reclaimed territories. In this hypothesis, the territories returned to water would not be subject to a retreat process, but would be converted into new inhabited amphibious territories. Experiments with aquaculture and fish farming could be run here, with the use of algae for energy production and halophytic plants for water purification, updating and radicalizing in these areas the ideas that had been put forward by the Front for the Defence of Venice and the Lagoon in the 1970s in response to the 1966 flood, which played a crucial role in the definition of the first special law for Venice of 1973. Architects and activists Piero Pisenti and Paolo Rosa Salva published in 1972 in *Casabella* and in the local press the idea of an aquaculture project for the lagoon that puts all the rules of modern Venice into play. In this project, the endemic productive characteristics of the territory (such as fishing) extend over the territory to build an alternative development model (Pisenti, 1971; Pisenti and Rosa Salva, 1972). It seems appropriate to emphasize that the idea of subdivision of the lagoon, although radical, is by no means new. In fact, in the long history of Venice, from Cornaro to Sabbadino to Moscatelli to Miozzi, the hypotheses of division or closure of the lagoon have not been lacking. Nor has the lagoon ever been conceptualized as a homogeneous space: in relation to the exchanges with sea water, the ecological and hydrodynamic characteristics, a division of the water space into a 'living lagoon' and 'dead lagoon' has always been recognized.[►7] Also for Bonometto, as for D'Alpaos, the theme of rebalancing does not allude to indifferentiation: in fact 'the concept of balance, like that of stability, in the environmental meaning on the contrary implies the tendency of systems to maintain their own complexity and functionality, in a dynamic and evolutionary context in which the dynamisms themselves, including human action, determine self-preservation capacities' (Bonometto, 2017, p. 61). These distinctions not only follow a hydraulic rationality but also geographical biological ones and use practices. 'In this sense we can recognize a subdivision of the lagoon into three vast expanses, not coinciding with the three lagoon basins but, approximately, with the areas indicated as the northern lagoon, central lagoon, and southern lagoon. In these, the combined effects of the actions that took place in past centuries and of the 20th century and current aggressions have led to different scenarios, which require different management strategies' (Bonometto, 2015, pp. 12–13).

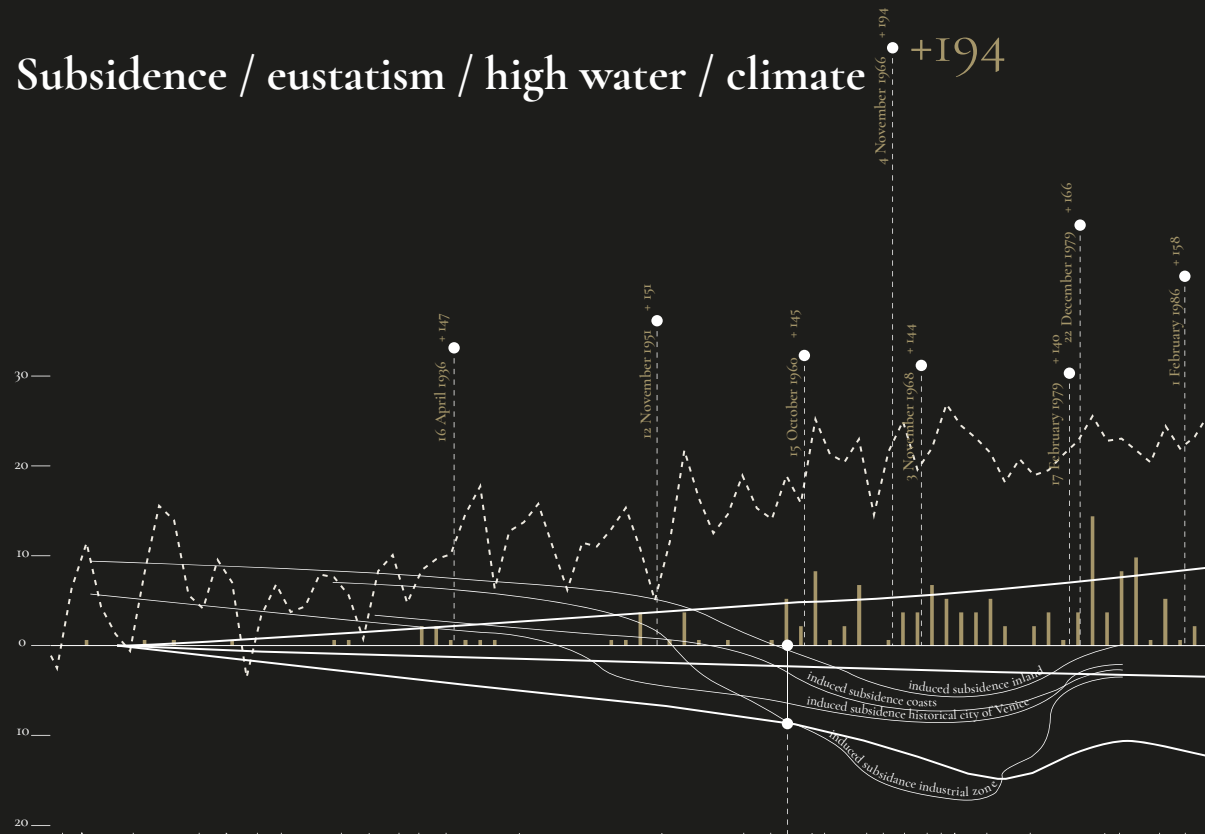
►7 'Speaking of living lagoon, we mean that part of the lagoon basin which is closest to the mouths and is most actively reciprocated by tidal currents. The dead lagoon, on the other hand, is formed by those parts of the lagoon basin that are located towards its mainland edges and are geographically and hydraulically decentralized with respect to the mouths, being separated from the living lagoon by the first imposing bands of *barene*' (D'Alpaos, 2010a, p. 72)

Pressure

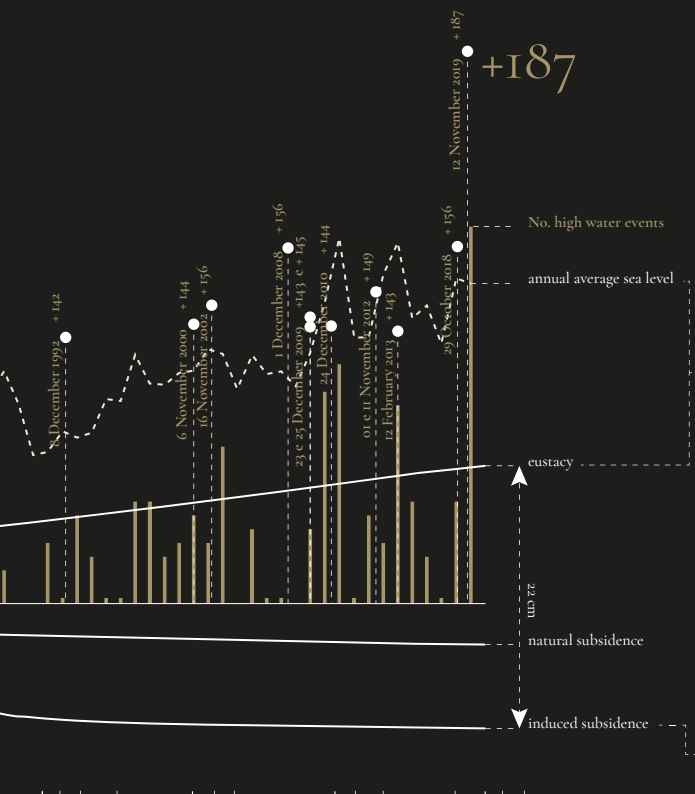
What threatens the Venice lagoon?

The Venice lagoon is a fragile environment whose survival depends on a delicate hydrodynamic equilibrium between sea currents and river deposits, artificially maintained over the centuries.
Threatening this equilibrium today and in the future are ever-increasing natural and anthropogenic pressures: natural and human-induced subsidence, sea level rise resulting from climate change, floods, erosion of sandbanks, lack of sediments, the deepening of the bathymetry and the flattening of the lagoon-bed.

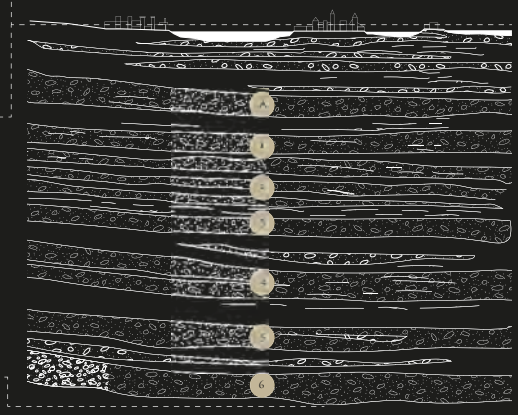
Subsidence / eustatism / high water / climate



It is a while since the sea level rise and high water phenomena have represented the main threat to the survival of Venice and the other historical islands. Graph A illustrates the increase in high water levels during the 20th century due to the combined effect of the lowering of the ground level (subsidence), the rise in the mid-sea level (eustatism) and the intense meteorological and climatic phenomena caused by the mutations of climate. If eustatism is derived from climatic phenomena of planetary origin, subsidence is partly derived from natural processes of soil compaction, partly from local processes induced by anthropogenic activity on the subsoil. Starting from the Thirties of the 20th century, the extraction of



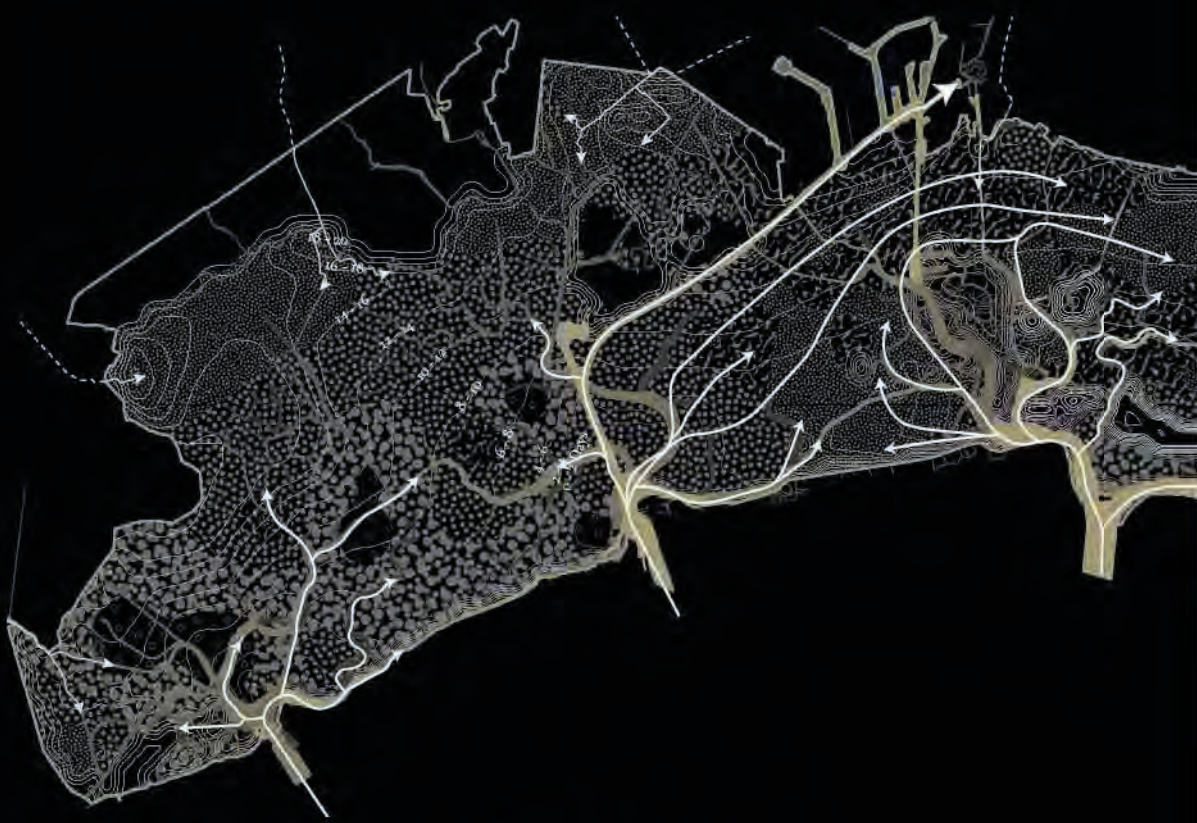
A. Subsidence, eustatism and high water
On the left page, the diagram shows the correlation between subsidence, eustatism, morphological transformation of the lagoon, increase in the mean sea level and high water during the 20th century.
Source of data: ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale, 2017; CPSM, Centro Previsioni e Segnalazioni Maree del Comune di Venezia, 2019; IPSS, Intergovernmental Panel on Climate Change, 2019.



B. Stratigraphy of the Venetian subsoil
The diagram above illustrates the stratigraphy of the Venetian subsoil. From a geological point of view, the subsoil of the lagoon is a multi-flake system characterized by an alternation of clayey-silty impermeable layers and sandy layers. In the first 350 metres of depth, the latter house the Venetian aquifer that was affected by the artesian exploitation carried out for the construction of the first industrial nucleus of Porto Marghera starting in the Thirties of the 20th century. After the war, exploitation also affected the sixth aquifer, leading not only to a lowering of the piezometric level but also to the lowering of the soil with an average value of 8 millimetres per year.

groundwater for the construction of the industrial core of Porto Marghera became intensive. In a multi-layer system (section B) this process has led to a lowering of the ground level of the Venice lagoon by about 10 centimetres over the last century. As mentioned above, the repercussions on sea level resulting from climate change with average increases in the last century of about 35 centimetres on the marine average are added to the subsidence. On the occasion of the floods and storm surges of 1966 and 2019, these combined phenomena resulted in high water levels of about two metres above the average sea level –considered as +/- 0– of Punta della Salute.

Sediments / currents / wave motion



Currents

Sediments

The Venice lagoon is the result of a complex hydrodynamic equilibrium existing between the tidal currents from the Adriatic and the deposit of sediments from the drainage basin. The difficult conservation of this equilibrium depends on the maintenance of the morphological structures of *barene*, *ghebi* and emerged lands, and with them the biological health of the entire lagoon. Map A illustrates the system of relationships existing between the currents coming from the Adriatic, the stay times and the transport of sediments of different nature and grain size coming from the drainage basin. If over the centuries the main challenge was to limit the risk of swamping, today the biological and hydrodynamic health of the lagoon appears threatened by the chronic lack of sediments and by the progressive erosion processes of the

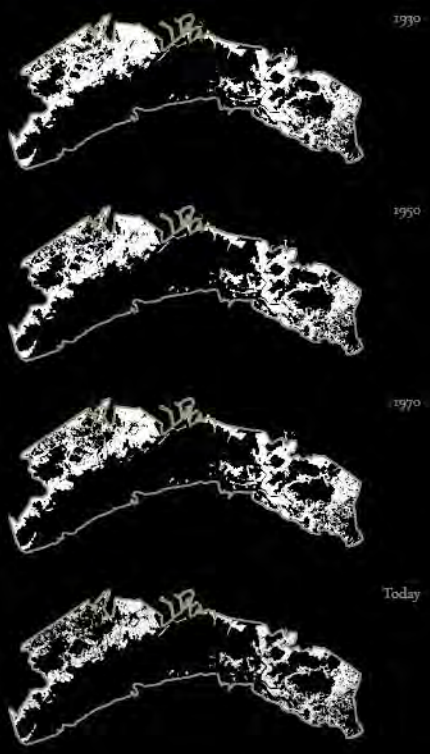
A. Sediments and currents

Below, the map illustrates the nature and stay times of the sediments in relation to sea currents and the speed limits in the lagoon channels.

Source of data: ISMAR, Istituto delle Scienze Marine, 2012; DSA – UniVE, Dipartimento di Scienze Ambientali - Università Ca' Foscari di Venezia, 2012; MAV, Magistrato alle Acque di Venezia, 2012.

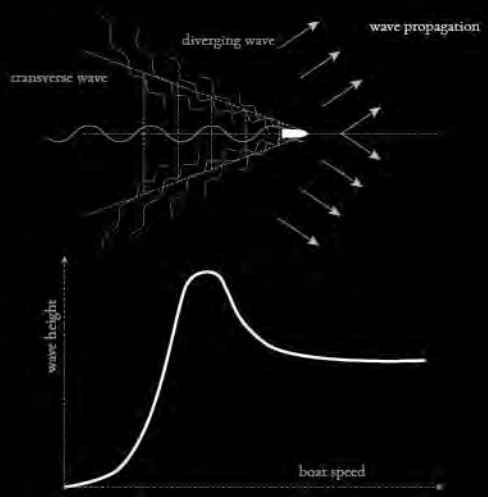
B. The erosion of the *barene* from 1930 to today

Source of data: CVN, Consorzio Venezia Nuova, 2012.



C. Waves and boats

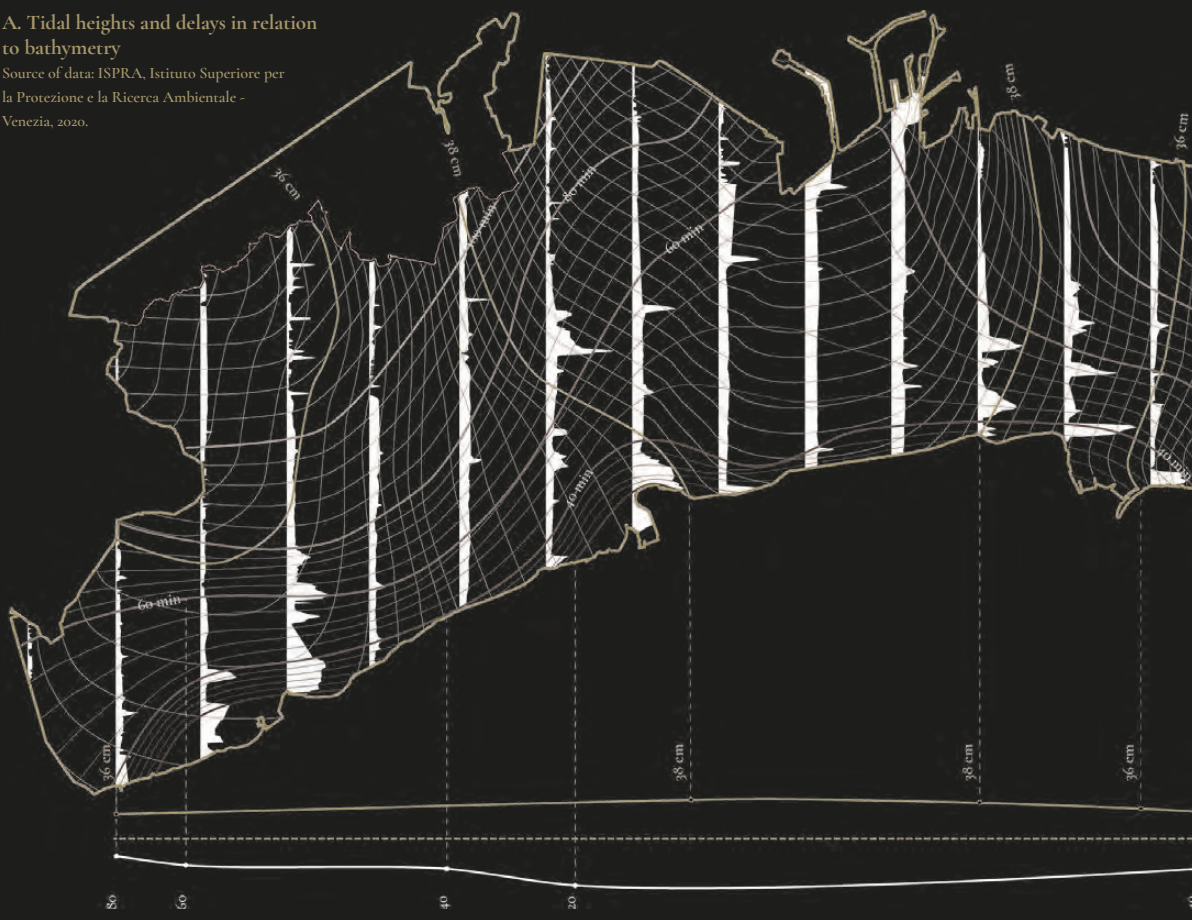
Below, the diagram illustrates the propagation mechanisms of wave motion derived from a vessel in relation to direction and speed.



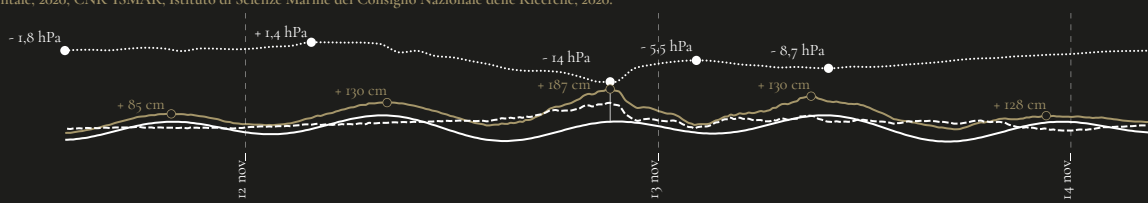
lagoon-bed and of the *barene* (see diagrams on the right). These latter aspects are largely determined by the hydrodynamic imbalances caused by climate change, by 20th century interventions on canals and lagoon mouths and by the wave motion produced by vessels with speeds and hulls that are not compatible with the fragile nature of the lagoon.

Tides / propagation times / bathymetry

A. Tidal heights and delays in relation to bathymetry
Source of data: ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale - Venezia, 2020.

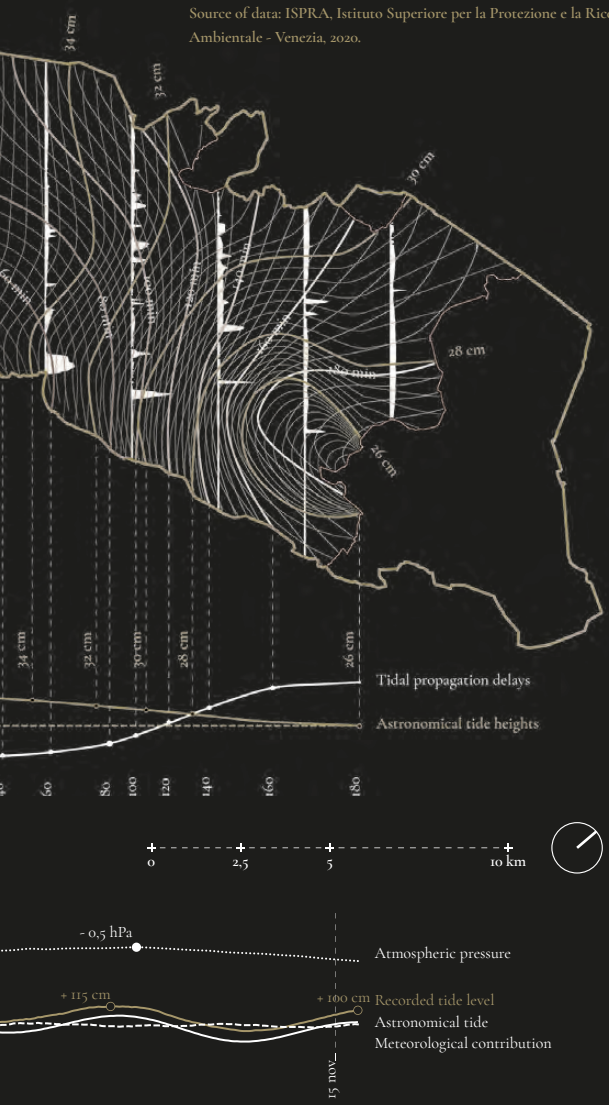


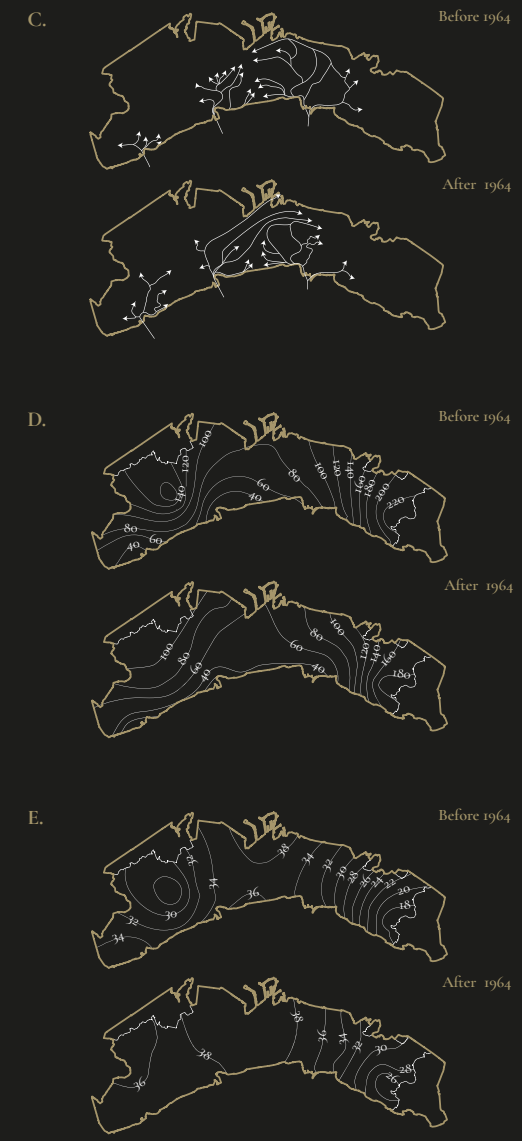
B. Tide, pressure, and sea level during the November 2019 flood.
Source of data: CPSM, Centro previsioni e Seganalazioni Maree, Comune di Venezia, 2020; ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale, 2020; CNR-ISMAR, Istituto di Scienze Marine del Consiglio Nazionale delle Ricerche, 2020.



The processes of erosion of the seabed and high water are closely related to the timing and propagation of the tide. Map A illustrates how the propagation times of the tides (white curves) and tidal waves (gold curves) are significantly damped due to the friction developed by sandbanks and shallow waters (vertical sections). The capacity of resistance to the tidal wave and to the impacts of high water have varied over time, with greater evidence after 1964, also following the changes in the hydrodynamic and bathymetric structure of the lagoon caused by the excavation of the *Petroli Canal* (see maps C-E). If before 1964 the tidal delay between

The effects of 20th century transformations on sea currents and tidal propagation
Right, from top to bottom: C) Propagation of marine currents, before and after 1964; D) Delays in propagation of the tide in minutes, before and after 1964; E) Astronomical tide heights expressed in centimetres, before and after 1964.
Source of data: ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale - Venezia, 2020.





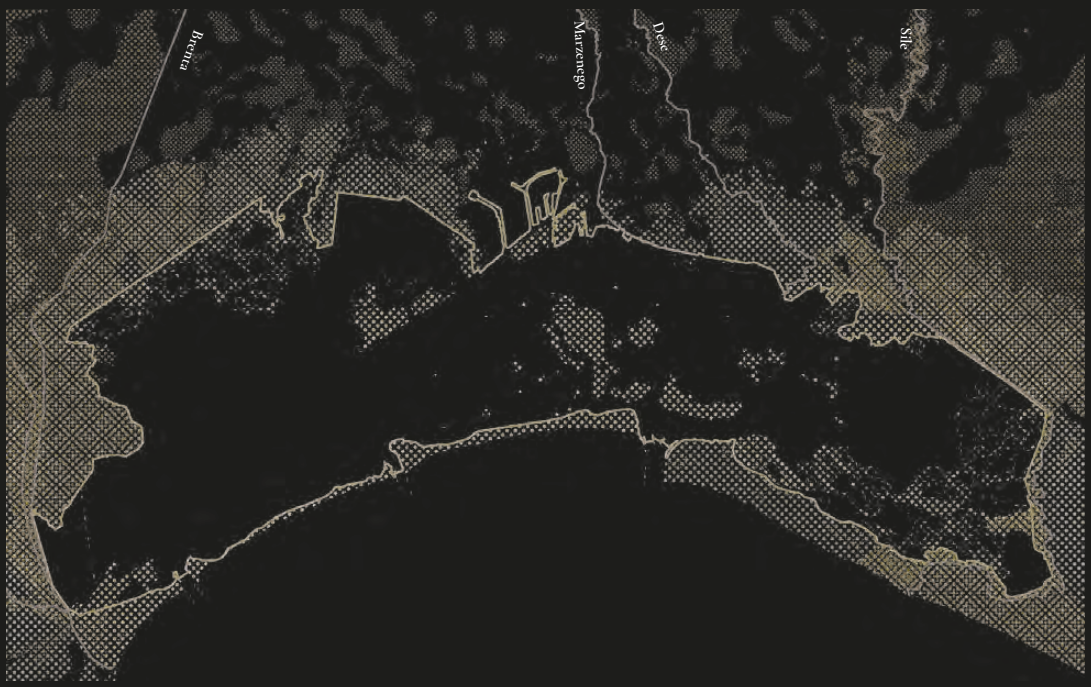
the lateral and the central lagoons was in the order of 160 minutes with tides that could vary up to 20 centimetres, at the beginning of the 21st century the tidal differences have almost disappeared and remain only partially at the far end of the North lagoon. Diagram B below the map shows how, during the November 2019 flood, the normal tidal oscillations of an astronomical nature (solid white line) were exacerbated by specific meteorological conditions, *sirocco* winds and atmospheric pressure differences (dotted white line) which, on the night between 12 and 13 November, brought the sea level (gold line) to reach a height of 187 centimetres.

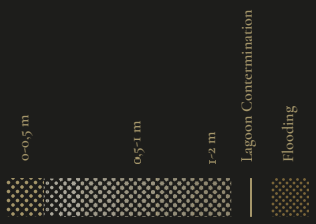
What-If

Lagoon Scenarios

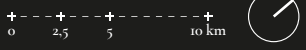
The incessant process of regulation of the Venice lagoon has not built a homogeneous and smooth geographical image. Indeed, it can be said with certainty that various moments of crisis have followed one another. These moments impose themselves in the history of the lagoon as occasions in which institutions and technicians initiate a series of "debates on the future". Starting from the long history of Venice and the challenges that await its lagoon in the future, in the following pages we will try to explore some alternative lagoon scenarios for 2100, when the movable bulkheads of the MoSe will no longer be sufficient.

01. Business-as-usual Scenario



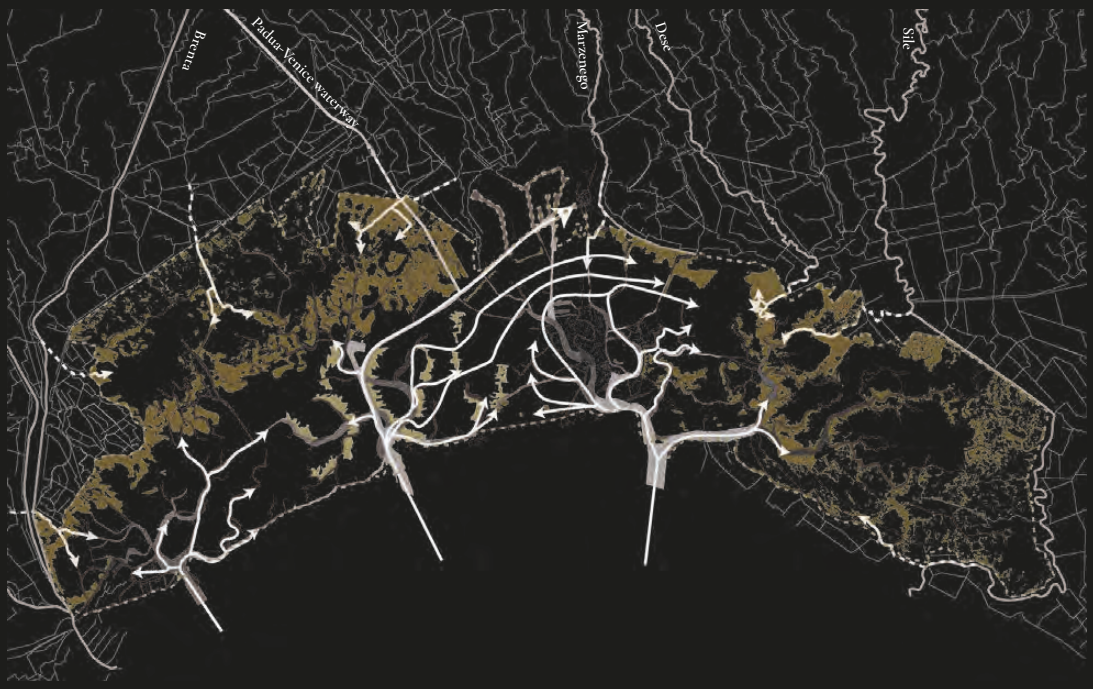


Scenario 1
Application of the business-as-usual scenario.
Source of data: PAI, Piano di Assetto idrogeologico della Regione Veneto, 2016; DTM, Digital Terrain Model della Regione Veneto, xxxx.



The Business-as-usual scenario answers the question: "*what would happen if there were no major changes in people's attitudes and priorities, in technology, in the economy or in local public policies, such as to expect normal circumstances to continue unchanged?*"
For the lagoon and its drainage basin, this means assuming that entire territories will be rendered uninhabitable due to the combined effect of the average sea rise and the intrusion of the saline wedge. Venice and the islands will be subject to repeated high water which will increase the need to close the MoSE. The effects induced by the tropicalization of the climate will increase, reducing the return times of floods.

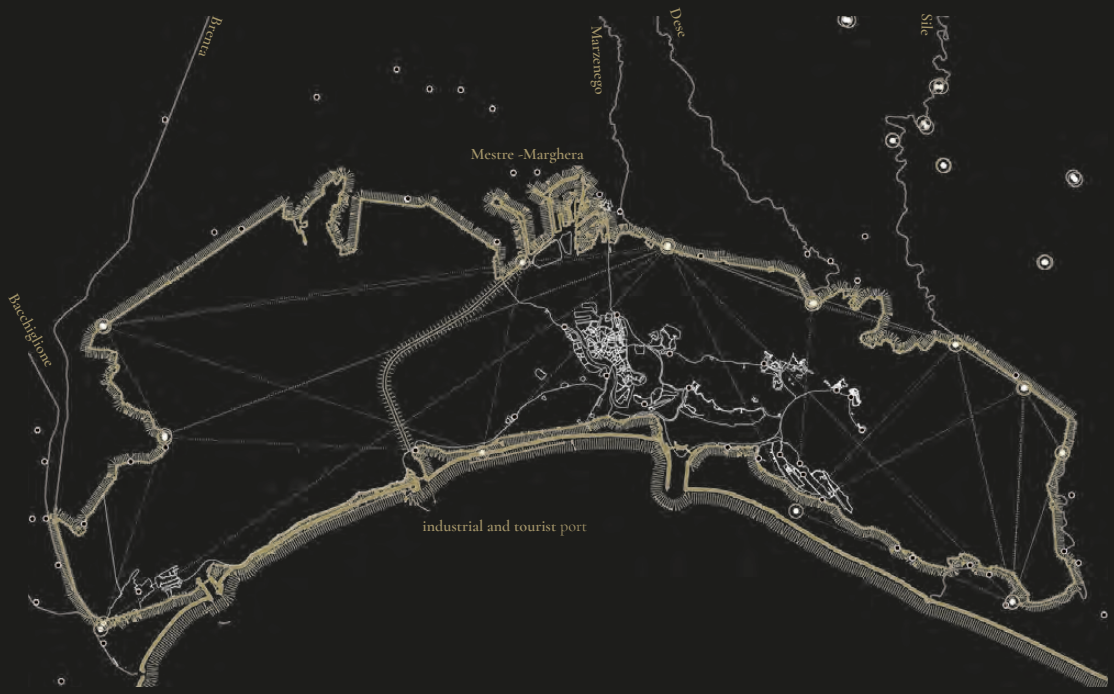
02. Conservative lagoon Scenario

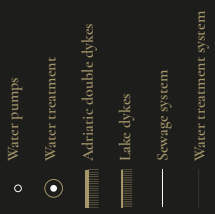


Scenario 2
Application of the conservative scenario of the hydrodynamic equilibrium of the lagoon.

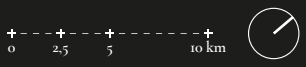
The scenario answers the question: "*what would happen if we wanted to preserve the fluid dynamic equilibrium of the lagoon by following the rationalities that had characterized the interventions of the great hydraulic engineers of the Serenissima?*" The scenario is inspired by the interventions proposed by Luigi D'Alpaos, concerning the re-introduction of sediments into the lagoon through the completion of the Padua-Venice waterway to counteract the erosion of the lagoon-bed and the contextual reconstruction of significant areas of *barene*. The scenario includes the construction of a discontinuous embankment along the *Petroli Canal* and along the Vittorio Emanuele III canal in the central lagoon, and lighter and reversible technologies to favour the terraforming of morphological structures useful for reducing the impacts of wave motion along the main waterways.

03. Enclosed lagoon Scenario



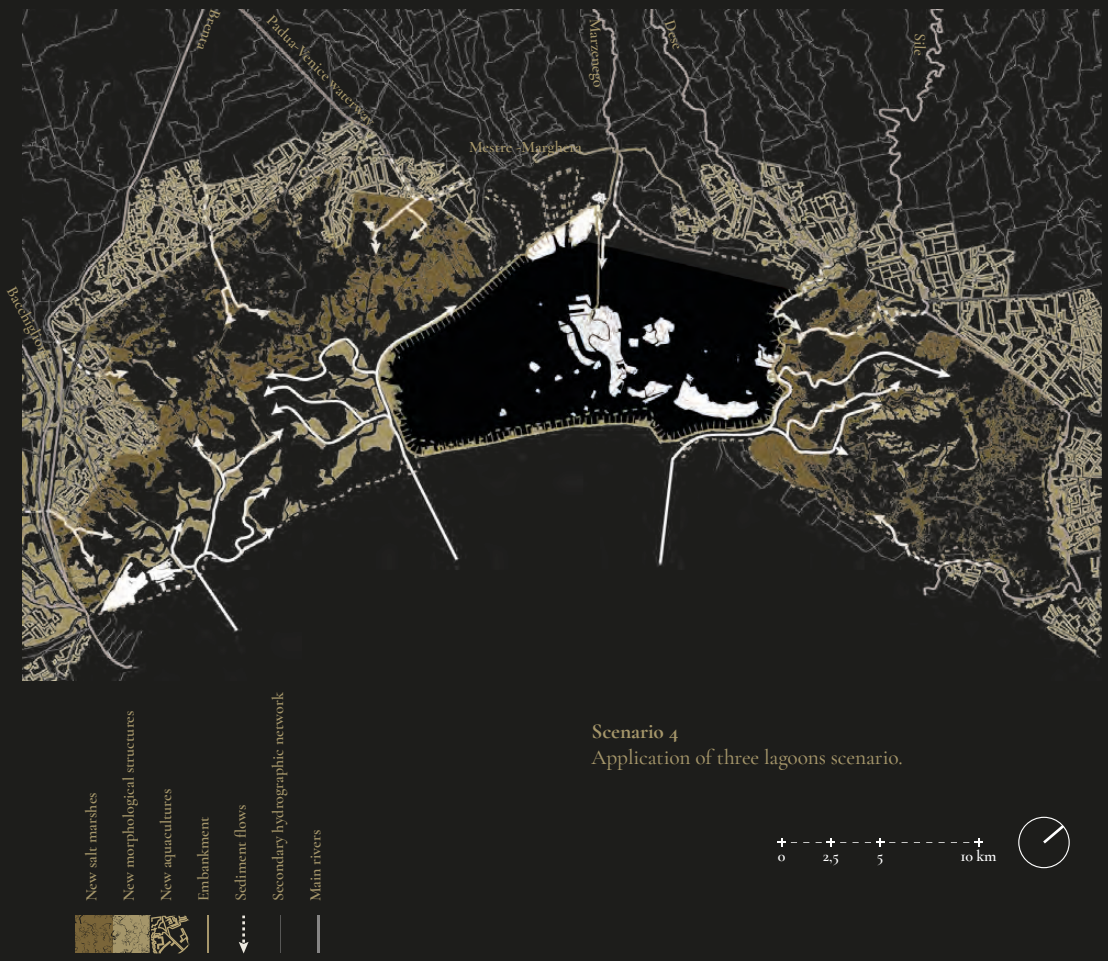


Scenario 3
Application of the lagoon closure scenario.



The scenario for 2100 answers the question *"what would happen if we want to safeguard Venice and the historic islands from the rising sea?"* The scenario, which is inspired by the hypotheses put forward by Georg Umgiesser, looks to the closure and separation of the lagoon as a long-term solution, when the rise in sea level will lead to an almost constant closure of the movable bulkheads of the MoSE to defend the lagoon. The transformation of the lagoon into a lake will have cascading consequences that involve rigid water control and purification systems, a transformation of the biological system that today characterizes the lagoon, interventions aimed at reducing aquatic pollution, providing the city with an efficient sewage system, as well as the ousting of the industrial and tourist port.

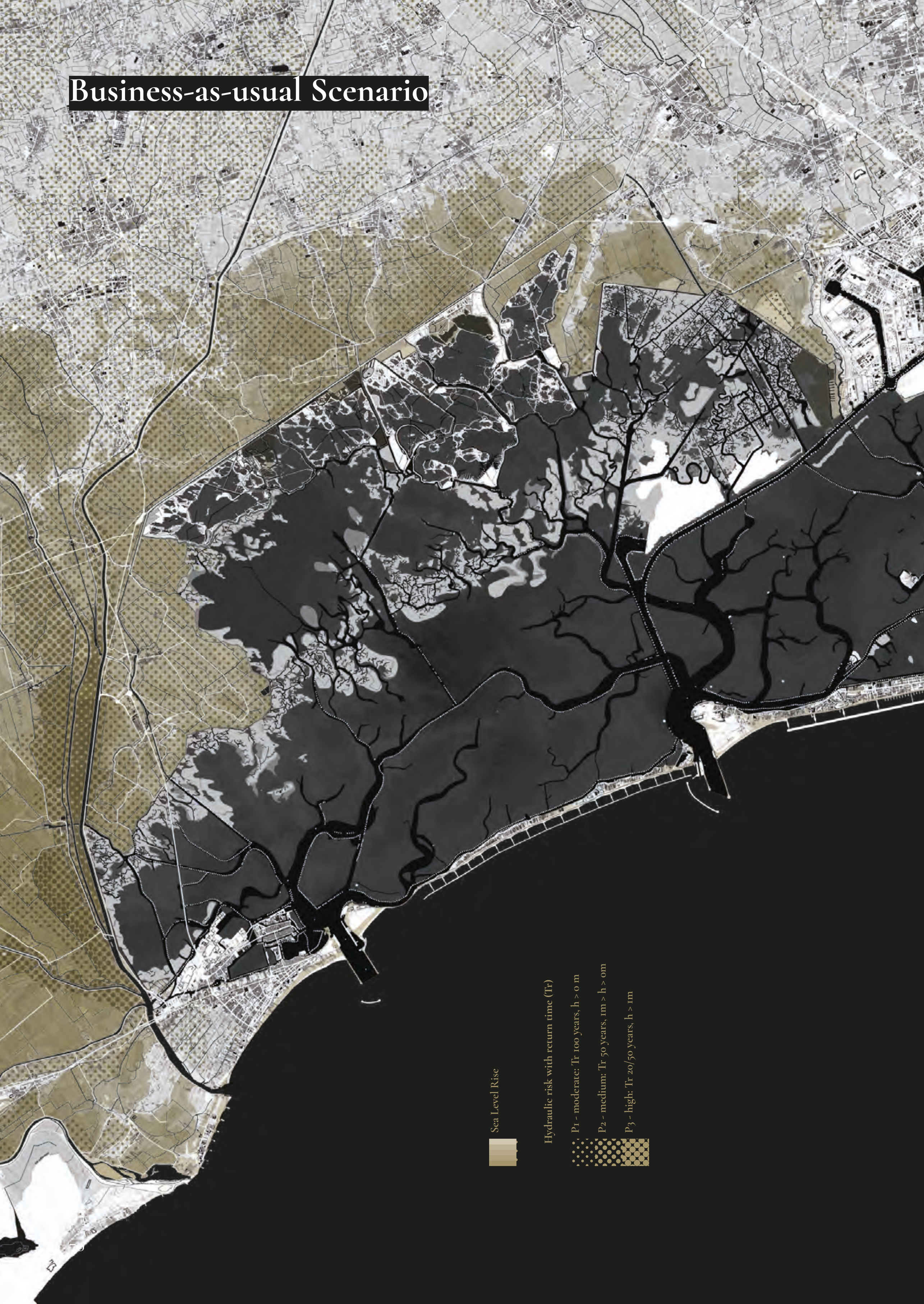
04. Three lagoons Scenario

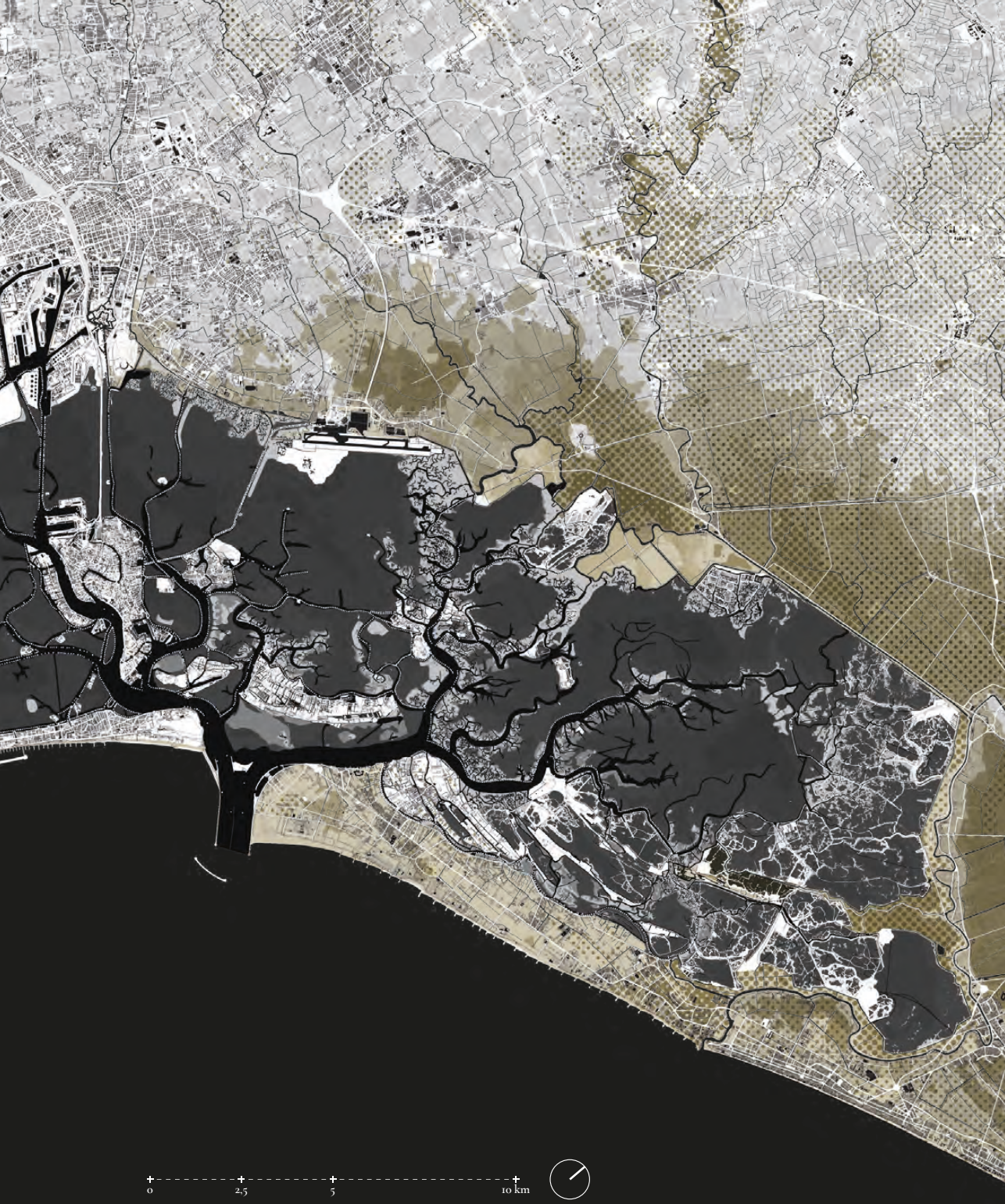


Scenario 4
Application of three lagoons scenario.

The scenario dates forward to 2100 and answers the question: *"what would happen if we separated the lagoon into three interconnected parts with different water levels, hydrodynamic, biological and use characteristics?"* The scenario explores the possibility of separating the central lagoon by means of embankments, sheet piles, navigation basins, dewatering pumps, and technological infrastructures such as to ensure a water level and use practices compatible with Venice and the other historical islands. The lateral lagoons, and with them the fishing valleys and the *barene* areas, expand into the territories maintained today through mechanical drainage: after the water pumps are turned off these are converted into new amphibious territories.

Business-as-usual Scenario



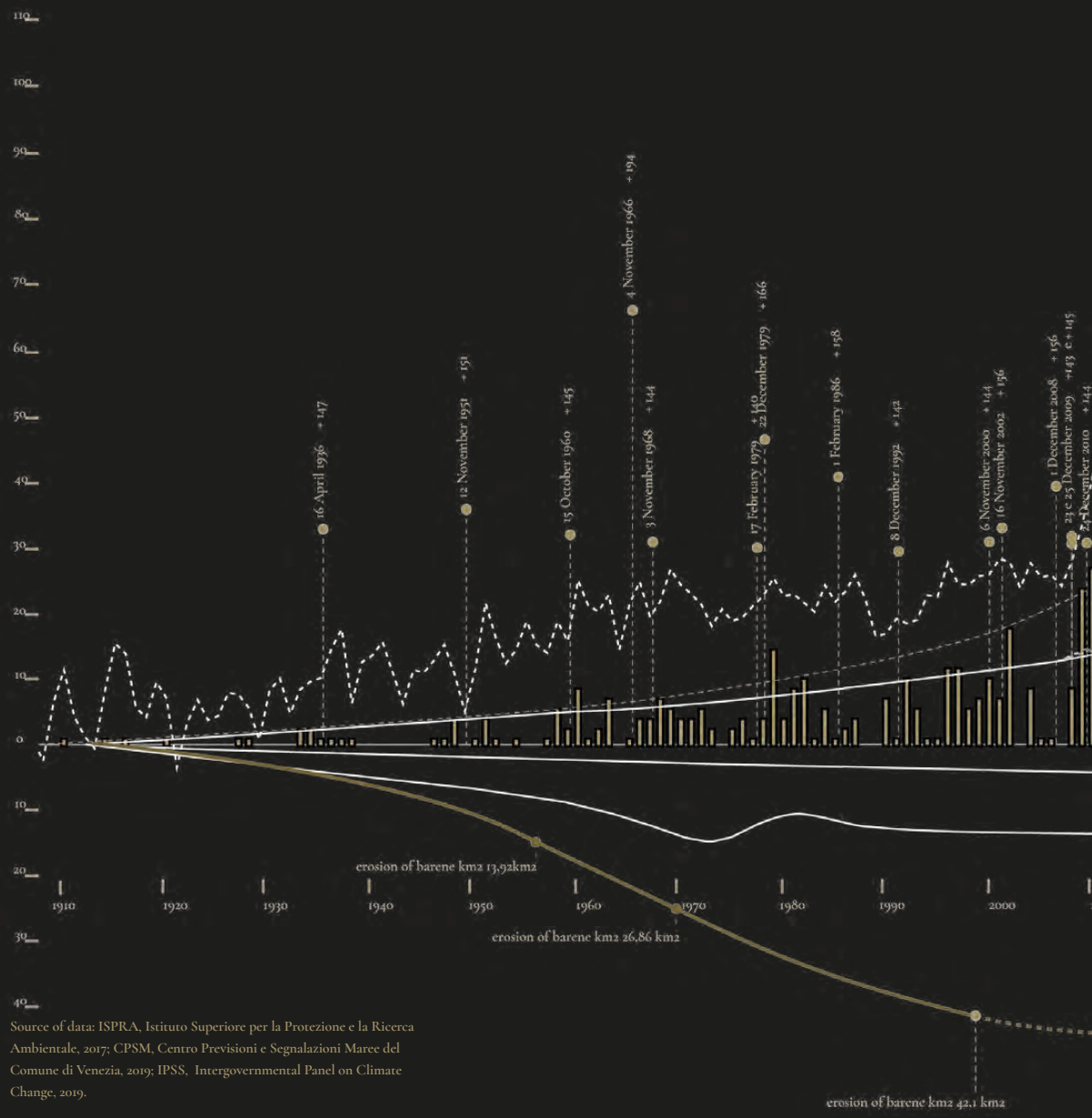


Business-as-usual Scenario

Application of the business-as-usual scenario.

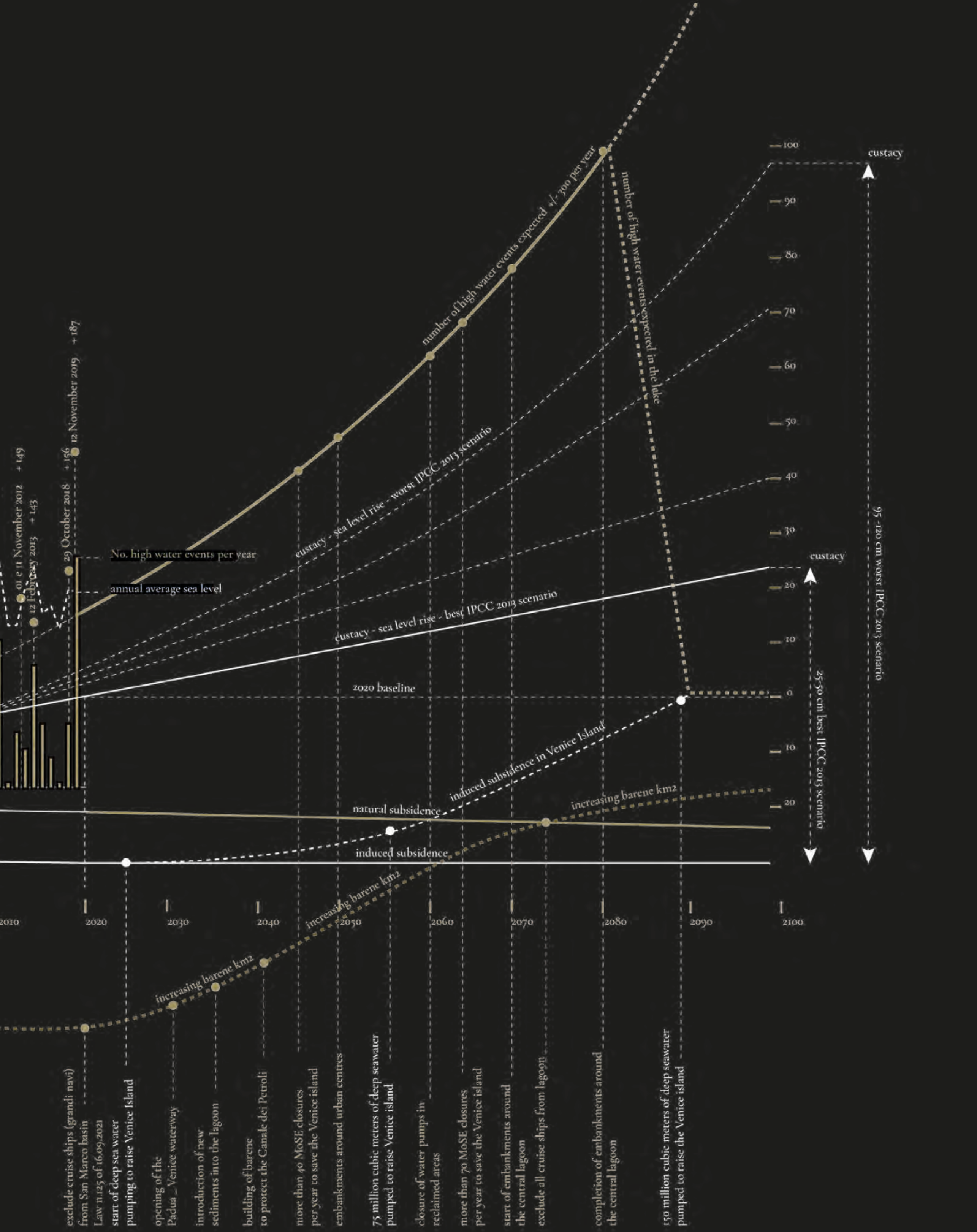
Source of data: PAI, Piano di Assetto idrogeologico della Regione Veneto, 2016; DTM, Digital Terrain Model della Regione Veneto, 2020.

Comparing scenarios



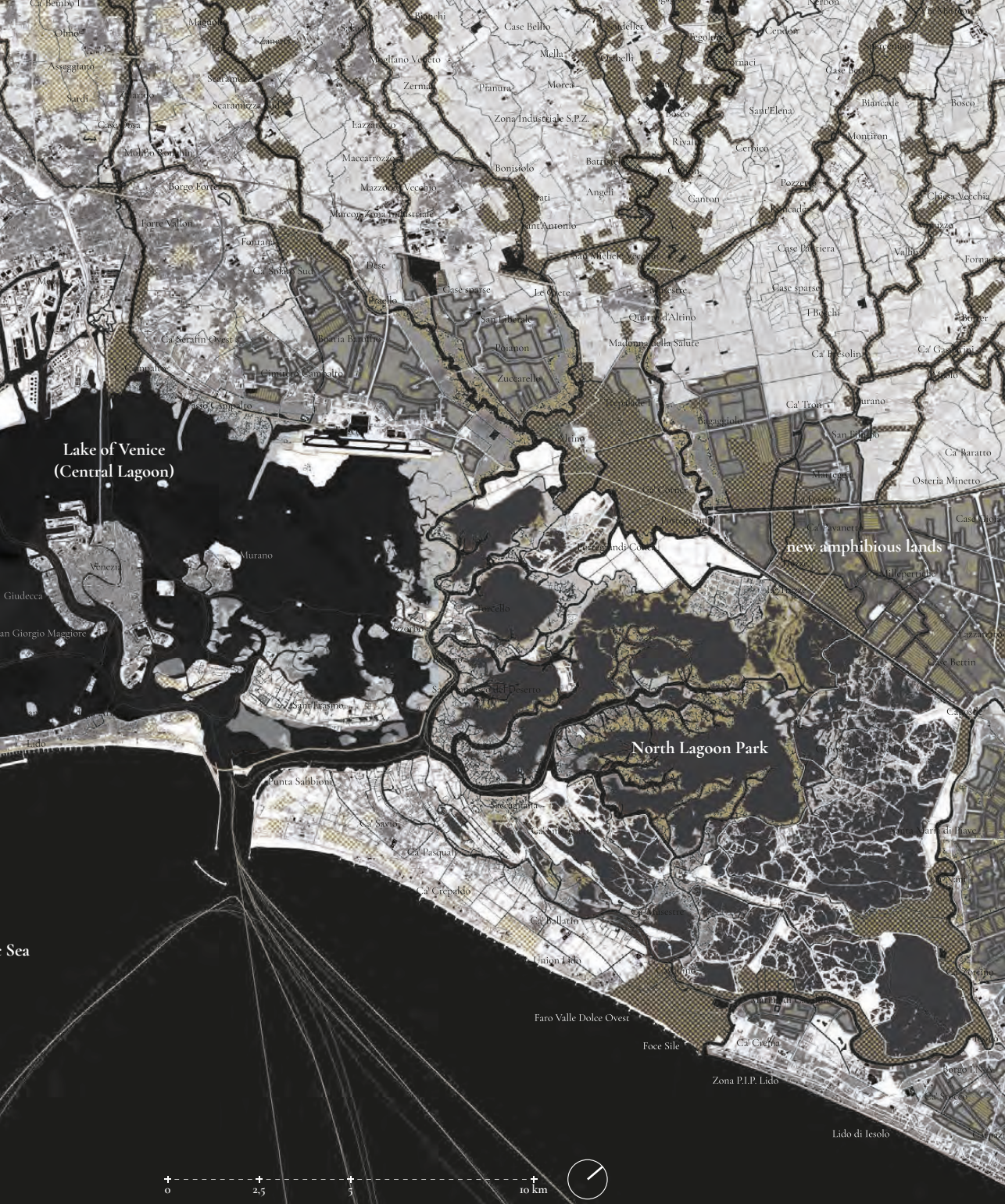
Source of data: ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale, 2017; CPSM, Centro Previsioni e Segnalazioni Maree del Comune di Venezia, 2019; IPSS, Intergovernmental Panel on Climate Change, 2019.

The graph compares from 1900 to 2020 –and projects to 2100– the trends of *barene* surfaces, eustatism, natural and induced subsidence, number of high water events. It compares the IPCC trend scenarios with the conservative and the partial or total closure scenarios for the lagoon, as well as with the hypothesis to pump sea water into the ground depths to "lift" Venice.

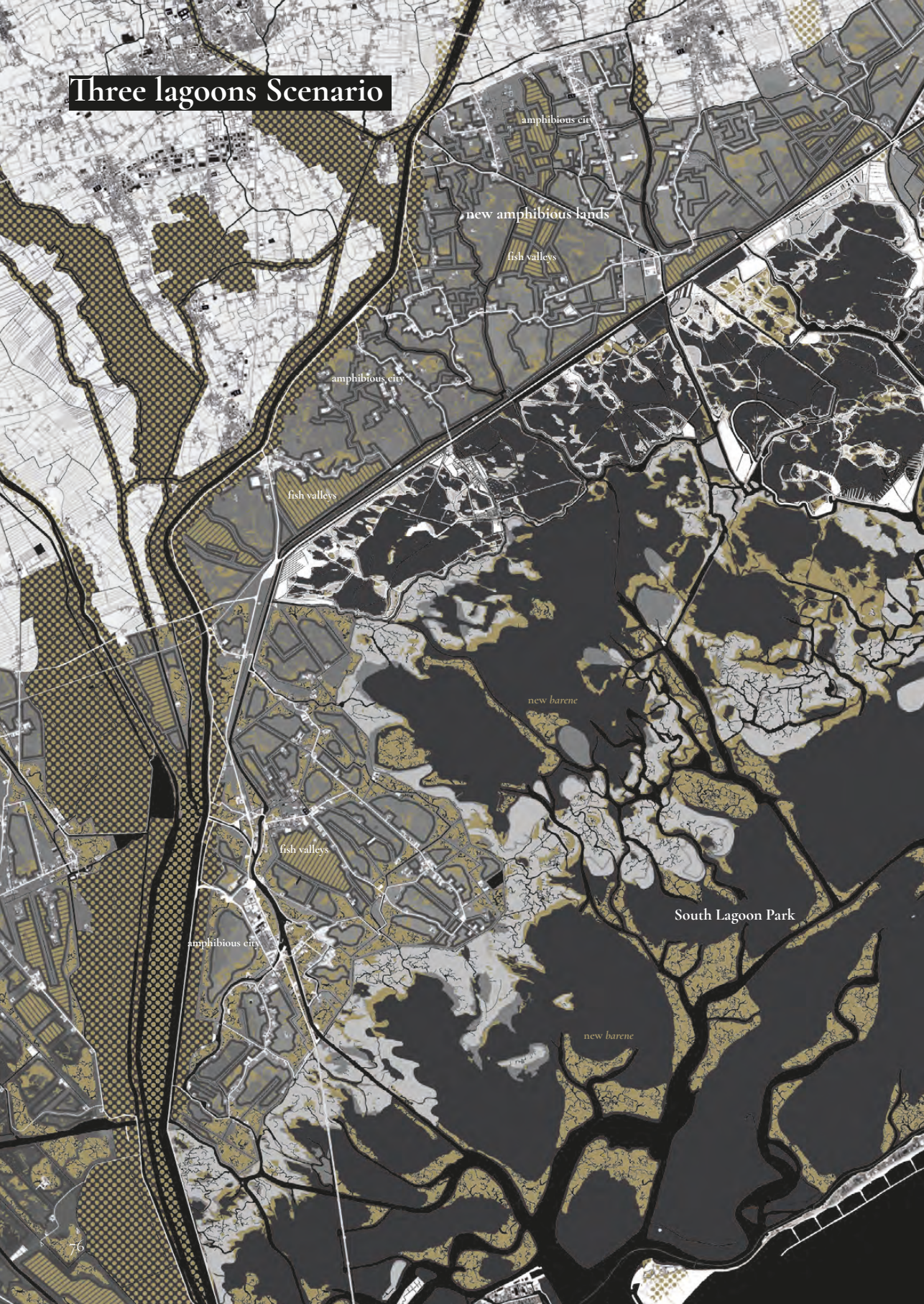


number of high water events expected +/- 300 per year
number of high water events expected in the lake
eustacy - sea level rise - worst IPCC 2013 scenario
eustacy - sea level rise - best IPCC 2013 scenario
No. high water events per year
annual average sea level
2020 baseline
induced subsidence in Venice Island
natural subsidence
induced subsidence
increasing barene km2
eustacy
95 -120 cm worst IPCC 2013 scenario
25-50 cm best IPCC 2013 scenario
01 e 11 November 2012 + 149
12 February 2013 + 143
29 October 2018 + 156
12 November 2019 + 187
100
90
80
70
60
50
40
30
20
10
0
10
20
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
exclude cruise ships (grandi navi) from San Marco basin Law n.125 of 16.09.2021
start of deep sea water pumping to raise Venice Island
opening of the Padua _ Venice waterway
introduction of new sediments into the lagoon
building of barene to protect the Canale dei Petroli
more than 40 MoSE closures per year to save the Venice island
embankments around urban centres
75 million cubic meters of deep seawater pumped to raise Venice island
closure of water pumps in reclaimed areas
more than 70 MoSE closures per year to save the Venice island
start of embankments around the central lagoon
exclude all cruise ships from lagoon
completion of embankments around the central lagoon
150 million cubic meters of deep seawater pumped to raise the Venice island


Three lagoons Scenario
new amphibious lands
South Lagoon Park
Adriatic
Località Darsena Marina del Sole
Campeggio Oasi
Campeggio Smeraldo
Salt marshes
New morphological structures
Environmental corridors
New aquacultures
main rivers
Embankment
Navigation routes



Three lagoons Scenario
Application of the lagoon division scenario.


Three lagoons Scenario
amphibious city
new amphibious lands
fish valleys
amphibious city
fish valleys
new *barene*
fish valleys
South Lagoon Park
amphibious city
new *barene*


amphibious city
fish valleys
fish valleys
Malamocco-Marghera embankment
Lake of Venice
(Central Lagoon)
new *barene*
new *barene*
Adriatic Sea

Chapter 2

On the lake defences

Venice, year 2100.
The tram that runs on the large embankment along the edge of the lagoon canal and connects the new districts of Marghera with the beaches of the Lido, offers a unique vantage point across the stretches of water that embrace Venice. From one side, towards the east, the view runs over the lake to frame the monuments with the historic islands and, closer and all around, the swarming of boats that have always ploughed the waters around Venice. On the other side, looking west, the gaze is still projected towards a liquid world but slower and denser, lingering on the amphibious landscapes of the large park of the southern lagoon. Dominating this point of view are the stretches of water with the light infrastructures for fish farming that form the backdrop to the daily work of fishermen and the vegetated wetlands that give home to cormorants, ducks, gulls, herons, as well as teals, mallards and a whole human and animal world united by the search for fish and shellfish. The robust strip of land –the Malamocco-Marghera embankment– built to protect Venice divides these two aquatic worlds. The trams are mainly used by the citizens of Mestre and Marghera who make the beaches of the Lido their daily destination for free time and seaside relaxation, but

also by the many tourists who can find cheaper and more comfortable accommodation in Mestre than the limited places now available to stay in the historical islands. The few minutes that today separate the Lido from Mestre have brought the industrious world of the mainland much closer to the beach, its practices, and frivolous rituals.

Construction of the Malamocco-Marghera embankment was slow and did not happen easily. The embankment was consolidated following an incremental process, such as the progressive stratification that leads to the solidification of sedimentary rocks. It took years to convince the islanders to metabolize the trauma of the partition of the lagoon and the construction of the lake, and above all to accept the inevitability of the separation and transformation of the central lagoon.

Already in the early years of the new century, engineer Luigi D'Alpaos, the greatest expert in lagoon hydraulics of the time, although starting from assumptions devoted to safeguarding the lagoon –and therefore to the salvation of the integrity of the stretches of water around Venice which by then enjoyed very bad health– spoke of the necessary construction of 'morphological structures' to be placed along the edges


Lake of Venice
(Central Lagoon)
Alberoni octagon
abandoned octagon
Alberoni waterbus stop
densification area
tram
Alberoni Beach
wetland
pinewood
Lido di Pellestina
new Murazzi
pinewood
dune
Alberoni tram stop
tram and bike lane
new Murazzi
Adriatic Sea

of what was once the *Petroli Canal*. On closer inspection, the artificial *barene* imagined by engineer D'Alpaos have little to do with the current embankment that dominates the liquid plain from its height of 2.5 metres, although looking at them today we can perhaps say that they already represented the first involuntary traces of foundation. The artificial *barene* around the canal were slowly built starting from the Twenties of the 21st century.

The construction site began the day after the entry into operation of the first version of the MoSE and the scandals that led to its construction, to counter the wave motion produced by large ships, when tankers filled with oil and cruise ships loaded with cheering tourists were still passing from the mouth of Malamocco towards Marghera. For years, these tiny sediments around 45 centimetres high, covered with a dense layer of glasswort and halophytic plants, had represented a fundamental safeguard for maintaining the fluid-dynamic equilibrium of the lagoon. They limited the phenomena of resuspension of sediments by wave motion, first responsible for the erosion of the lagoon slums which had already led to a strong flattening of the bathymetry and simplification of the landscapes of the central lagoon.