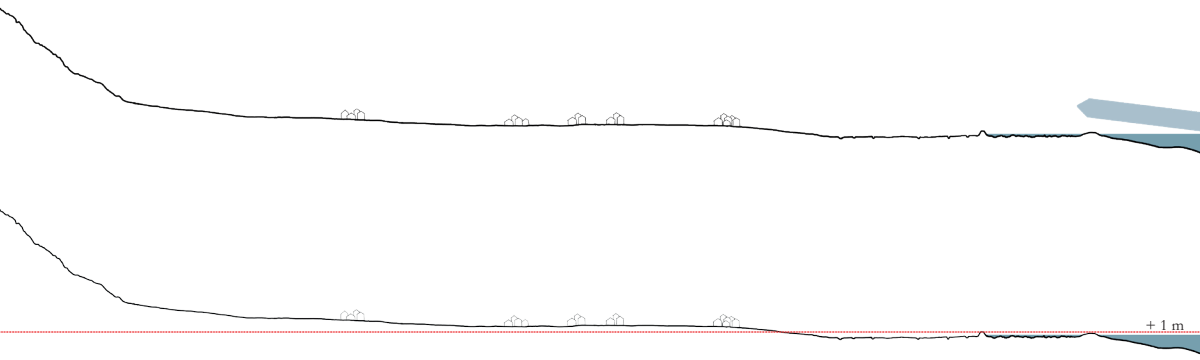


Fig. 35 «The main pollutants analyzed by Arpa FVG in water.» ARPA FVG, 2022.

4.2 Downstream threats



4.2.1 Sea level rise

Climate change is a reality that we are already experiencing today. It implies numerous changes that modify natural systems. The lagoon, as an environment that relies on delicate balances, is sensitive to these changes.

Sea-level rise is the main disturbance to the lagoon system. It is caused by a number of factors:

- Thermal expansion. As ocean water warms, it expands, taking up more space.
- Melting of glaciers and ice caps.
- Changes in land water storage. Human practices such as groundwater extraction and deforestation are altering the distribution of water resources. This contributes to sea-level rise by moving water from the land into the oceans.

4 scenarios have been established by the IPCC⁸ reflecting the likely trajectories of climate change by 2100. These are RCP2.6, RCP4.5, RCP6.0 and RCP8.5⁹, with RCP2.6 being the most optimistic scenario, predicting a sea-level rise of 0.43 m by 2100, with an uncertainty range of 0.29 m to 0.59 m. This would mean an increase of 4 to 9 mm per year until 2100. Scenario RCP8.5, the most unfavourable, envisages an increase of 0.84 m, with a wider range

⁸ Intergovernmental Panel on Climate Change

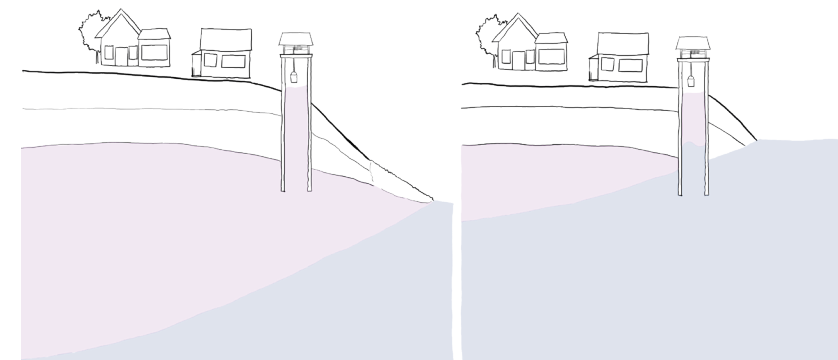
⁹ RCP stands for «Representative Concentration Pathways» and the number X.X refers to the concentration of greenhouse gases.

of uncertainty from 0.61 m to 1.10 m. This means a rise in water levels of 15mm per year until 2100 (IPCC AR5, 2014).

The RCP2.6 scenario implies a loss of balance between salt and fresh water. Currently composed of 70% freshwater, the lagoon would undergo a shift towards more marine conditions. This change would lead to an increase in the « salt-water wedge » phenomenon, where salt water penetrates deeper into the land soils and affects freshwater quality. As a result, this would lead to increased soil salinization, which would be damaging for agriculture, as plants are sensitive to high levels of salt in the soil, which can affect growth and yield. Increased salinity in agricultural soils can also render land unfit for cultivation.

Sea level rise +1m

Sea level rise +2m



The RCP8.5 scenario predicts a sea-level rise of between 0.61 and 1.10 m, with serious impacts for the Marano and Grado lagoons.

The coastal barriers that enclose and protect the lagoon would be submerged for the most part. This would tend to turn the lagoon into a bay, leading to its disappearance. Ecosystems would see their habitats disappear. Some mobile species could move to other areas favourable to their development. But other less or non-mobile species would then find themselves in conditions to which they are not adapted and would eventually perish.

Sea level rise +1 m
Sea level rise +2 m

0 7,6 km

Fig. 37 « The threat of rising waters » Data developed by the author. From Territorial data catalog and Climate Central, 2021. (AUTHOR, 2024)

4.2.2 Extreme events

Rising sea levels are also associated with an increase in the frequency of unusual extreme events¹⁰. Historically, they occurred on average once a century. Today, extreme events are reported every year in some regions (IPCC AR5, 2014).

These events are known as « Mariaggiata » in the region. This corresponds to a « storm surge » that combines all the unfavorable factors: high tide, low air pressure, strong winds such as sirocco¹¹, sea-level rise and rain.

To illustrate these events, here's what the keeper of the Valle Cavanata nature reserve had to say:

To illustrate these events, here's what the keeper of the Valle Cavanata nature reserve had to say:

« Last December we encountered a storm surge that caused the sea to pass over the seawalls. It smashed a sluice that allows us to control the inflow of salt water into the reserve, which is a former fishing valley and therefore functions like one. For the moment, we've tried to repair it with wooden panels, but the water still gets through. In other words, we've completely lost control of this inflow. We know that in the coming years it's going to be a real battle to maintain this area. » says Paul Tout.



Fig. 38 Sluice broken during a storm

Many of these events have taken place in recent years, such as November 22, 2022, which represents a significant event, as the water level rose by 169 cm in 24 hours in relation to mean sea level, due to the interaction of high tide, strong sirocco winds and a strong depression.

¹⁰ Refers to intense meteorological or hydrological events, such as storms or floods, likely to cause major damage.

¹¹ A hot, dry, often dusty wind from the south or southeast, which can occur in Mediterranean regions.

4.2.3 Morphological modification of the lagoon

The lagoon is an environment in perpetual motion due to the constant flow of water. In recent years, these movements have intensified, and the lagoon seems to be evolving towards a more bay-like configuration. This is known as the «marinization of the lagoon».

Erosion is one of the causes. It is accentuated by events involving greater wave movement combined with the passing of boats.

This phenomenon can be observed along the coastal barriers, which are becoming thinner.

We can also see it inside the lagoon. The salt marshes are shrinking in size. The higher the water rises, the greater the erosive capacity. In 2011, a loss of 2,672 hectares of salt marsh was recorded, i.e. 45.9% of the original area (Segnali, 2023). This is a cause for concern, given that salt marshes are indicators of change in the lagoon.

The velmes and barenes are also affected by these changes, and there is a tendency for the lagoon bottom to deepen as a result of rising water levels and the lack of sediment supply from the rivers, which are blocked by upstream dams and therefore do not reach the lagoon and the sea (Sarcinelli, 2022).

1988



Fig. 40 « State of the lagoon and its barenes in 1988 » Geoportale Nazionale MAZE, 2014.



Fig. 39 Effect of erosion

2012



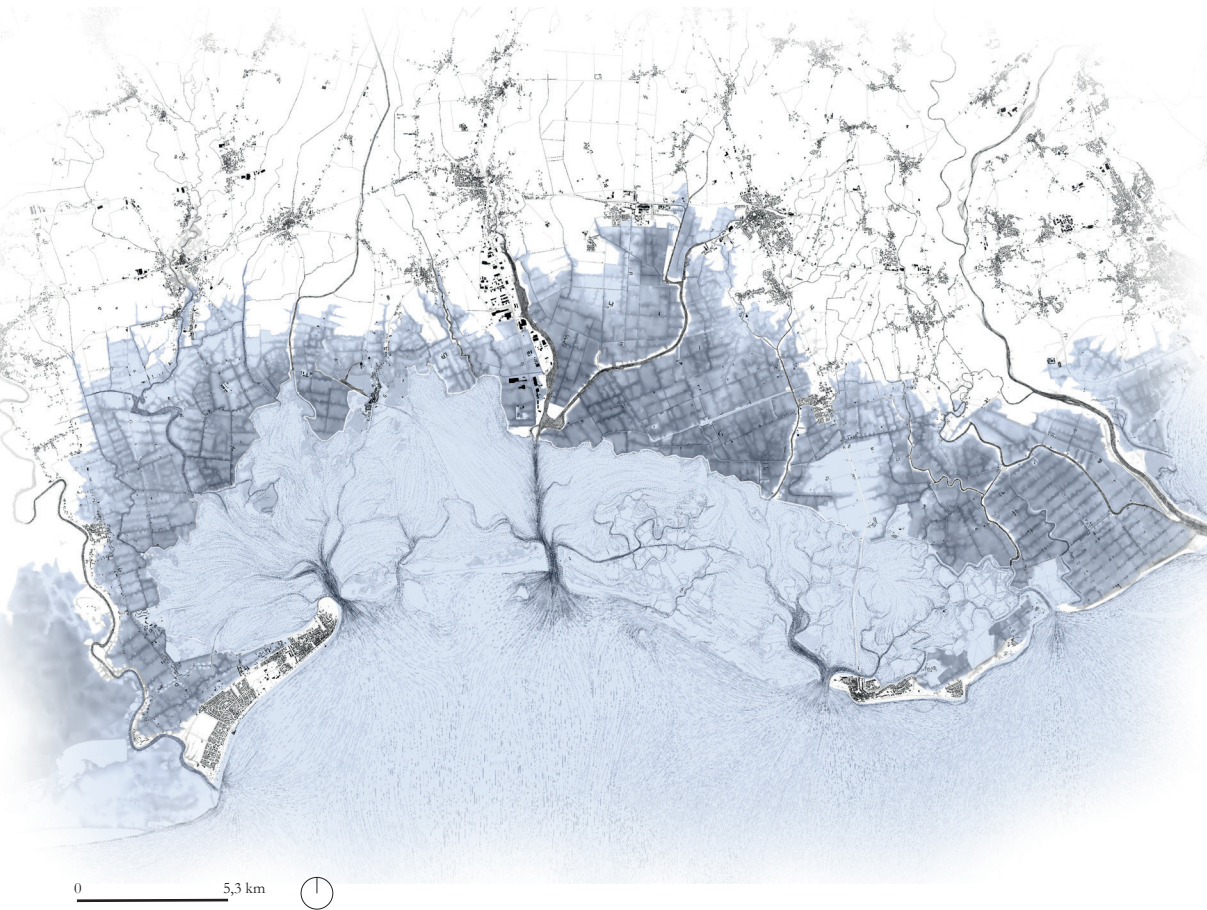
Fig. 41 « State of the lagoon and its barenes in 2012 » Geoportale Nazionale MAZE, 2014.

4.2.4 Drought

In 2022, the Friuli-Venezia Giulia region experienced one of the hottest years on record, resulting in a severe and prolonged drought with significant impacts on the Marano and Grado lagoons. In such conditions, river water volumes decrease, allowing salt water to penetrate flat areas of the watercourses and even reach field irrigation channels. This summertime salinization is all the more significant when we consider the origin of the rivers. Most of them are resurgent¹², which is enabled by the limestone composition of the soil. Small channels “aquifers” in the soil transport water from the mountains and emerge as springs closer to the coast. However, during droughts, these channels can reverse their flow, carrying salt water inland.

Moreover, as the water in the lagoon is very shallow, it is highly sensitive to changes in temperature. The water can heat up very quickly during hot periods, and ecosystems that have difficulty adapting to sudden changes do not survive.

¹² Rivers or springs that reappear on the surface after circulating underground.



5 A RENEWED LAGOON

By 2100, the lagoon is destined to change, or even disappear. In this part, we explore and design how the lagoon might evolve to address the threats it faces while reconnecting its inhabitants to its lagoon through a promenade.

5.1 Lagoon expansion

By 2100, the area dedicated to the lagoon will have to be expanded. With the sea level rise, the lagoon will disappear, and the sea will extend to the land located below the sea level.

However, if we reinforced the lidos, the lagoon would gradually reclaim the spaces that have been taken away from it over the course of its history. This return to its original form will occur because, as sea levels rise and the volume of water to be managed from the sea and rivers increases, the drainage system put in place in the past will no longer be viable.

Indeed, these pumps were designed to manage water permeation through the soil and overflow over the dikes, which were built at a time when climate change was not a concern.

The flow rate of a pump is +/- 15,000 l/s today. They have been sized to handle the water levels of the last century. If we consider the worst-case scenario (RCP 8.5), with water levels 1m higher, the water pressure will be higher, resulting in increased infiltration of water into the ground.

To compensate for the higher water infiltration through the soil caused by higher average sea level, the pump capacity will need to be increased.

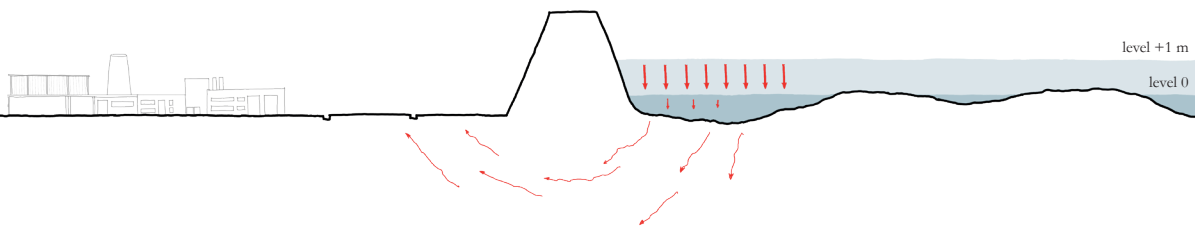


Fig. 43 « Water infiltration diagram » (AUTHOR, 2024)

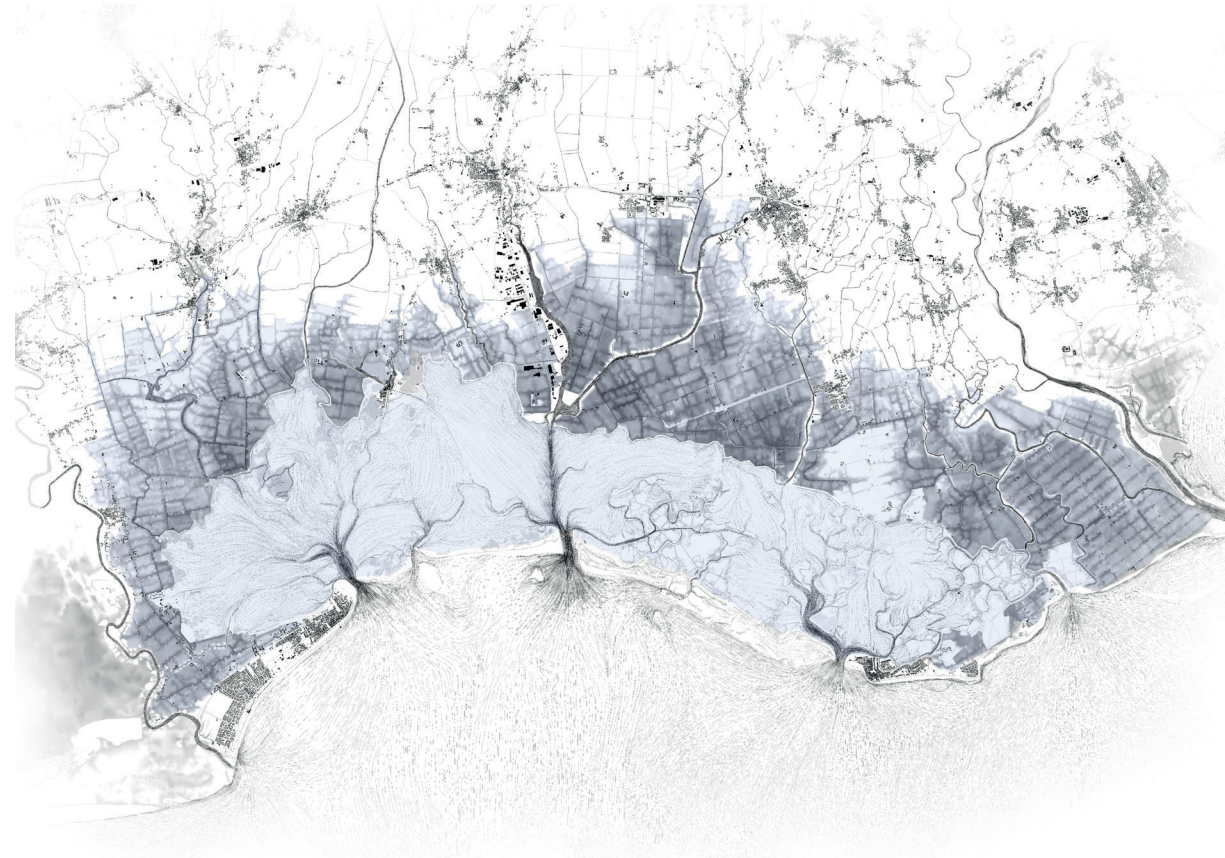


Fig. 44 « Evolution of the lagoon with rising water levels if the lido is reinforced » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

5.1.1 Wetlands in this vision

On the map we can see that the darker the area, the deeper the waters will be, with depths ranging from just a few centimeters to 3 meters in the drainage channels. This varied landscape will contain as much diversity as the current lagoon.

Today, wetlands are no longer seen as carriers of disease, but as environments to be protected and developed. We can take advantage of them to meet the challenges of today and tomorrow.

Located at the interface between the marine and continental domains, these zones act as a buffer against flooding. Their capacity to absorb and retain water during heavy rainfall and overflow from the sea reduces the risk of flooding in adjacent areas. They also protect against storm surges. They act as natural barriers, absorbing and dissipating wave energy.

When faced with excess nutrients and contaminants in the water, they can be a first line of defence. Marshes act as natural filters and purify the water.

As we have understood throughout this work, wetlands are habitats rich in biodiversity, providing ecological niches for a wide range of species. It is therefore important today to develop and restore these areas in order to preserve their ecological functions.

However, there are already initiatives in place to protect the lagoon's biodiversity, as it has been identified as a «Natura 2000» site. This implies that the lagoon is made up of different types of sites of interest, which proves the importance of its preservation.

These are:

- Site of Community Interest (SCI)
- Special Area of Conservation (SAC), which aims to protect habitats and animal and plant species in accordance with European Directive 92/43/EEC on habitats.
- Special Protection Area (SPA) to specifically protect birds and their habitats in accordance with European Birds Directive 2009/147/EC (Governo italiano, 2023).

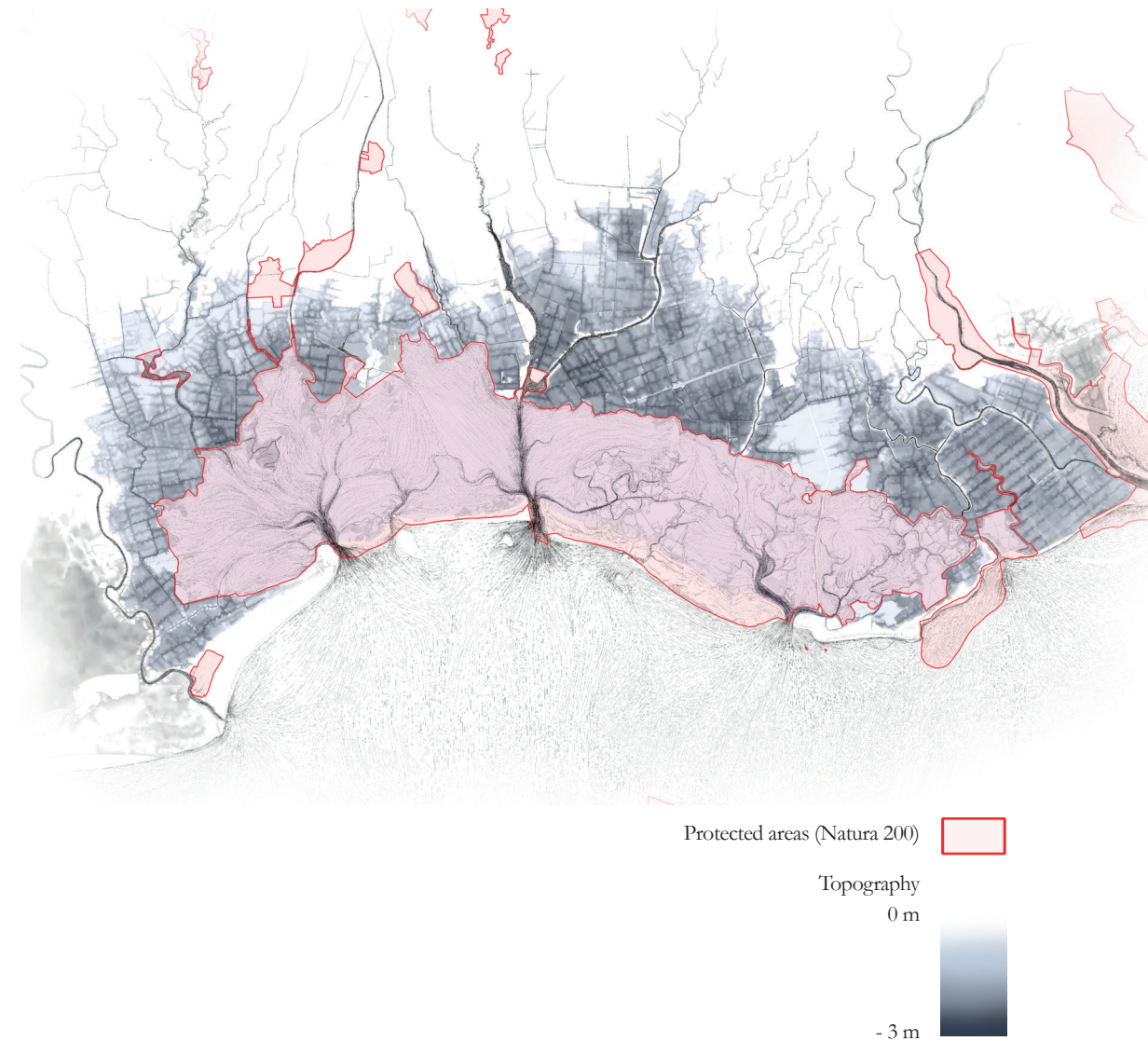


Fig. 45 « Protected areas » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

5.1.2 A new coastline

As the lagoon expands, it will have a new link with the land around it. This involves the emergence of a new coastline, a new relationship between man and lagoon.

Since the pumping capacity will have to be increased, a hybrid system would therefore be of interest. It would make it possible to keep out of the water the areas we want to preserve, by leaving only some of these pumps active, while allowing the lagoon to return in part to its original shape. In some places, the land reclaimed from the lagoon will return to its original marshland state, while in others it will be completely submerged depending on the terrain topography.

The municipalities of Torviscosa, Carlinò, Aquileia and Cervignano del Friuli would become coastal towns, with the new coastline located at the boundary between of today's land below and land above water level.

This means that the towns of Marano Lagunare and the industrial zone of Aussa-corno would be underwater.

It is of course primordial to preserve them. The town of Marano Lagunare has a special link with the lagoon. It's the only town to have direct access to the lagoon, and to benefit from it. It's from here that the main tourism infrastructures in relation to the lagoon can be found. This tourism could develop into eco-tourism, which could compensate for the loss of agricultural land, the region's main economic activity.

The industrial zone will also be preserved in a first phase. It is an important economic hub for the region, and getting rid of part of its agriculture and industry at once could be destabilizing for the economy. We could therefore imagine preserving it at first and considering the development of other activities before being able to detach ourselves from it in the future.

The pumps in these sectors should therefore continue to operate as they do today

- Favole sector for Marano
- Belvat sector for Torviscosa
- Planais sector for the Aussa-Corno industrial zone

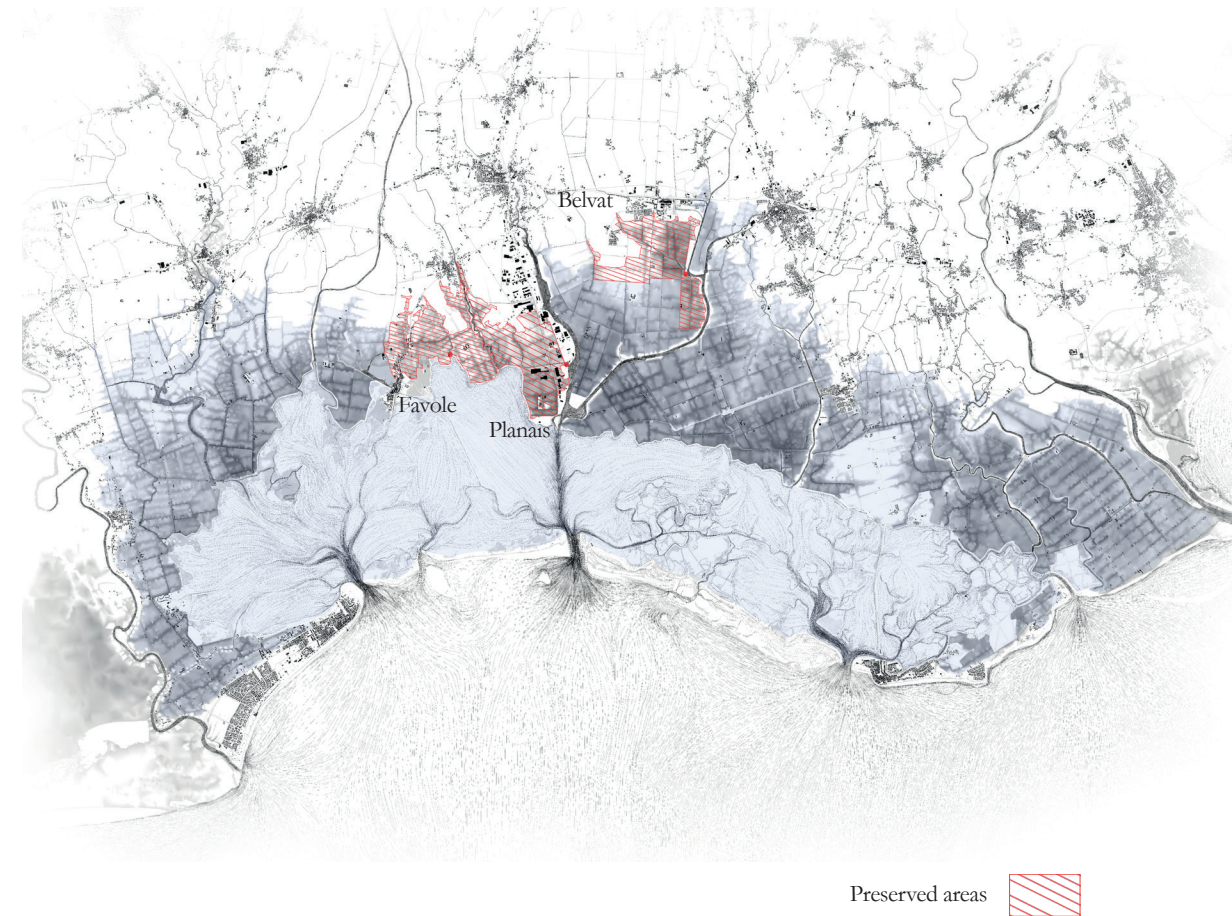


Fig. 46 « Areas chosen for protection » Data developed by the author. From Territorial data catalog and Tarquini, 2023.
(AUTHOR, 2024)

5.2 Scenarios for inland lagoon expansion

The expansion of the lagoon can take various forms, depending on whether we allow it to spread naturally or guide and control its development based on what we want to preserve and how we intend to use it.

Scenario 1 :

In the first scenario, the lagoon naturally returns to its original shape before the reclamation works. The dikes erected at that time will still be present, partially separating the new lagoon area from the existing lagoon. Only the lidos, the coastal barriers protecting the lagoon, will be reinforced to preserve the lagoon's current state and all that it represents.

This scenario thus represents a situation of planned natural evolution that would not result in the loss of the lagoon.

ADVANTAGES	DISADVANTAGES
No major intervention required	Loss of productive land
Better preservation of the current lagoon	Important areas such as Marano Lagunare and the industrial zone of Aussa-Corno will be underwater
Gain of new wetlands	
Almost two separate lagoons, but still connected, allowing for different uses	
The upstream area can serve as a purification zone before water enters the current lagoon	

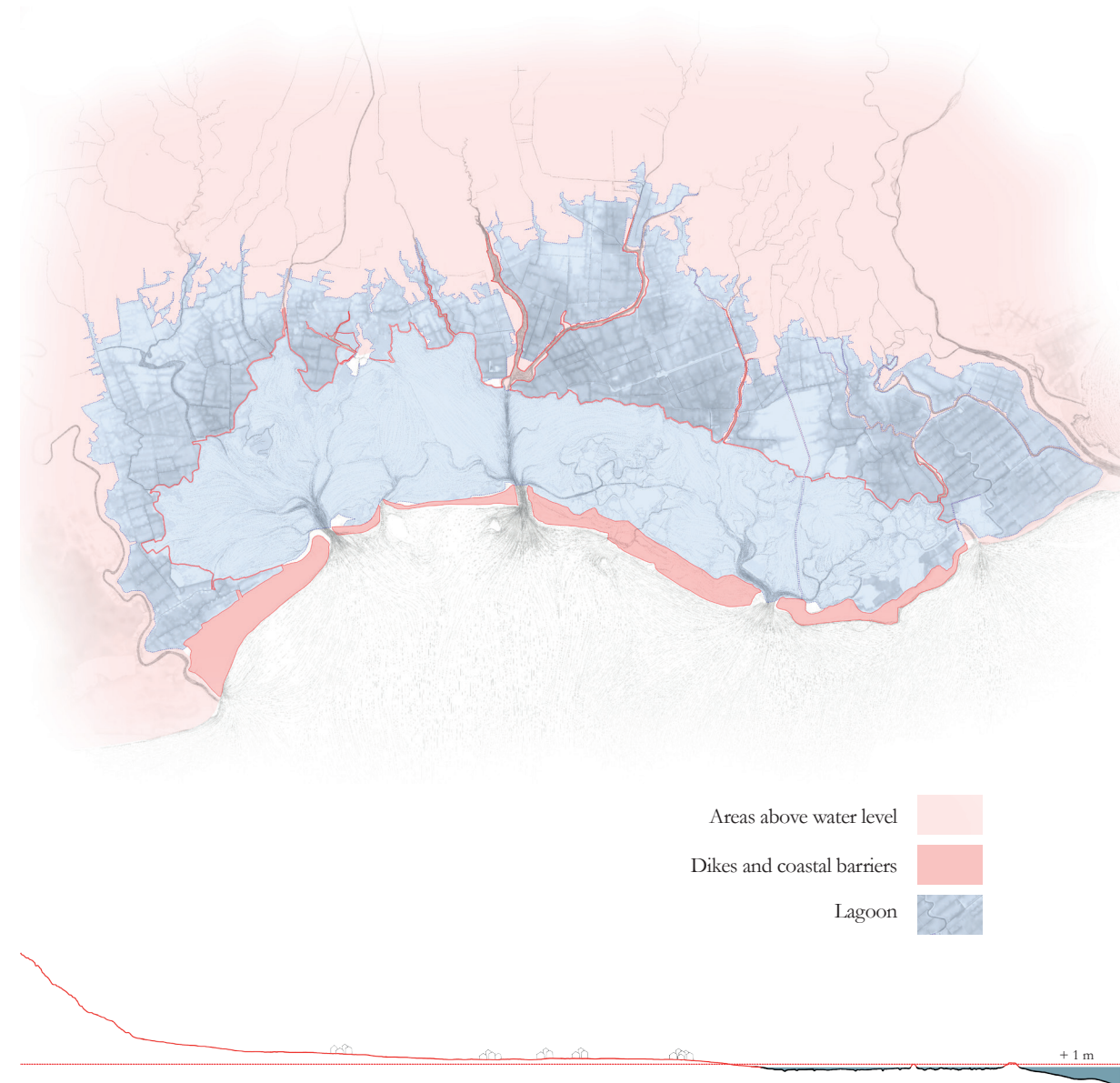


Fig. 47 « Natural development scenario with lidos reinforcement » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

Scenario 2 :

The second scenario considers what would happen to the lagoon if the coastal barriers were not reinforced. In this case, the waters would submerge these barriers, causing the lagoon to disappear and its rich habitat to be swallowed up by the sea. This is the most likely outcome if no action is taken. Only the land below sea level would be flooded, forming a new lagoon surrounded by the existing dikes, which would then act as new lids. The coastline would thus resemble its current state, acting as a transition zone between land and sea.

ADVANTAGES	DISADVANTAGES
Almost no intervention required, allowing natural evolution	Loss of the current lagoon and its biodiversity
Emergence of a new lagoon with the development of a new ecosystem	The same threats apply to this new lagoon, including pollution run-off and other risks.

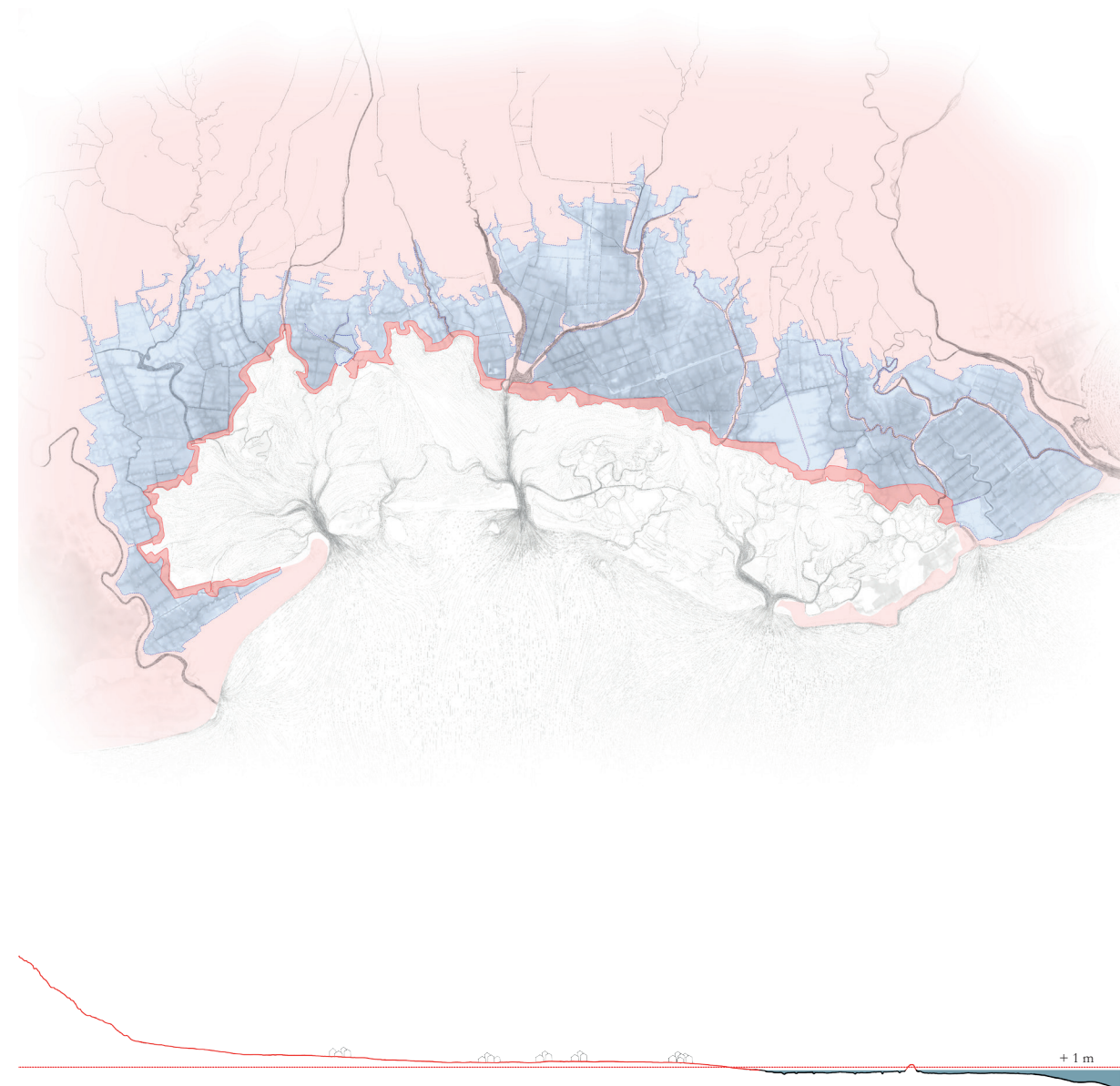


Fig. 48 « Development of the lagoon as a bay » Data developed by the author. From Territorial data catalog and Tarquini, 2023.
(AUTHOR, 2024)

Scenario 3 :

The third scenario partially resembles the first. The difference lies in the demarcation between the «new lagoon» and the current lagoon. The existing dike would be reinforced, creating a strong separation between the two lagoons. They would then be more or less independent of each other.

ADVANTAGES	DISADVANTAGES
Two distinct lagoons allow one to serve in preserving the other. The «new lagoon» could be dedicated to purifying the waters entering the second lagoon.	Loss of productive land
Preservation of the current lagoon's ecosystem	Marano Lagunare and the industrial zone of Aussa-Corno would be submerged
Gain of new wetlands and expansion of biodiversity in the «new lagoon»	

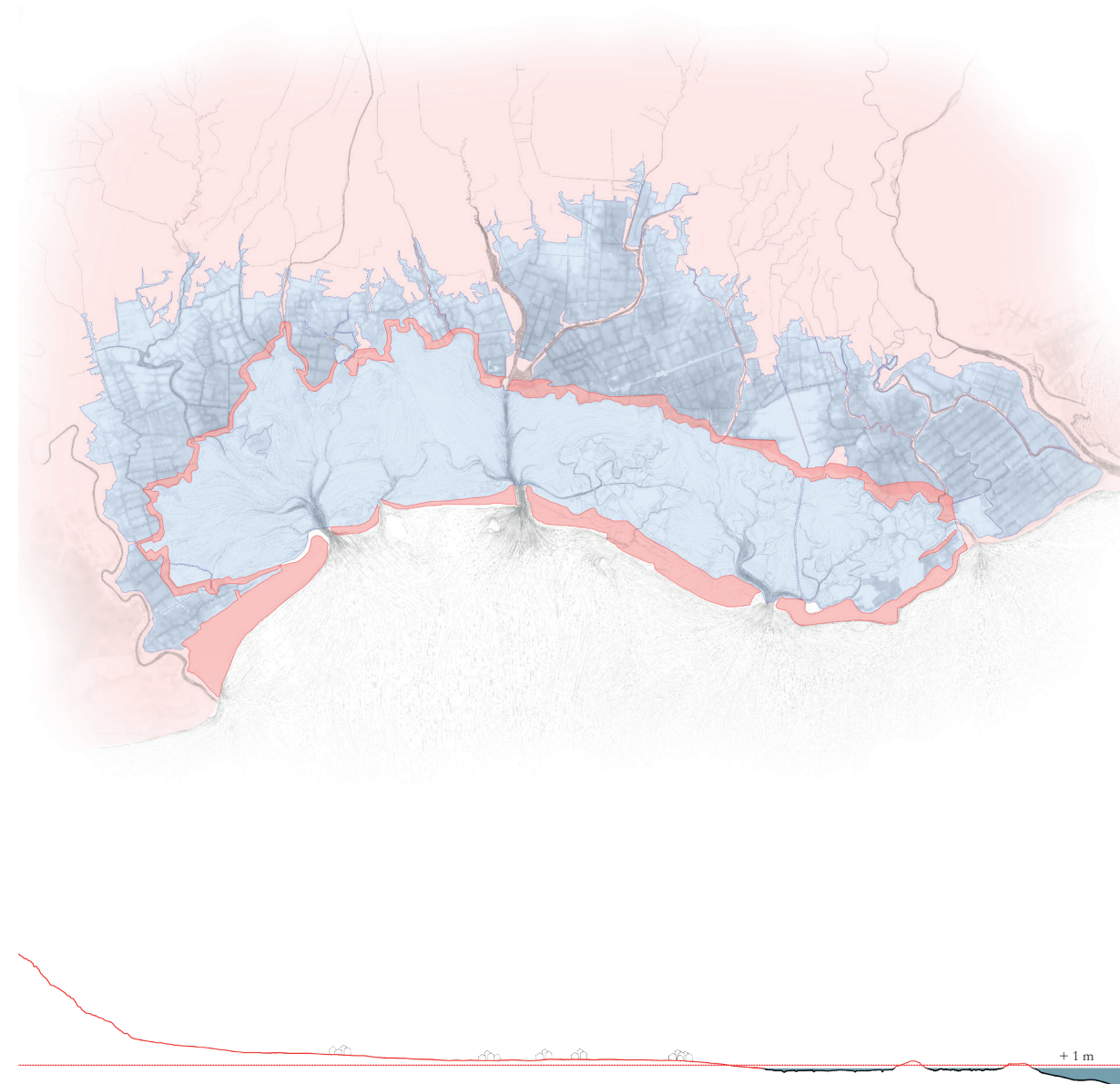


Fig. 49 « Lagoon development with reinforcement of dikes and lidos » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

Scenario 4 :

The last scenario envisages the expansion of the lagoon without creating a separation between the new and existing lagoon areas. The dykes that currently protect the dry areas will disappear. As a result, these areas will be submerged and there will be just one large lagoon. The biodiversity of today's lagoon may extend over a larger area, but it will represent the same situation as today, just on a larger scale. Material from the dismantled dikes will be reused to build new dikes along the new coastline to protect the built-up areas.

ADVANTAGES	DISADVANTAGES
Protection of built-up areas	One single large lagoon, without a purification zone
Development of the ecosystem	Loss of productive land
Increase in wetland areas	

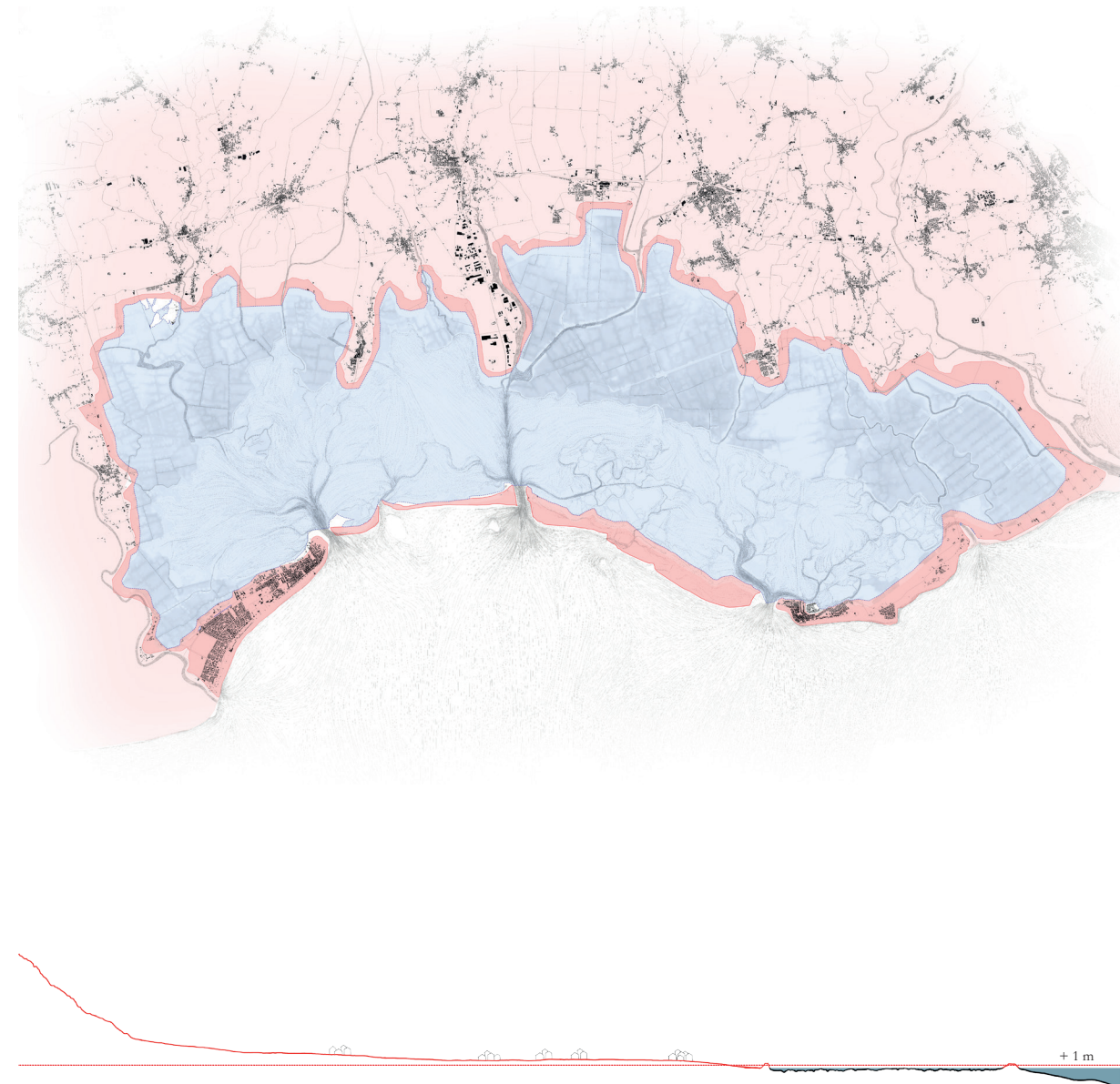


Fig. 50 « Development of the lagoon with reinforced dikes to protect built-up areas » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

5.3 New landscapes for the lagoon

The scenario chosen in this project vision is the first scenario that has been developed in order to respond to the threats facing the Marano and Grado lagoons.

In fact, this scenario offers opportunities to divide various environments while keeping them partially connected.

This renewed lagoon is composed of a series of diverse landscapes, reflecting and enhancing the diversity that exists in these kinds of environments. It takes up a number of protection challenges and responds to threats to its survival.

These different landscapes are defined as preserved, purification and productive. They are set-up in the areas where reclaimed land used to be and over which the lagoon extends.

These different landscapes can be explored through a walk that we'll describe later.

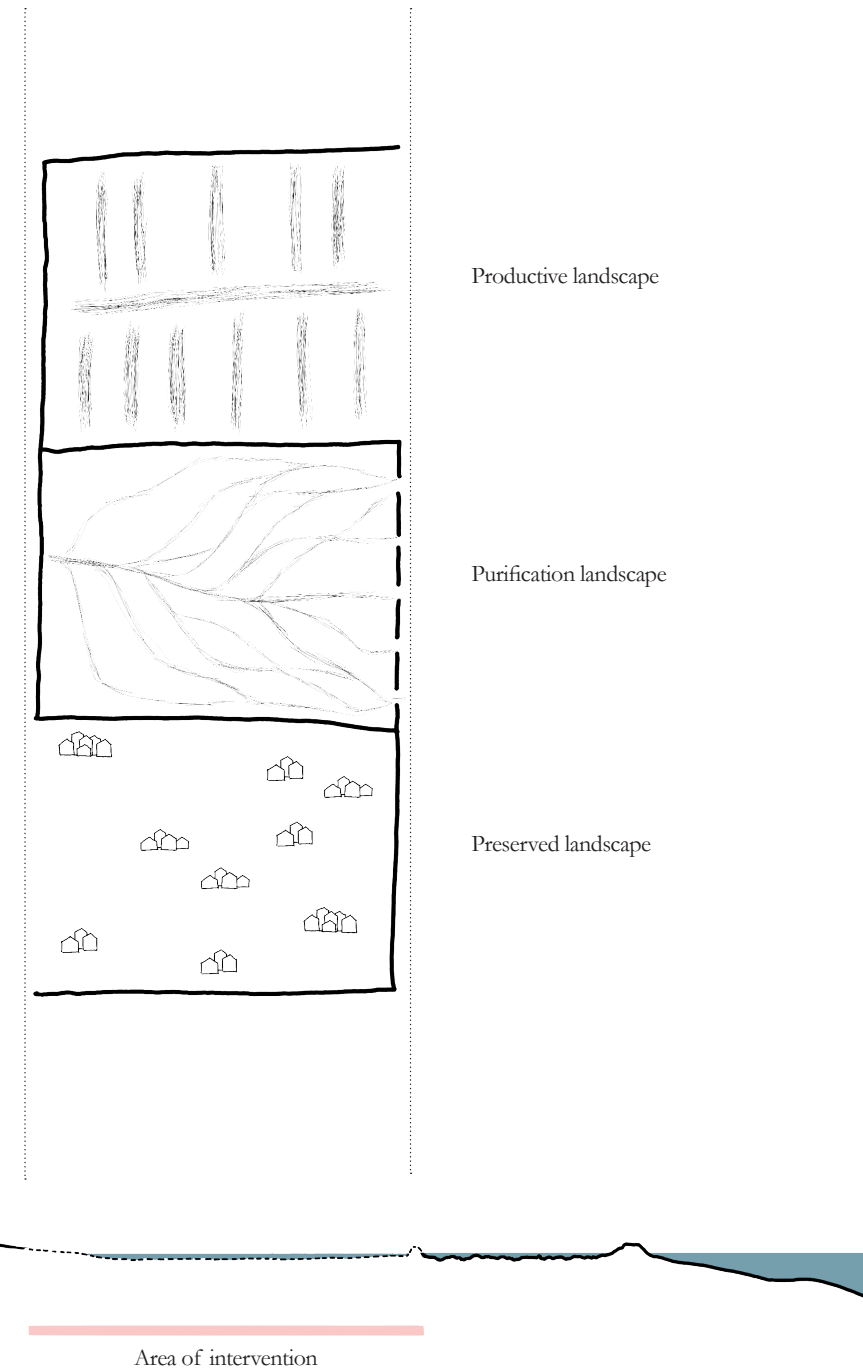


Fig. 51 « Overview of the different landscapes » (AUTHOR, 2024)

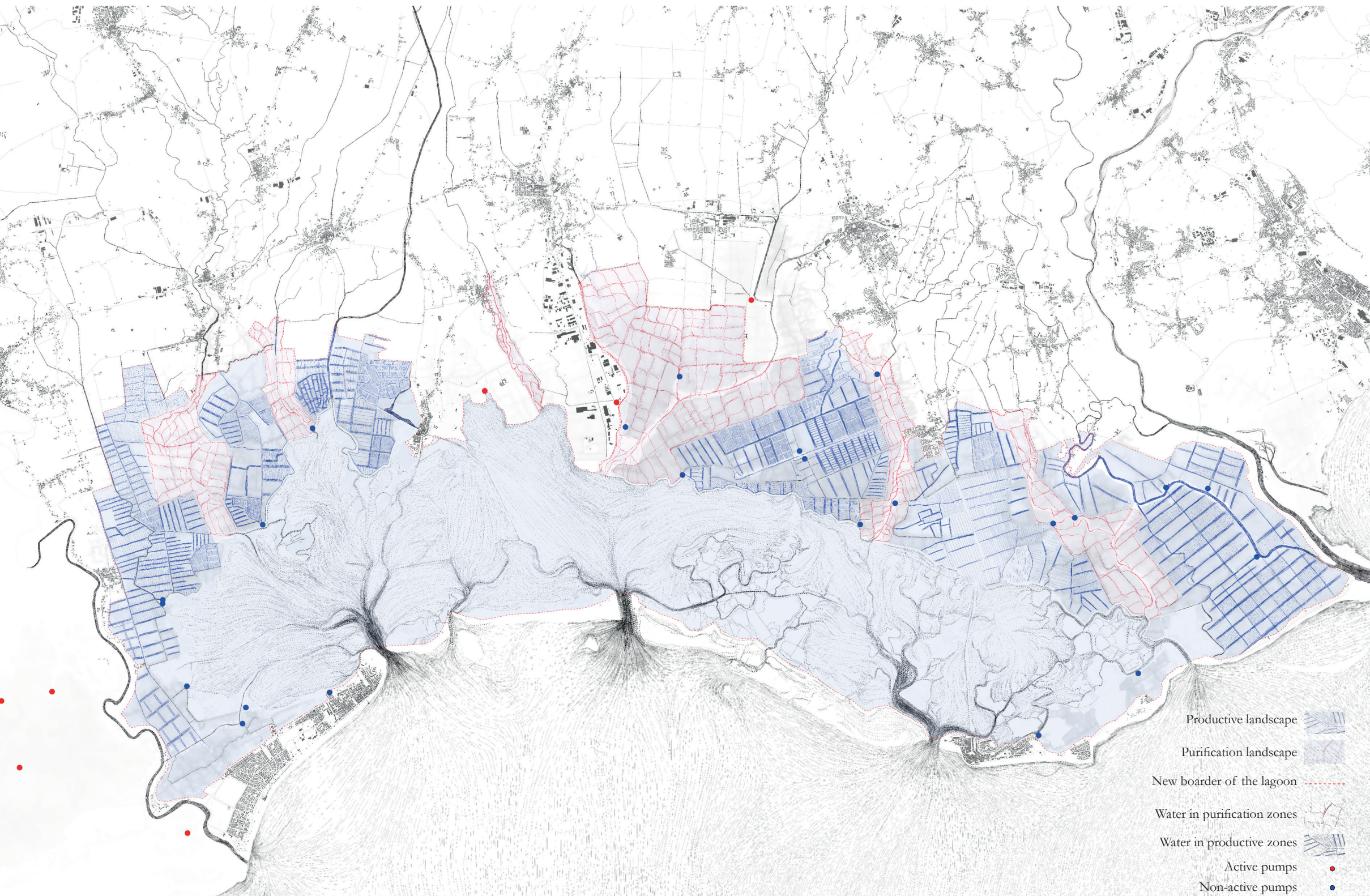


Fig. 52 « The renewed lagoon » Data developed by the author. From Territorial data catalog. (AUTHOR, 2024)

5.3.1 Preserved landscape

The first type of landscape consists of preserved areas, as mentioned above in the section on the « new coastline ». These areas create enclaves in the lagoon. The dikes protecting them will be reinforced, and pumps will be either increased in number or capacity. The link with the lagoon will also be strengthened by the installation of infrastructures connecting the land to the lagoon.

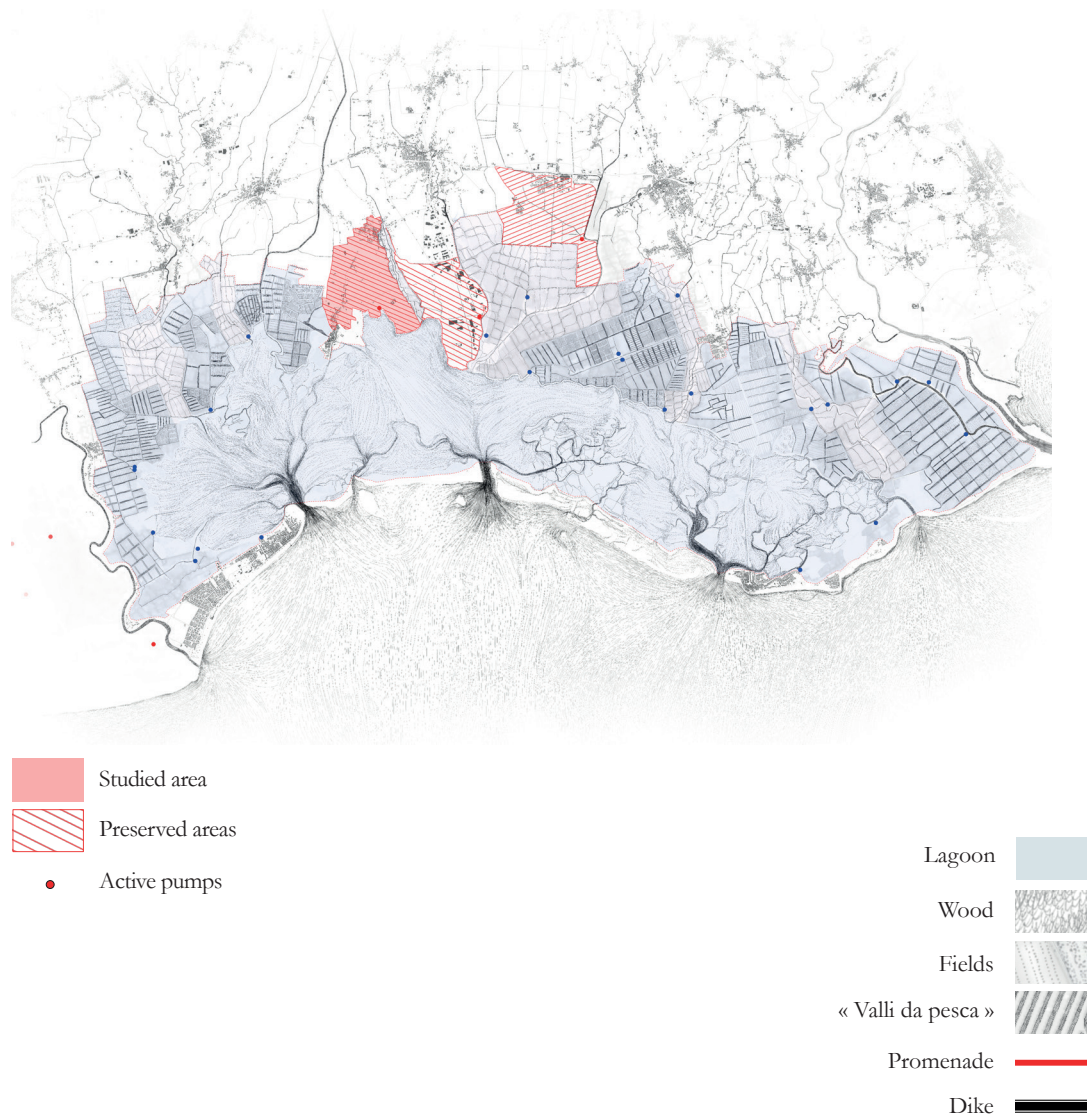


Fig. 53 «Location of preserved and studied areas » Data developed by the author. From Territorial data catalog. (AUTHOR, 2024)

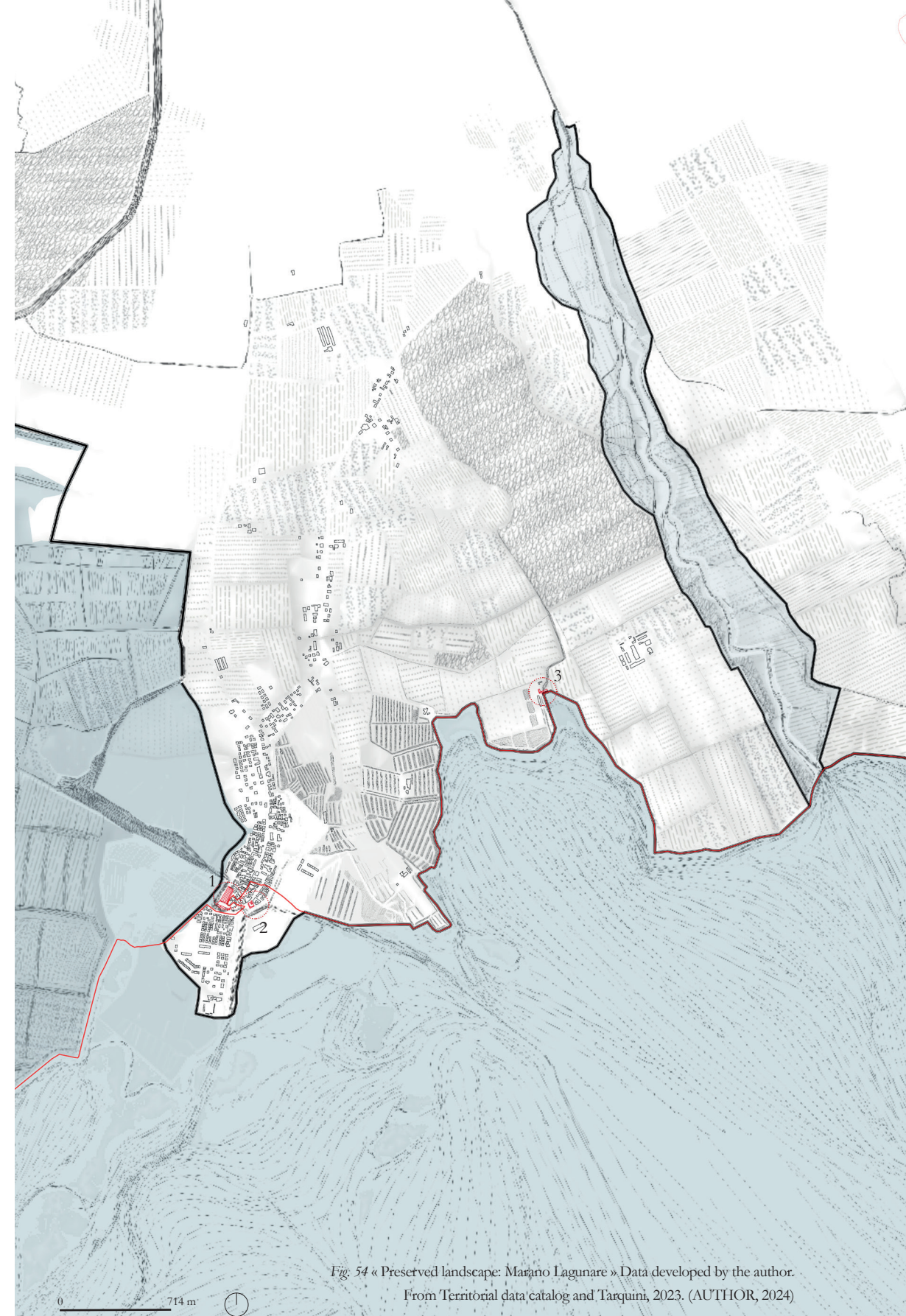


Fig. 54 « Preserved landscape: Marano Lagunare » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

1

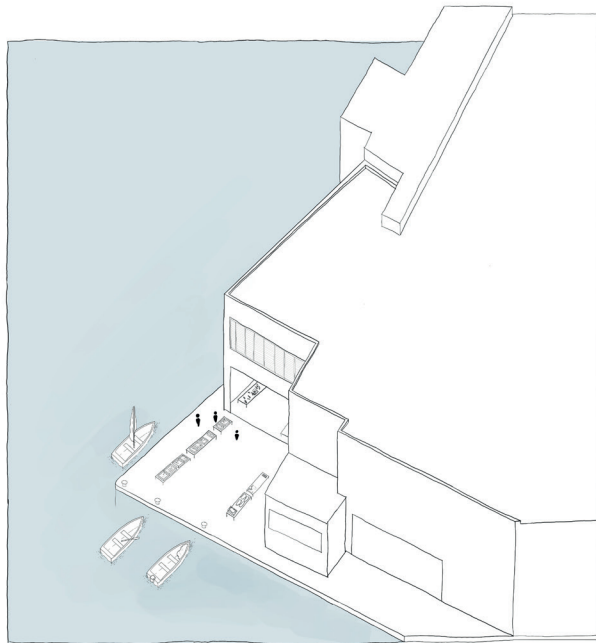


Fig. 55 « Market Hall » (AUTHOR, 2024)

An old abandoned tuna canning factory has been reused as a market hall where lagoon fishermen can sell products directly to individuals.

2

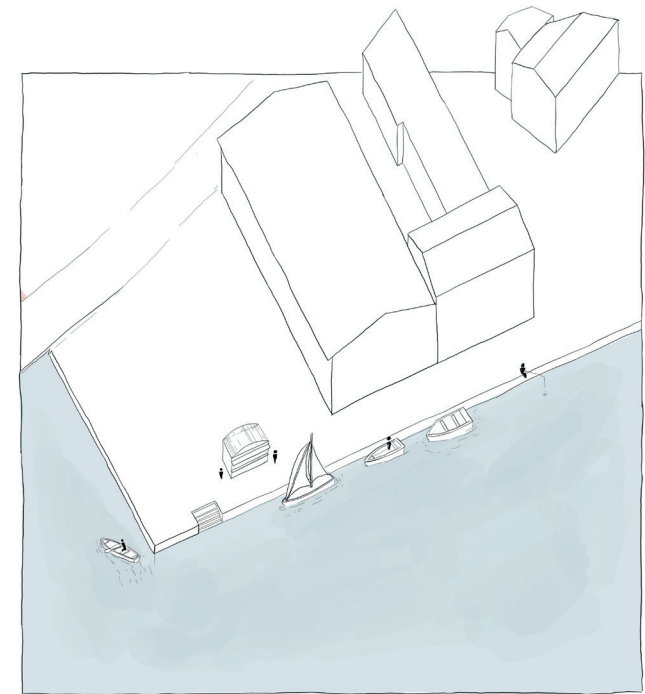


Fig. 56 « Starting point to the lagoon » (AUTHOR, 2024)

Departure spot of the tourist boats (kayak, canoe, pedal boat, etc.) to discover the lagoon.

3

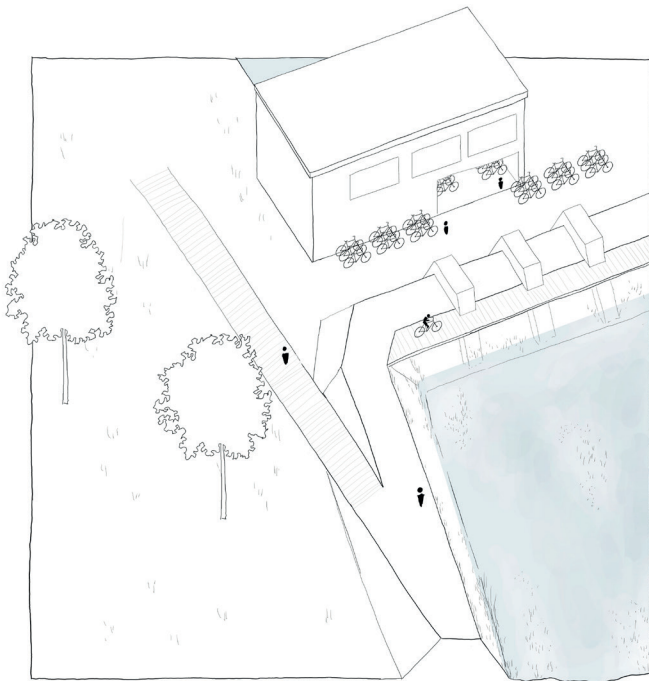


Fig. 57 « Pump converted into a bike rental » (AUTHOR, 2024)

Pump still active, located on the promenade. It includes an old house where the pump manager used to live before the pump was automatized. This building has been converted into a bike rental center, offering walkers the opportunity to rent a bike to continue their journey.

5.3.2 Purification landscape

The second type of landscape is dedicated to water purification of streams that have collected agricultural runoff.

These areas are formed around watercourses as a buffer. The river flow is allowed to expand into a delta-like area. A delta forms near the mouth of a river, creating an alluvial plain where the water, previously confined to the main river channel, splits into multiple smaller channels. This increases the contact surface with natural purification elements and reduces the water's velocity. Water purification is achieved by contact interaction between water and soil, including vegetation, sediments and micro-organisms, filtering elements. For a constant river flow, the increased, spread-out, flow cross-section means a reduction in water velocity, extending the time of interaction by contact between water and filtering elements.

Flow = Cross-section x Speed.

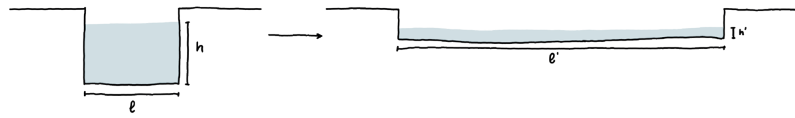


Fig. 58 « Water flow diagram » (AUTHOR, 2024)

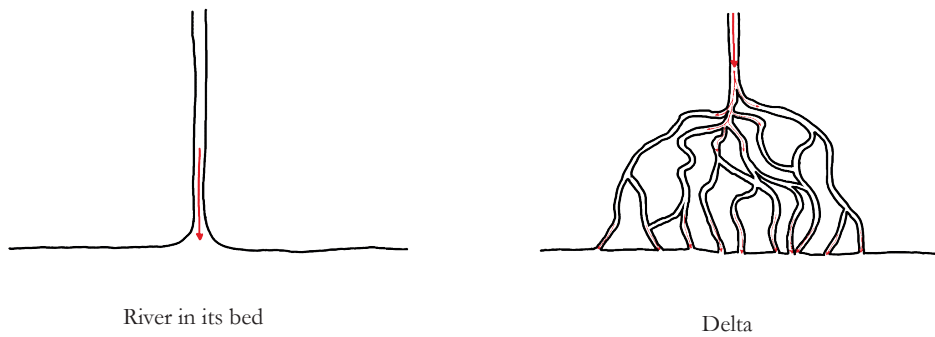


Fig. 59 « Splitting the river into a delta » (AUTHOR, 2024)

In this landscape, we take a fragment covering the area between the Corno and Aussa rivers. This environment has been transformed into an artificial delta, redirecting the waters of these 2 rivers inland. The major riverbeds are narrowed and the water, no longer having enough room in them, begins to flow into the adjacent canals, which were previously used for drainage and field irrigation. These canals connect different purification basins, functioning like a large-scale lagooning system or like a water treatment plant. Each of these basins contains different filtration elements, such as reeds, gravel and micro-organisms. To ensure that the water can circulate from one to the next, the basins are laid out in the form of terraces to promote gravitational flow.

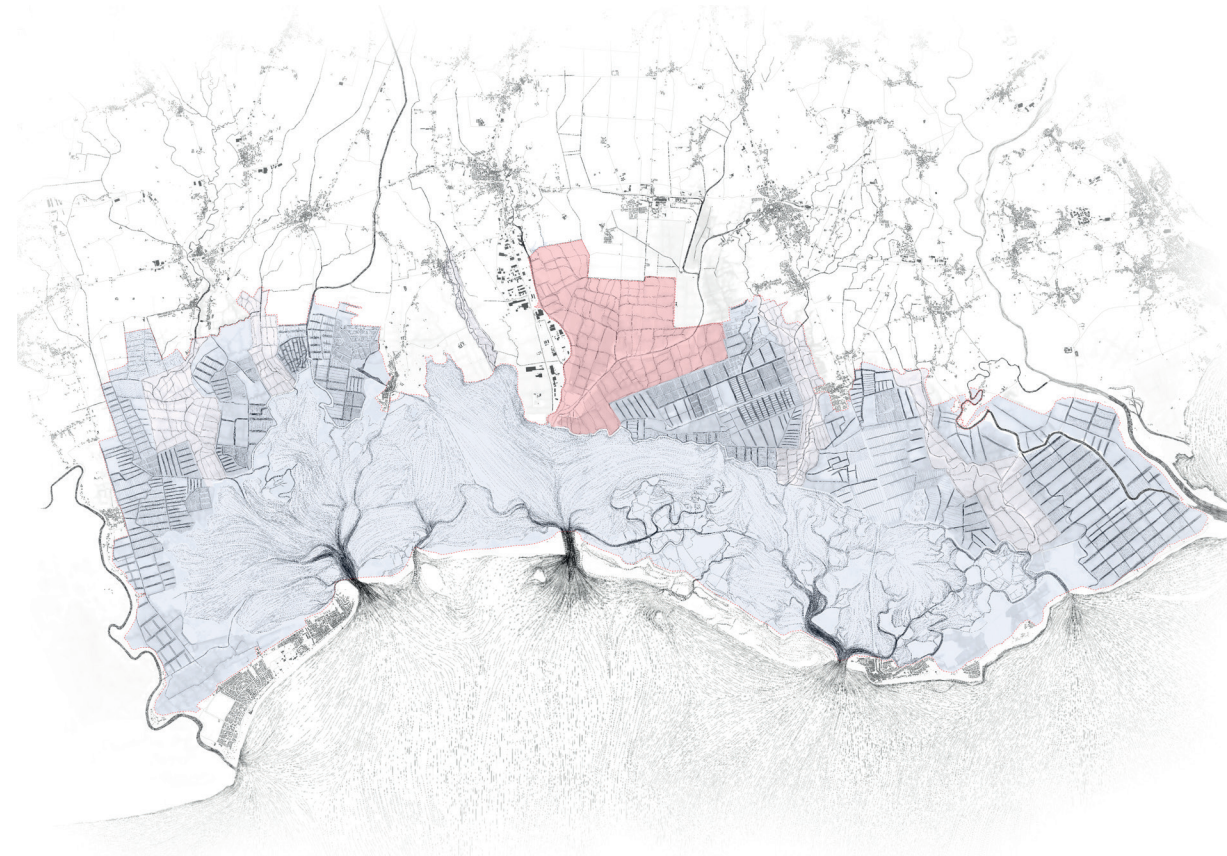


Fig. 60 « Location of the purification landscape studied » Data developed by the author. From Territorial data catalog (AUTHOR, 2024)

What makes this area different from a traditional delta is that the land used for water purification is below the water level of the lagoon at high tide. This is why the land is still enclosed by dikes in this vision. However, these dikes maintain communication channels with the lagoon to enable the water to be evacuated. This is done through man-operated gates «sluices» that allow to choose when to discharge the water. This is best done at low tide, when the water can be evacuated without the lagoon rushing in.

In this area, the flora and fauna are allowed to develop naturally, as deltas are particularly conducive to their growth. Similarly to the lagoon itself, these environments provide rich habitats that support diverse ecosystems, fostering the development of various plant and animal species.

- Purification basin with gravel 
- Purification basin with plants 
- Delta branches 
- Lagoon 
- Purified area 
- Promenade 
- Dike 
- Sluice 

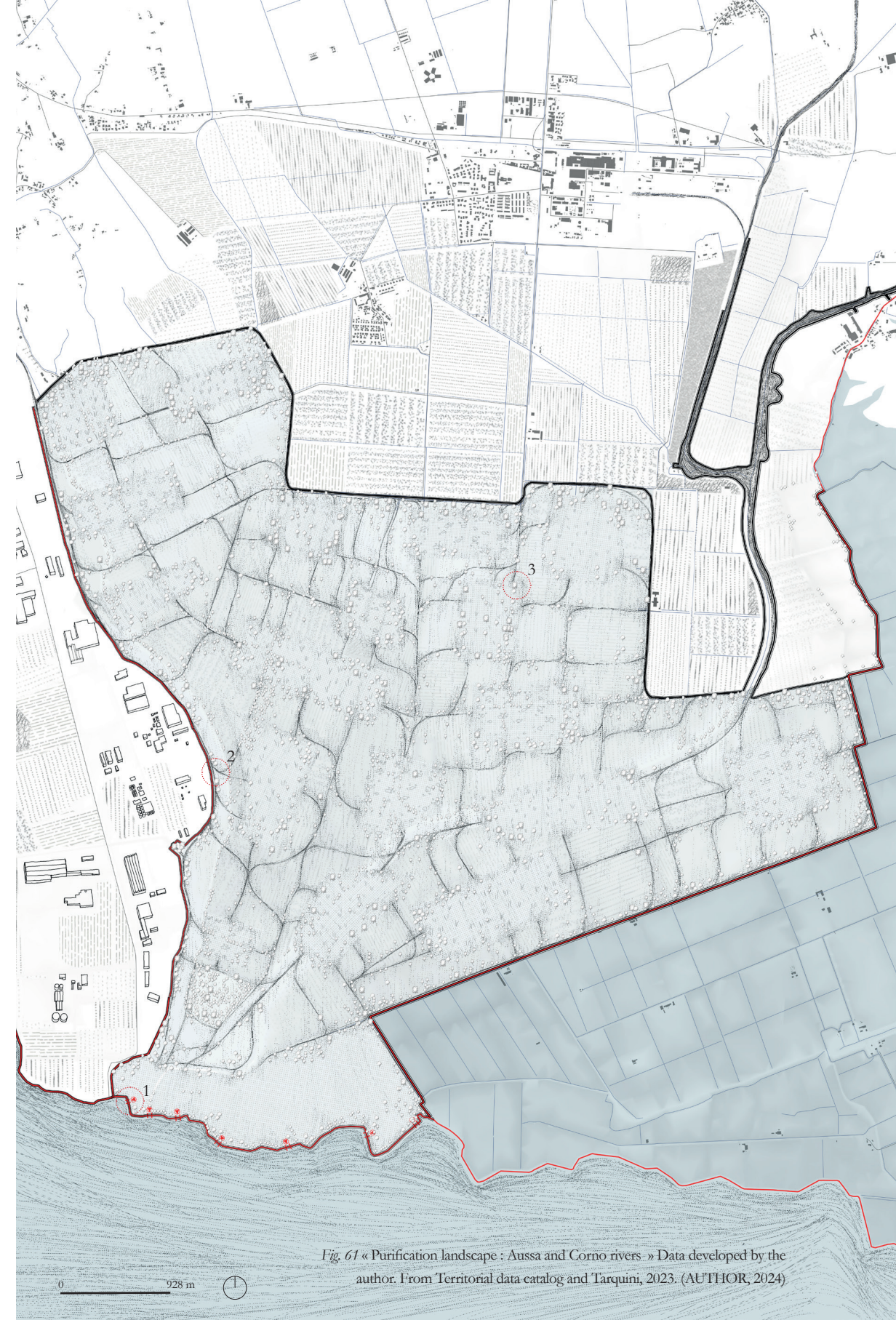


Fig. 61 « Purification landscape : Aussa and Corno rivers » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

1

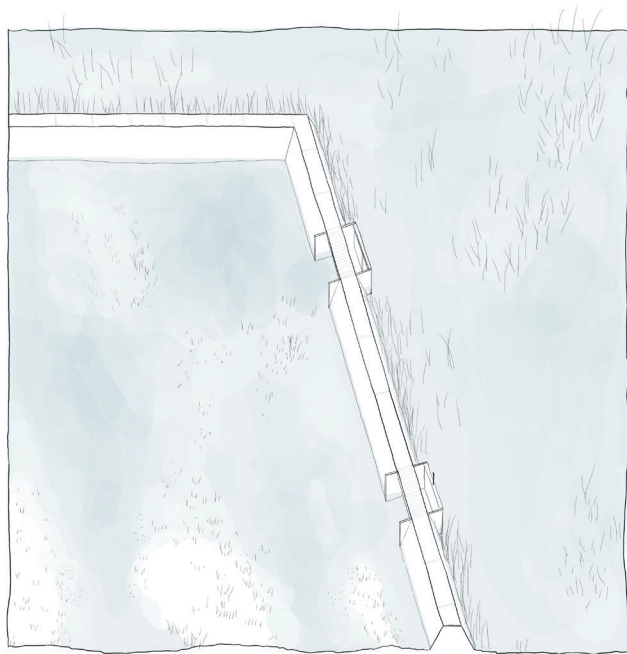


Fig. 62 « Sluice gate for discharging purified water into the lagoon » (AUTHOR, 2024)

2

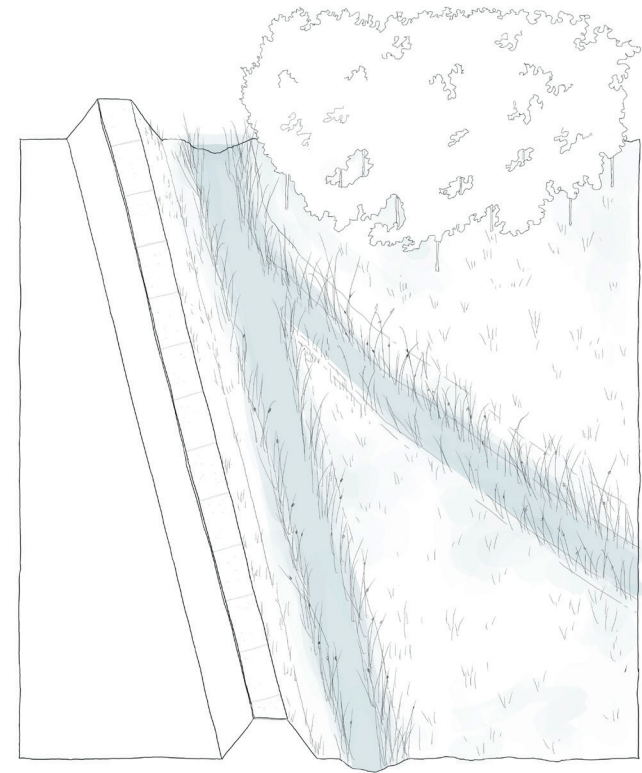


Fig. 63 « Splitting of the delta branches » (AUTHOR, 2024)

3

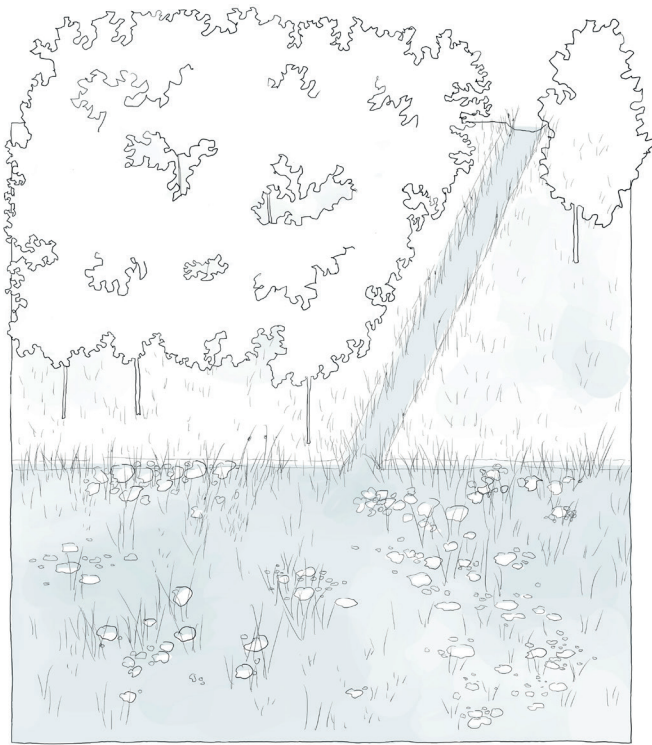


Fig. 64 « Water from branches discharged into basins » (AUTHOR, 2024)

5.3.3 Productive landscape

The third type of landscape is a series of small new lagoons emerging between the river purification zones.

These lagoons are connected to the main lagoon but have different uses. They counterbalance the loss of agricultural land, and thus the loss of a part of the region's main economy.

These lagoons are used for productive purposes, enabling the region's economy to keep up with the changes and challenges of our times. The region would then turn to what aquatic environments can produce, being used largely for aquaculture.

This landscape is inspired by the region's distinctive fishing techniques. Indeed, traditional fishing is practiced here, but in this project, it's a different kind of fishing that interests us. These are the « Valli da pesca¹³ ». Today, these are located in the lagoon and along its shores, especially around the town of Marano. They are private fishing areas consisting of a series of basins that are connected to the lagoon by «sluices» that control the flow of water into the basins.

Each of these basins contains several thousand fish, grouped according to age and species to facilitate fishing. The fish can be harvested at any time when there is a demand, or when they reach maturity, they are all caught at the same time by discharging the water from the basins into the lagoon. The basins are then left «dry» and all the fish are collected at the same time, in a process that resembles “miraculous fishing”.

13 Fish-rearing ponds, « fishing valleys»

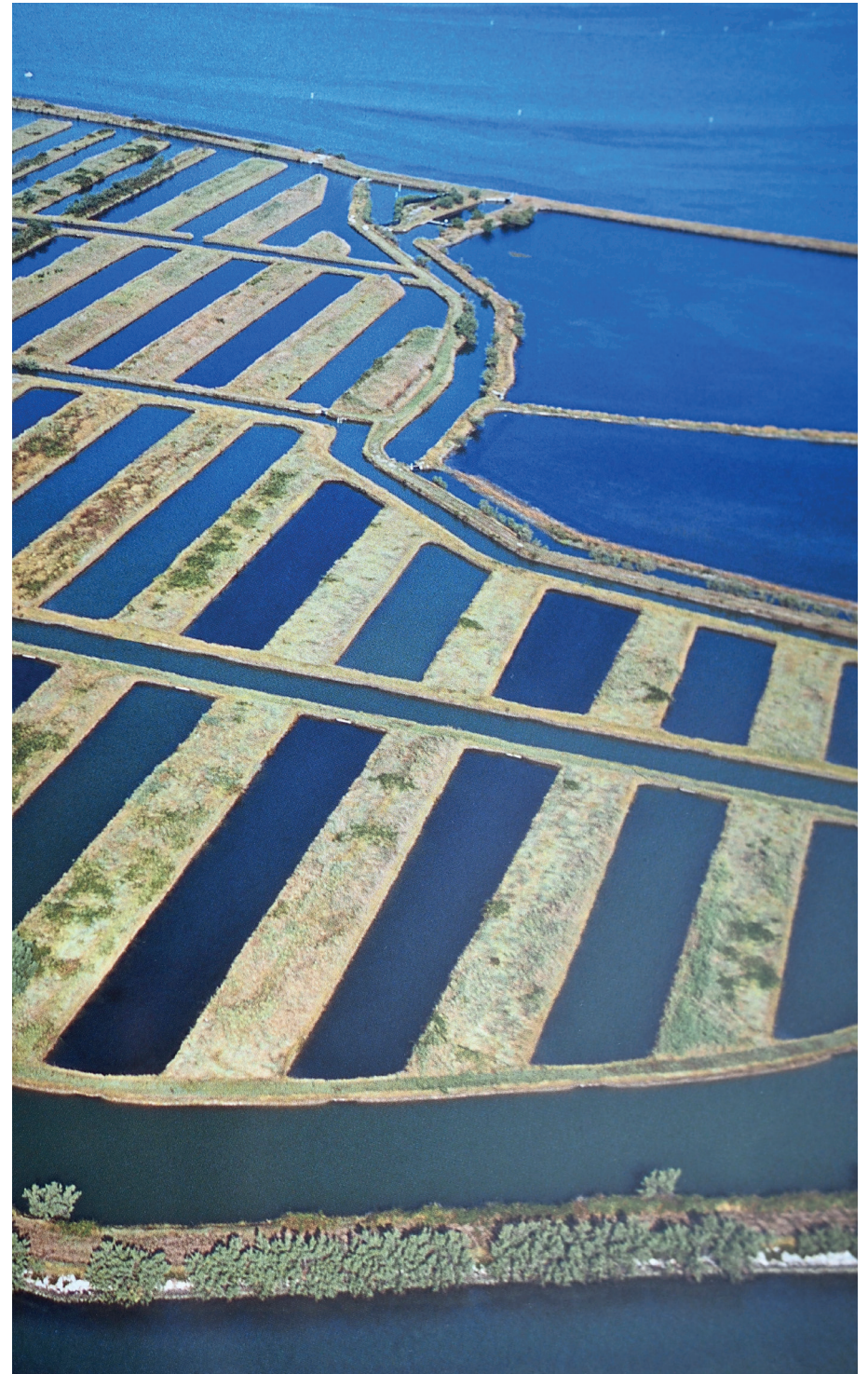


Fig. 65 «Landscape of the lagoon» Perco, 2004

In this new landscape, irrigation canals widen and deepen to become fishing valley canals. Excavated soil is reused to reinforce coastal barriers and build new dikes around the various landscapes.

As the water is higher in 2100, fishing channels are spaces where fish are enclosed, but the principle of discharging water to harvest them all at once is no longer possible. The fish found here are typical lagoon fish, as they must be able to live in brackish water (fresh water - salt water). Other areas are dedicated to them, with a series of basins. Others are dedicated to the production of algae and plants that grow in these specific environments and are suitable for consumption, such as samphire¹⁴.

Other types of culture are also possible, such as shellfish farming. This activity can take different forms, depending on the type of mollusc raised. Oysters, for example, are cultivated on longlines or in ponds, while mussels are grown on wooden stakes or suspended longlines. As for clams, they are bred in specially delimited areas.

To manage this system of cultivation, a network of canals for boat traffic has been installed, linking the various farming areas. These areas are dotted with pontoons for foot traffic to facilitate harvesting.

There is also a series of other infrastructures necessary for aquaculture, such as farms, sheds for storing equipment, and harbors for boats passing through these areas. These buildings are either elevated or enclosed by dikes to allow them to coexist with the water present in the area.

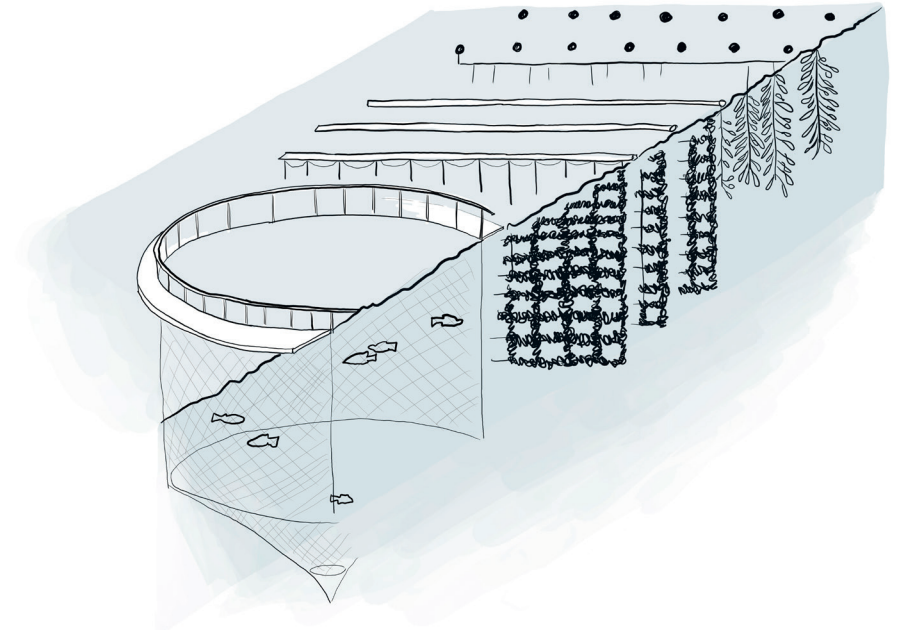


Fig. 66 « Aquaculture » (AUTHOR, 2024)

¹⁴ « A plant that grows on rocks by the sea whose leaves can be eaten » (Cambridge dictionary)

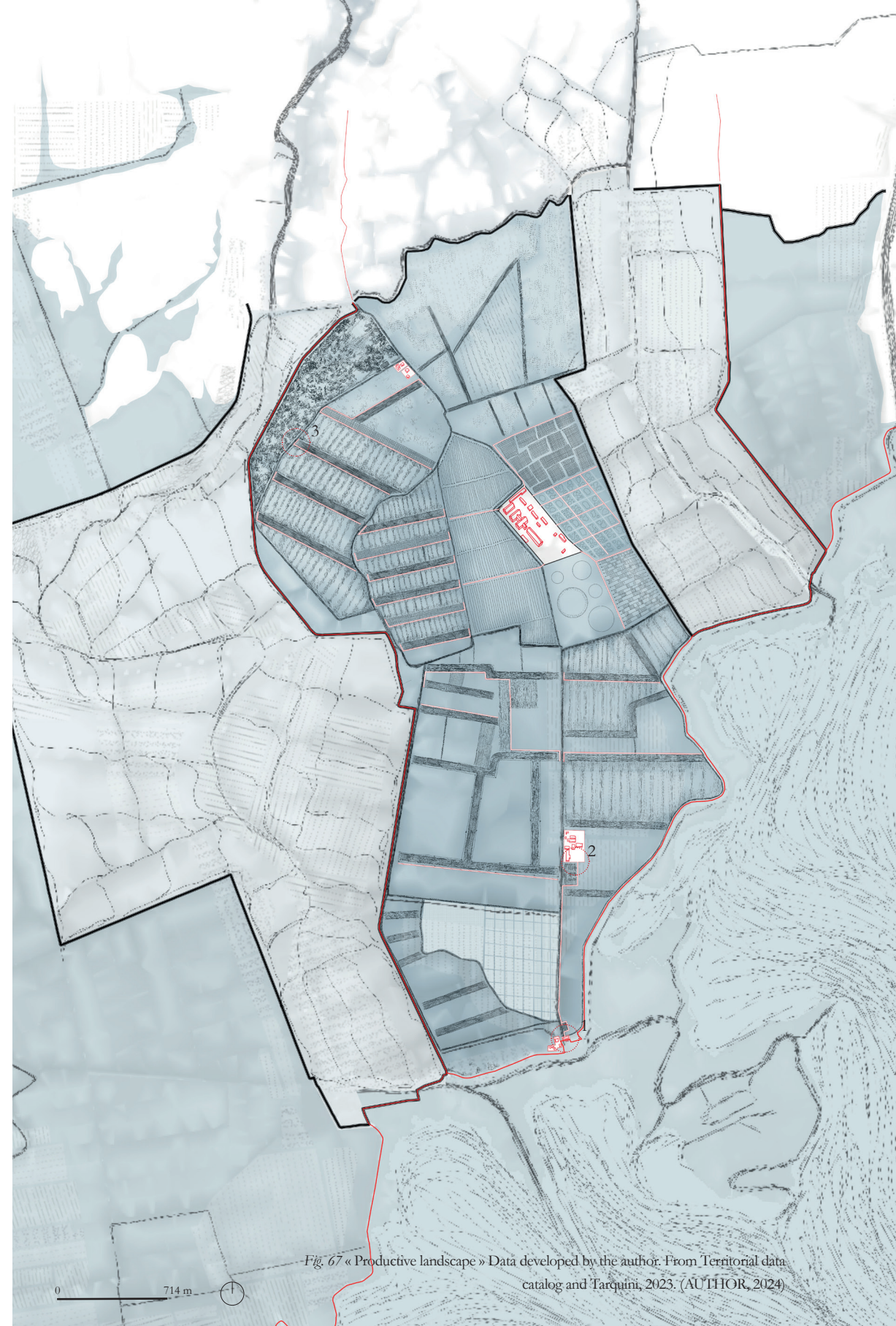
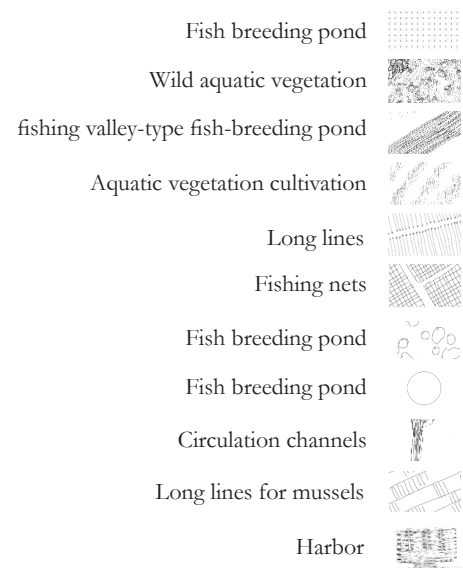


Fig. 67 « Productive landscape » Data developed by the author. From Territorial data catalog and Tarquini, 2023. (AUTHOR, 2024)

1

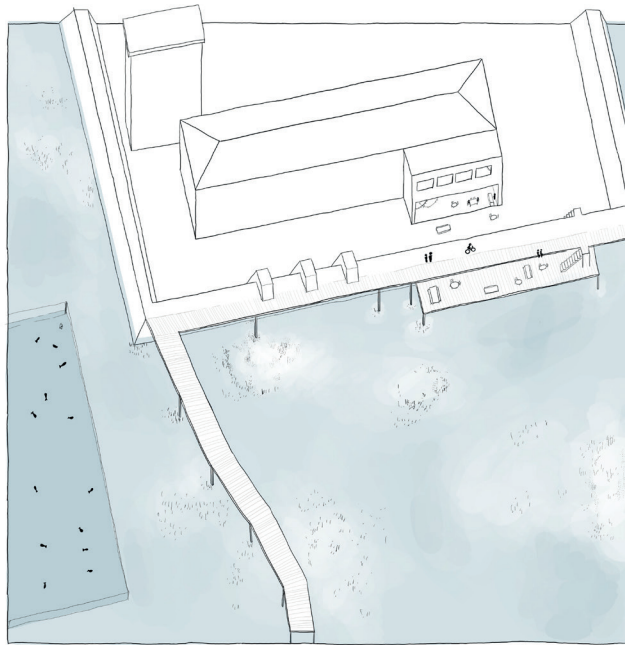


Fig. 68 « Pump converted into fish restaurant » (AUTHOR, 2024)

2

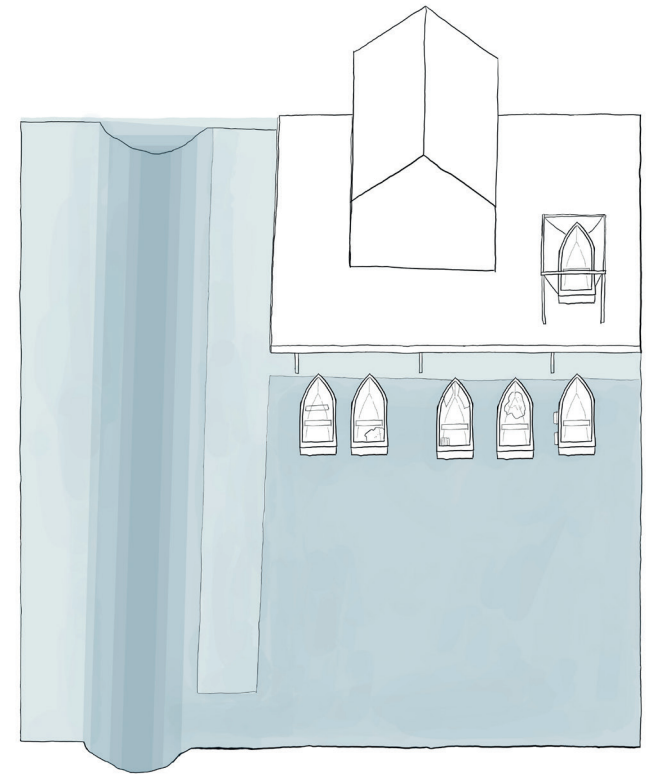


Fig. 69 « Harbor and water farm » (AUTHOR, 2024)

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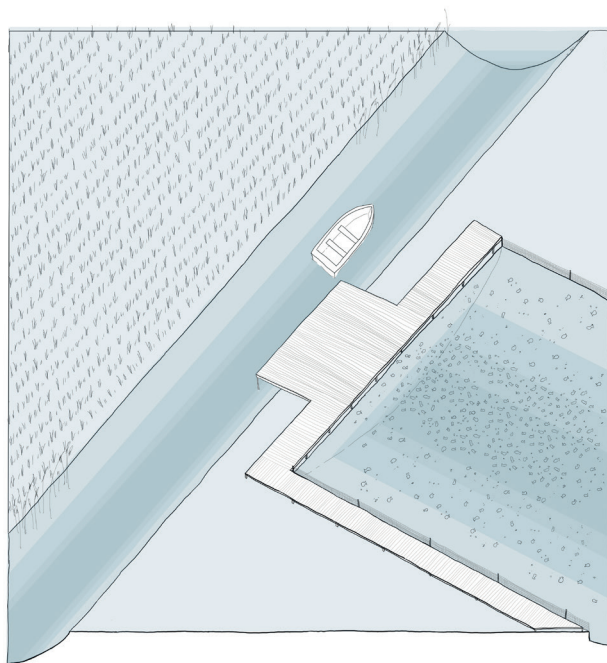


Fig. 70 « Circulation channels and access to fishing valleys » (AUTHOR, 2024)

5.4 The role of dikes

In order for these different landscapes to coexist, they need to be separated while still being connected. Until now, this has been achieved by creating dikes to protect reclaimed land from water but this practice has created a real wall between the different environments.

Dikes are also used in this new proposed vision, but their shapes vary according to the landscapes they encounter.

Some dikes are based on those already present, separating the purification zones and the preserved area from the original lagoon.

Others are built perpendicular to the lagoon to separate the purification landscapes from the productive and preserved ones.

Those protecting the preserved areas are reinforced.

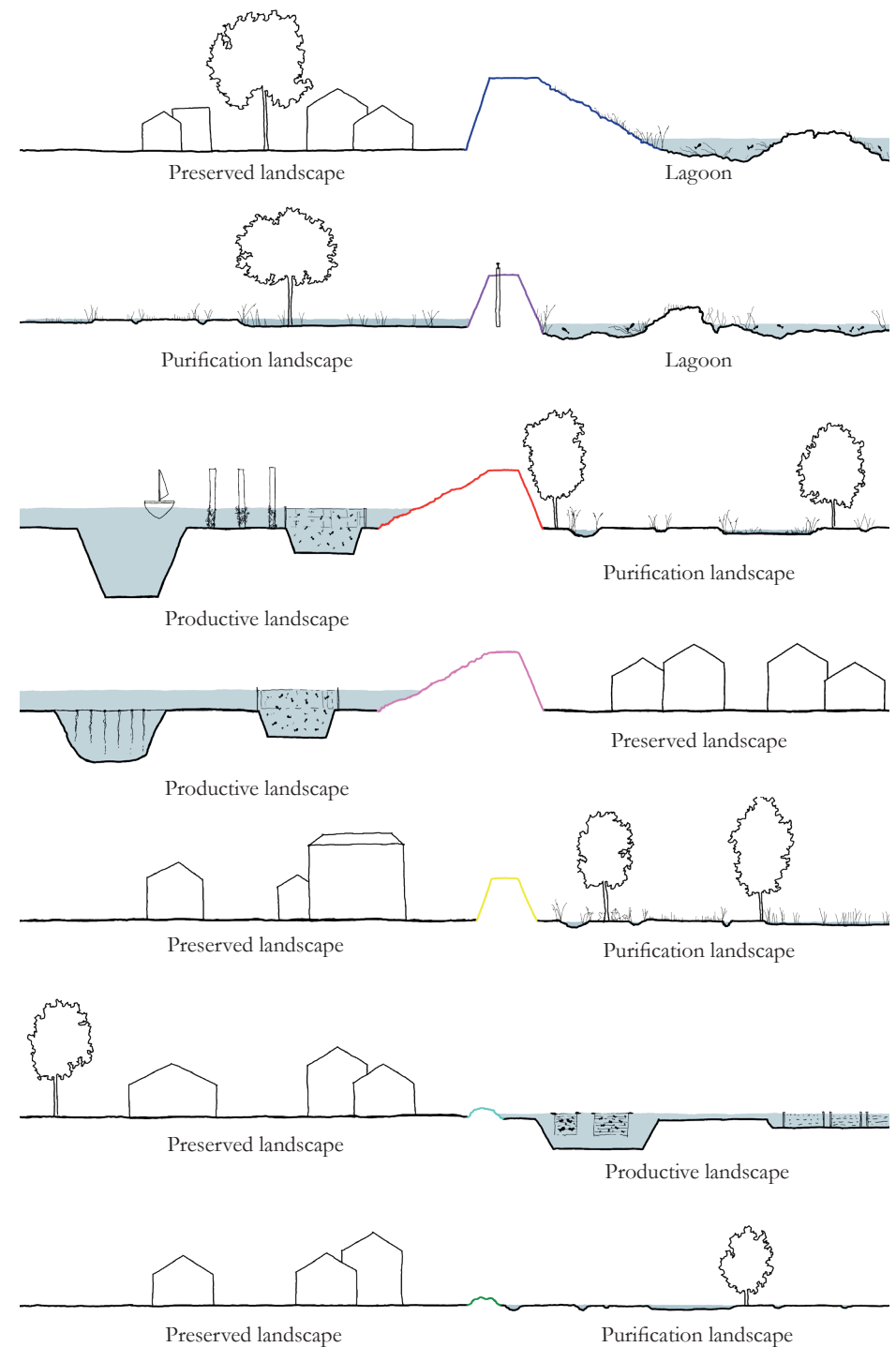


Fig. 71 « Schematic legend of the various dikes found in the new lagoon landscape (fig.72) ». (AUTHOR, 2024)

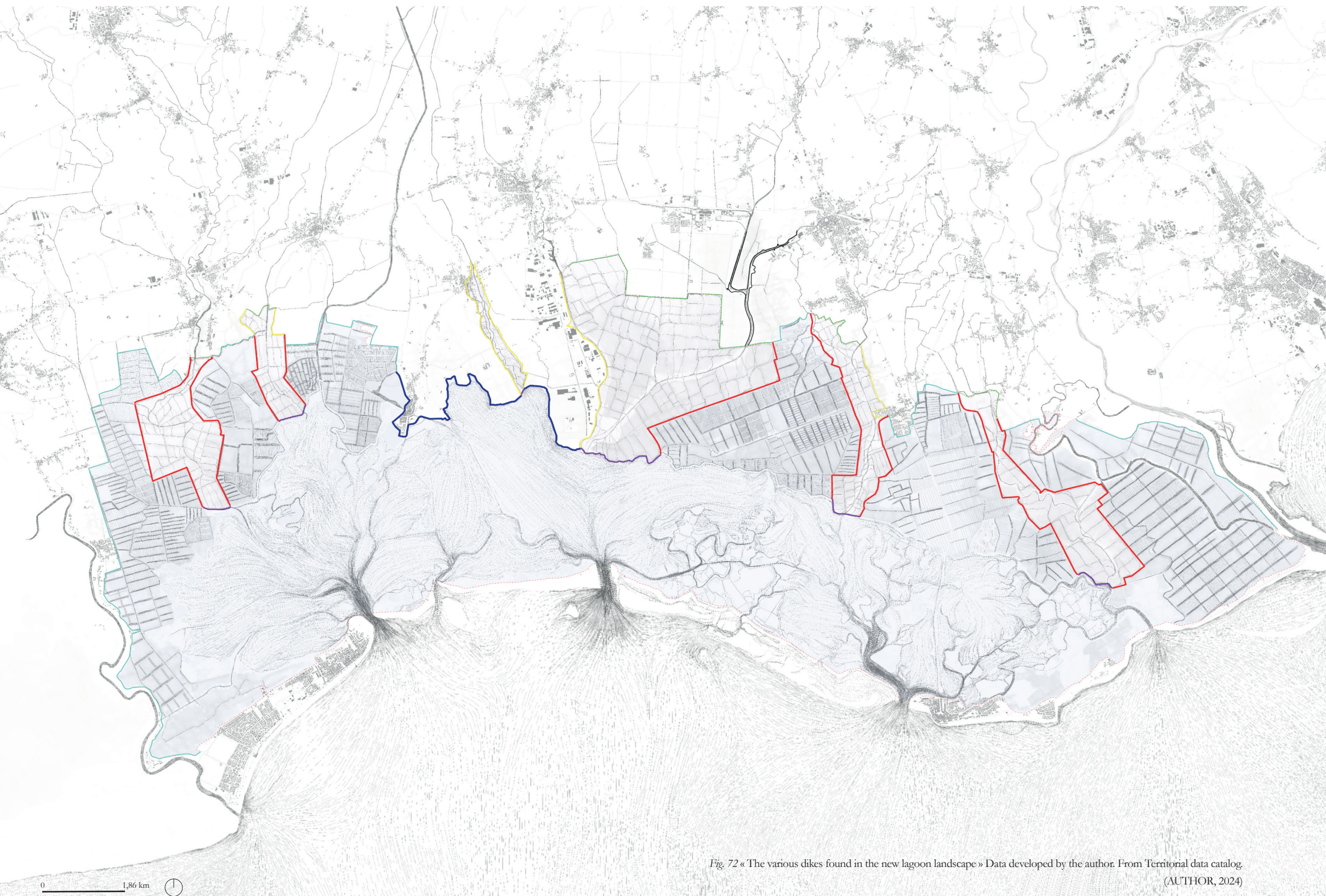


Fig. 72 « The various dikes found in the new lagoon landscape » Data developed by the author. From Territorial data catalog.
(AUTHOR, 2024)

5.5 The “Lagoon Discovery Trail”

The dikes are seen as the element separating the different environments, but in fact, in this project, they are the support for a lagoon discovery trail that re-creates the link between man and lagoon.

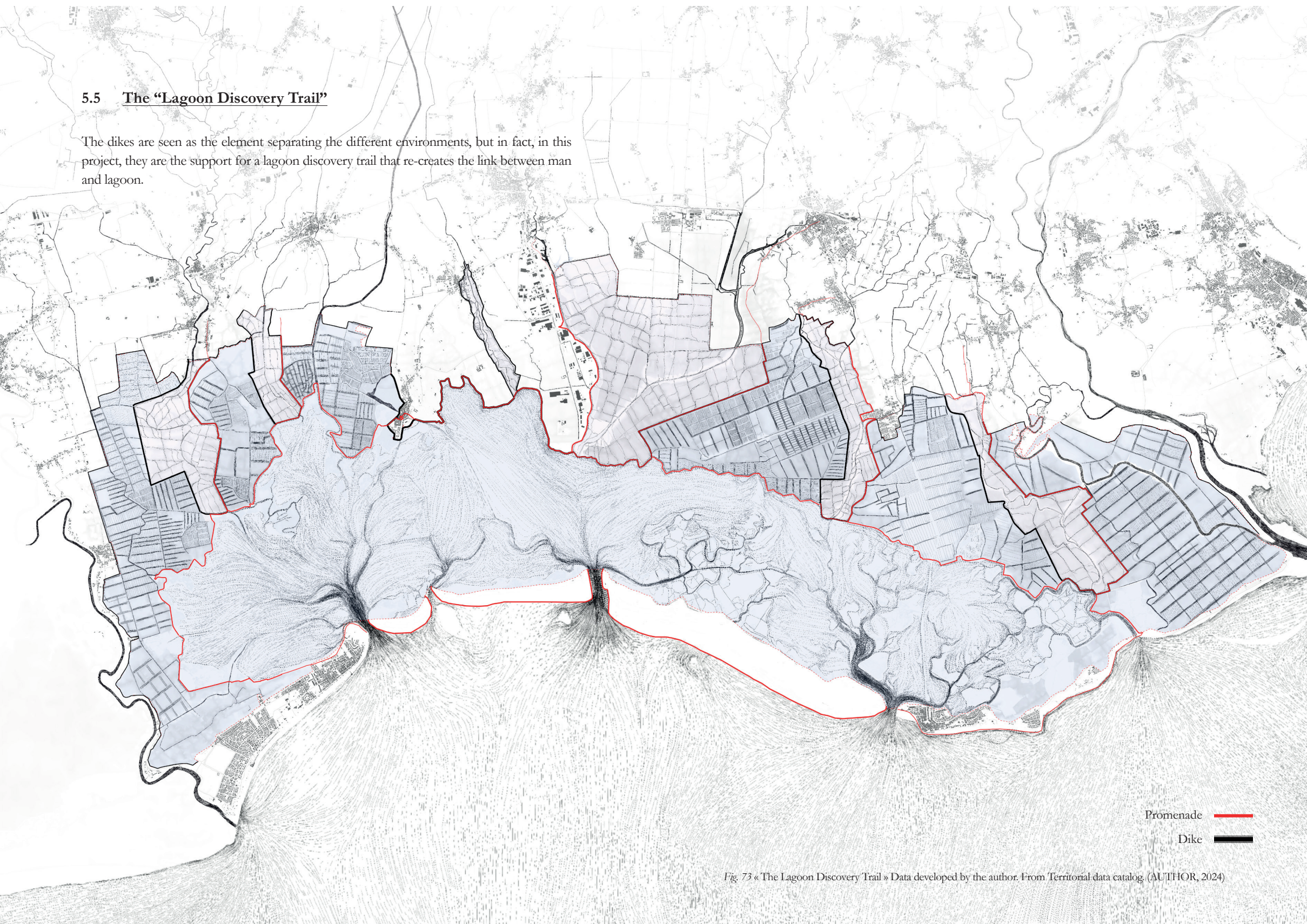


Fig. 73 « The Lagoon Discovery Trail » Data developed by the author. From Territorial data catalog. (AUTHOR, 2024)

5.5.1 A walk through points of interest

The discovery trail leads to various infrastructures and points of interest associated with it.

Some of these have already been developed in the chapters on the various landscapes, and therefore take their place along this trail, such as the fish market in Marano Lagunare (in the preserved landscape) or the abandoned pump converted into a restaurant (in the productive landscape).

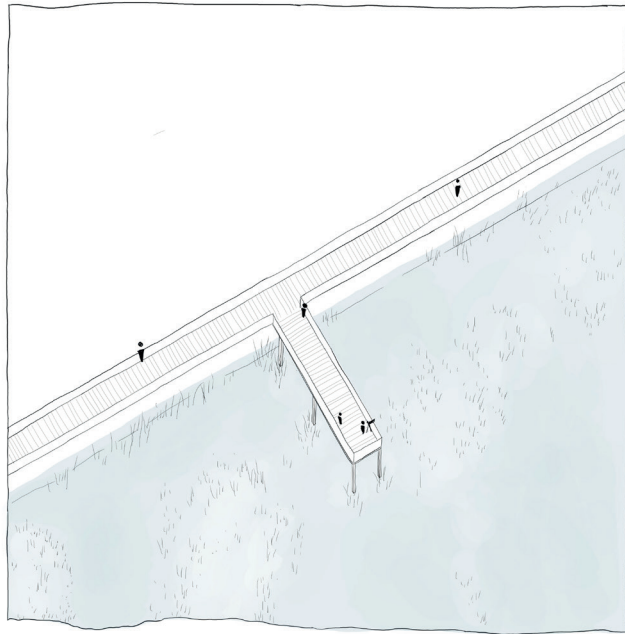


Fig. 74 « Observation pontoon » (AUTHOR, 2024)

Other infrastructures are directly integrated into the trail course, such as observation pontoons stretching out over the lagoon, or recesses in the structure of the trail path to incorporate a bench.

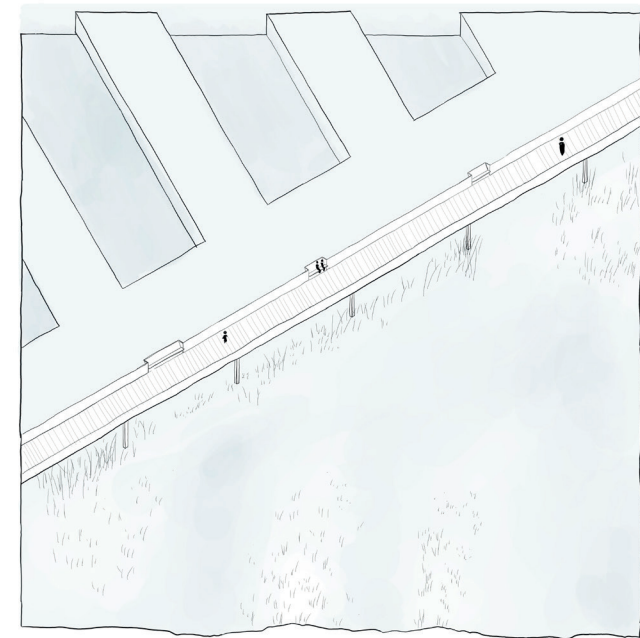


Fig. 75 « Benches integrated into the promenade » (AUTHOR, 2024)

5.5.2 The walk as a symbol of the old coastline

The 'Lagoon discovery trail' takes its place as a marker of the old coastline. It stands in the middle of the new lagoon, as a reminder of where the limit between the lagoon and the land used to be.

In practical terms, the trailpath develops on the dikes separating the preserved and purification landscapes from the actual lagoon.

However, this dike no longer exists between the productive areas and the lagoon. At these locations, it takes the form of a wooden slatted path on piles to minimize the impact on the lagoon floor and its ecosystems.

The dikes are covered with concrete slabs, making them comfortable for pedestrians and cyclists too.

5.5.3 A loop around the lagoon

In order to create a unified promenade all along the lagoon, it will continue on the islands separating the lagoon from the sea. This part of the promenade is installed on the embankments created to reinforce the coastal barriers and thus preserve the lagoon. The embankments were built using soil reclaimed from the excavation of fishing valleys in the productive landscapes.

The islands can be reached either by shuttle bus or by renting small boats, which are available all year round.

This part of the walkway will allow users to explore the interface between two environments. Visitors will be able to appreciate the differences between the marine and lagoon environments. On the one hand, they will observe the rich diversity of islands, barenes and habitats for different ecosystems, while on the other, they will see the sea and its waves as far as the eye can see.

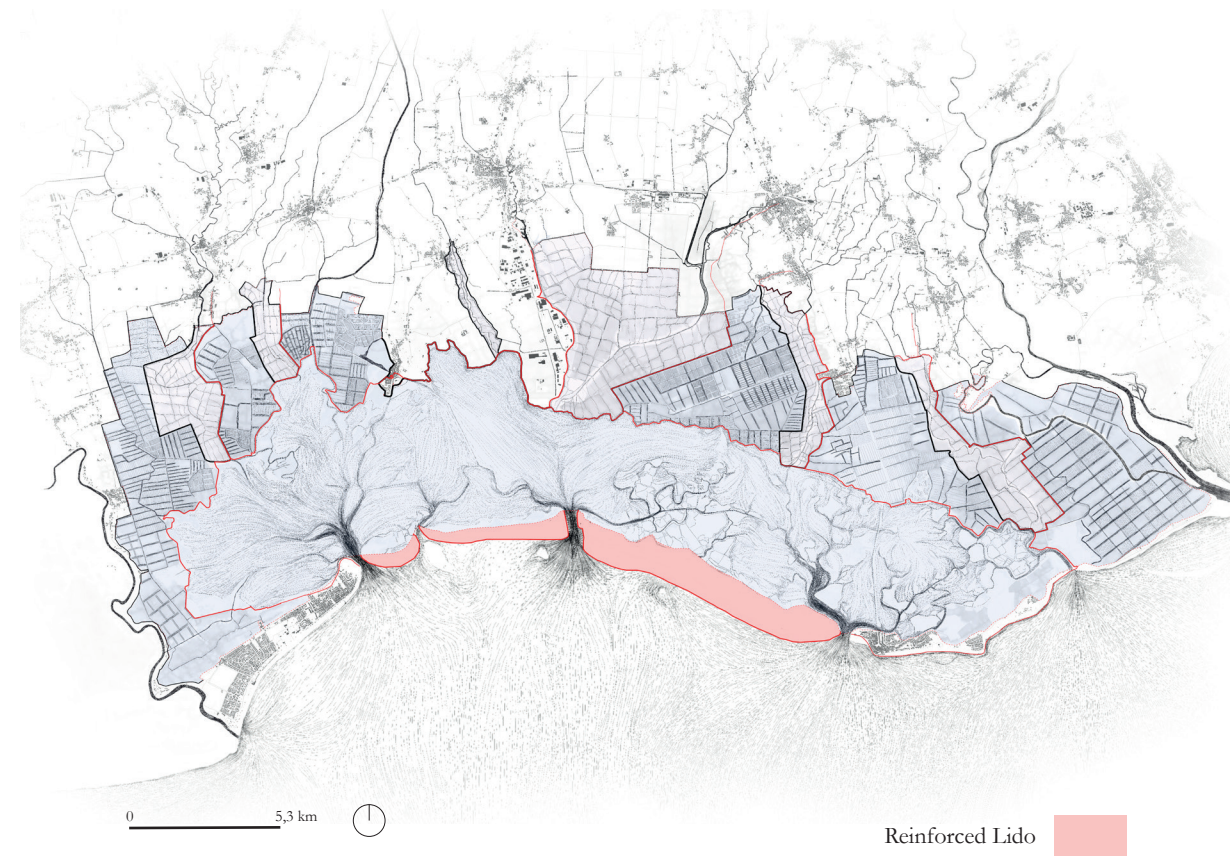


Fig. 76 « Reinforced Lido » Data developed by the author. From Territorial data catalog. (AUTHOR, 2024)

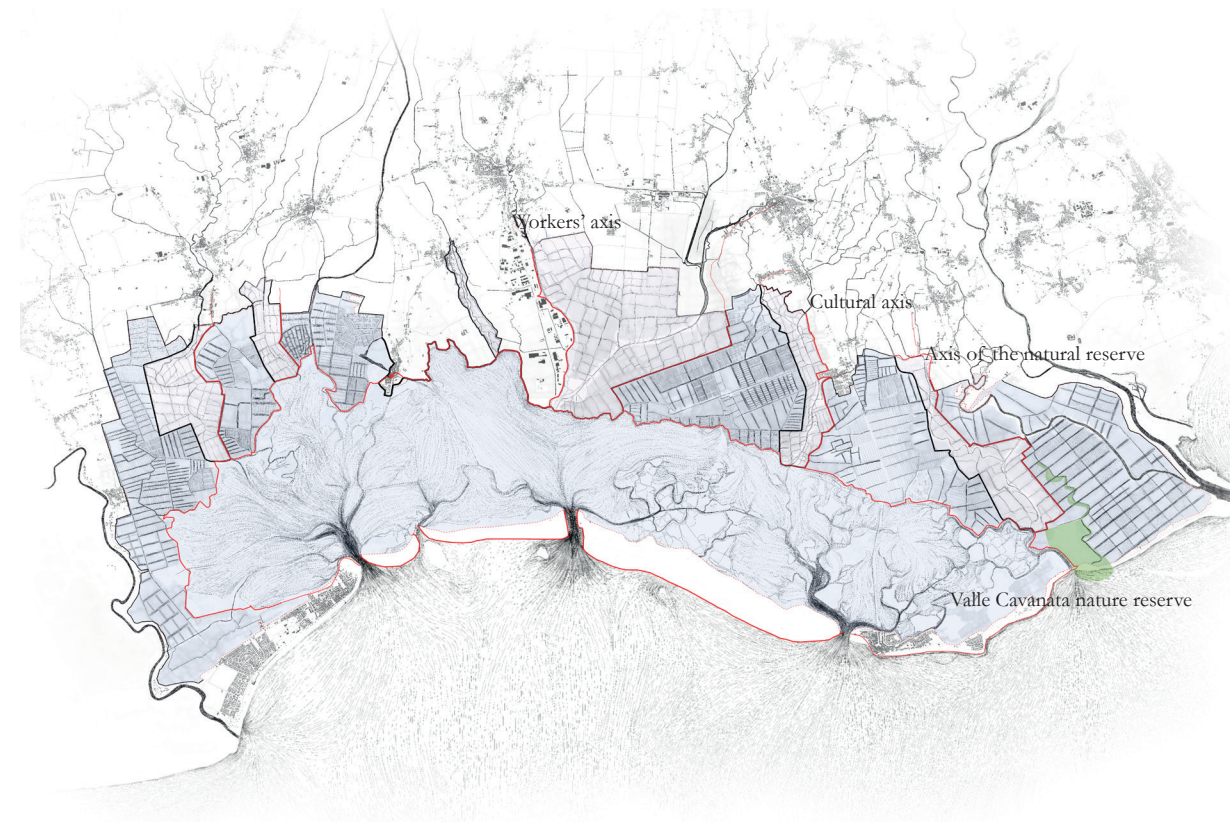
5.5.4 The promenade network

To reach the main part of the promenade, several perpendicular axes are built on the new dikes erected around the different landscapes.

They allow visitors to stroll at the interface of different environments.

These axes are designed for different uses and users. For example, one of them is intended for workers in the industrial area, another run close to Aquileia and is therefore more of a cultural axis, aimed rather at tourists.

The promenade loop is therefore the spine of a wider network, supporting reconnection with the lagoon and enhancing links with its ecosystem.



6 CONCLUSION

In this work, we have looked at the nature and history of the Marano-Grado lagoon eco-system, its richness and its fragility. We have seen that till well passed the middle of last century, the lagoon, and the fishermen people living in this area, have been completely neglected by the state. During fascist times, the focus was on reclaiming land on the sea, and a complex of dikes and pumps was put in place. The interest was on the new land and new agriculture areas to serve the economy. The lagoon was on the ‘other side of the dike’, beyond the ‘wall’, an unnecessary transition zone towards the sea. It was hidden from view by the dikes surrounding the field land.

Somehow, the lagoon and its rich bio-diversity survived, even deprived from any special attention. An aquaculture activity developed, making use of the very nurturing lagoon waters to feed fisheries breeding ponds. Interest groups formed to defend the lagoon eco-system from economic ambitions and industry expansion.

Today however, the water level rise induced by the global climate change is threatening the future of the lagoon.

This project proposes a way to cope with this threat by re-structuring the lagoon environment to simultaneously achieve multiple objectives. First, safeguarding the future of the lagoon eco-system and its rich bio-diversity. Second, use newly submerged lowlands to naturally depollute nutrient-loaded waters drained from the agricultural fields. Third, help the further development of the aquaculture industry, fed from rich lagoon waters.

And finally, the last goal is to reconnect the lagoon environment with the man society by making it accessible to explore and discover. The latter will be achieved by a newly created ‘lagoon discovery trail’. Its beauty and richness, long hidden behind walls, will finally be exposed to all. Unknown and ignored yesterday, the Marano-Grado lagoon will be visible and admired tomorrow. And this new understanding of its beauty and value will be the best guarantee for its survival, for the future good of the whole society.

7 BIBLIOGRAPHY

Gardner, R. Finlayson, M. and all. (2018). « Global wetland outlook : state of the world's wetlands and their services to people 2018 ». RAMSAR.

Robertson, H. Van Dan, A. de Souza, M. and Amerasinghe, P. (2022). « Zones humides et agriculture : effets des pratiques agricoles et pistes pour la durabilité ». La Convention sur les zones humides. RAMSAR.

Wetlands International. (2023). « Wetlands - Hidden Wildlife Havens ». consulted on 5 april 2024. URL : <https://www.wetlands.org/blog/wetlands-hidden-wildlife-havens/>.

RAMSAR « The Convention on Wetlands, The Convention on Wetlands ». Consulted on 30 march 2024. URL : <https://www.ramsar.org/>.

Barbanti, A. Ramieri, E. Picone, M. Menchini, G. Bressan, E. and Forno, E. (2011). “Integrated plan for the sustainable management of the Lagoon of Marano and Grado”. URL : <https://doi.org/10.1051/litt/201105008>.

ARPA Friuli Venezia Giulia (Regional Environmental Protection Agency). (2005). “Rapporto sullo stato dell’ambiente, aggiornamento”.

ARPA FVG . (2023). « Il territorio : acque di transizione – il complesso lagunare di Marano e di Grado ». Consulted on 19 november 2023. URL : <https://www.arpa.fvg.it/temi/temi/acqua/ultimi-pubblicati/il-territorio-acque-di-transizione-complesso-lagunare-di-marano-e-grado/>.

Piazza, A. (2022). « Modellazione idrodinamica bidimensionale della laguna di Grado-Marano ». Università degli studi di padova.

Fontola, G. Bezzi, A. Fachin, G. Pillon, S. (2010). « Le trasformazioni ambientali della laguna di grado e marano ». Università degli studi di Trieste, Arpa FVG.

Paskoff, R. (2010). « 6. Les lagunes ». In Les littoraux, 3e éd.:128 56. Collection U. Paris: Armand Colin. URL : <https://www.cairn.info/les-littoraux--9782200249267-p-128.htm>.

Cosolo, M. Sponza, S. Fattori, U. (2015). « La laguna di Marano e Grado: un mosaico di biodiversità – un patrimonio da preservare » Regione Autonoma Friuli Venezia Giulia, Udine.

Governo Italiano. (2023). « Rete Natura 2000 ». Ministero dell’Ambiente e della Sicurezza Energetica. Consulted on 2 april 2024. URL : <https://www.mase.gov.it/pagina/rete-natura-2000>.

Anonymous. (2018). « Bacino dei tributari della laguna di Marano-Grado ». In Piano di gestione dei bacini idrografici delle Alpi Orientali. Autorità di Bacino.

Crew intereg Italy-Croatia. (2021). “Report of the wetland contract : Marano lagoon”. Comunità Riviera Friulana.

Marin, A. De Marchi, M. and al. (2021). « Il fenicottero rosa di Rosario parla della Laguna di Marano e della scuola estiva residenziale Terr_a_mare, l'ultimo evento locale del Contratto d'area umida per il sistema Laguna di Marano ». Consulted on 6 march 2024. URL : <https://arts.units.it/handle/11368/3004915?mode=complete>.

Felcher, S. (2020). « Da sbirro a bonificatore. Cesare Primo Mori e la sua attività ai vertici dei Consorzi di Bonifica della Bassa friulana e dell'Istria durante il ventennio fascista ». Udine.

Scaini, M. (2012). “Utopia and Fascist foundation cities The case of Torviscosa”. In Utopia e contro-utopie. p. 301-323.

Robiony, M. “Tradizione e innovazione nello sviluppo economico del Friuli”. Consulted on 4 april 2024. URL : <https://valoridentitari.uniud.it/tradizione-e-innovazione-nello-sviluppo-economico-del-friuli/>.

Perez, T. Coen, L. (2018). « Il consorzio di bonifica: una forma di partenariato pubblico-privato ». Università degli studi di Udine.

CAFC-Acque del friuli. (2024). « La fognatura e la depurazione ». Consulted on 15 march 2024. URL : <https://www.cafcsa.com/it/15376/la-fognatura-e-la-depurazione>.

ARPA FVG. (2022). « I principali inquinanti analizzati da Arpa FVG nelle acque ». Consulted on 21 february 2024. URL : <https://www.arpa.fvg.it/temi/temi/analisi-ambientali-laboratorio/news/i-principali-inquinanti-analizzati-da-arpa-fvg-nelle-acque/>.

IPCC. (2014). « AR5 :Chapter 4: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities — Special Report on the Ocean and Cryosphere in a Changing Climate ». Consulted on 20 march 2024. URL : <https://www.ipcc.ch/srocc/chapter/chapter-4-sea-level-rise-and-implications-for-low-lying-islands-coasts-and-communities/>.

IPCC. (2022). “Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-Industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty”. 1re éd. Cambridge University Press. Consulted on 15 february 2024. URL : <https://doi.org/10.1017/9781009157940>.

Anonymous. (2023). « Segnali dal Clima in FVG - ARPA FVG ». Consulted on 6 april 2024. URL : https://www.arpa.fvg.it/temi/temi/meteo-e-clima/sezioni-principali/cambiamenti-climatici/segnali-dal-clima-in-fvg/?fbclid=IwAR0z-O3Cws91wJCw_Zq5aopr1_KnTGW74ULtadpSrph0nvcCeey1yn9TE9o.

Climate Central. (2021). « Land below 1.0 Meters of Water ». Consulted on 1 december 2024. URL: https://coastal.climatecentral.org/map/8/12.9006/44.838/?theme=water_level&map_type=water_level_above_mhhw&basemap=roadmap&contiguous=true&elevation_model=best_available&refresh=true&water_level=1.0&water_unit=m

Bezzi, A. Fontolan, G. (2013). « Le barene della laguna di marano e grado: analisi degli aspetti morfoevolutivi nella prospettiva gestionale ». Università degli studi di trieste.

Scarcinelli, U. Tiziano, F. (2022). « 'Tagliamento: Il fiume dei tigli-The lime - Tree River » Tiglio edizioni.

Perco, F. Corso, M. Filiputti, W. (2004). “Nell'incanto delle lagune”. Magnus edizioni SpA. Udine.

Sbarigia, S. (2023). « Un nouvel équilibre entre terre et mer : le territoire du nord Adriatique ». UCLouvain, Faculté d'architecture, ingénierie architecturale, urbanisme. Bruxelles.

Databases

Territorial data catalog « Enviromental and territorial data catalogue, Regione Friuli Venezia Giulia ». URL : <https://irdat.regione.fvg.it/consultatore-dati-ambientali-territoriali/search>

Tarquini, S. Isola, I. Favali, M. Battistini, A. Dotta, G. (2023). « TINITALY, a digital elevation model of Italy with a 10 meters cell size – Dataset”. Istituto nazionale di geofisica e vulcanologia . URL : <https://data.ingv.it/dataset/185>.

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4.838/?theme=water_level&map_type=water_level_above_mhbw&basemap=roadmap&contiguous=true&elevation_model=best_available&refresh=true&water_level=1.0&water_unit=m (AUTHOR, 2024)

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