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

CLIMATE CHANGE EFFECTS IN THE EBRO DELTA. STRATEGIES FOR ADAPTATION

Taller de Ingeniería Ambiental, SL

Oficina Catalana del Canvi Climàtic

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CONTEXT OF THE STUDY

1. Proposed by the Department of Environment and Housing of the Government of Catalonia

Generalitat de Catalunya
Departament de Medi Ambient i Habitatge

Oficina Catalana del Canvi Climàtic

2. Developed by Taller de Ingeniería Ambiental S.L

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3. Collaboration of the Hydraulic Institute of the University of Cantabria

IH cantabria
INSTITUTO DE HIDRÁULICA AMBIENTAL

OBJECTIVES OF THE STUDY

1. Establishment of the **methodological and analytical bases** that can be used subsequently in other vulnerable areas
2. Analysis of the **vulnerability** to climate change
3. Establishment of the zones of **risk** from climate change effects
4. Proposal of the possible climate change adaptation and prevention **measures** for the particular case of the Ebro Delta.

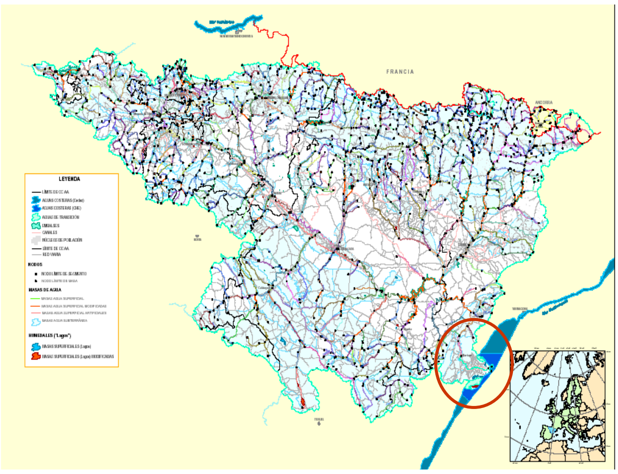
THE EBRO RIVER BASIN

Ebro Basin surface: 85.000 km^2

Involve:
•9 Autonomous communities
•18 Provinces
•1.717 Municipalities

Population:
•3.019.176 habitants
•In 5.423 villages.

Ebro Delta surface: 450 Km^2



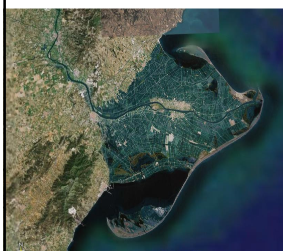
CHARACTERISTICS OF THE EBRO DELTA

Delta's surface:
450 Km²

Costal zone and marine influence in the river:

- **50 Km of river**
- **169 Km of coastline**

CHARACTERISTICS OF THE EBRO DELTA



Environment

- Natural area of international importance (Natural Park, RAMSAR, Natura 2000 Site, etc)
- 40% of its surface is legally protected
- Diversity of Habitats: beaches, marshes, river systems, estuary, bays, salt works, etc.
- Key resting point in bird migration routes in the Western Mediterranean Basin.

CHARACTERISTICS OF THE EBRO DELTA

Economics

- Predominance of rice fields (its interaction with the natural systems is crucial for the Delta's ecological functionality)
- Fishing: favoured by the nutrients carried by the river to the sea
- Fish and shellfish farming
- Tourism: significant growth over the past two decades
- Port Activity
- Growth of urban systems
- Lack of infrastructures and facilities

CHARACTERISTICS OF THE EBRO DELTA

Social

- **Recent human occupation**
- **Last territory in Catalonia to have access to good quality education and health services**
- **Overlap of Administrative jurisdictions, including national, regional, county and local.**
- **Complex network of socio-economic entities and institutions with a significant capacity to take action on the territory.**
- **Opposed economic interests of certain social groups.**
- **Relevantly high level of social conflict tendencies over the past few years.**
- **High sensitivity regarding the ownership of the natural resources, mainly the river water.**

MAIN CURRENT IMPACTS AND PRESSURES

Impacts

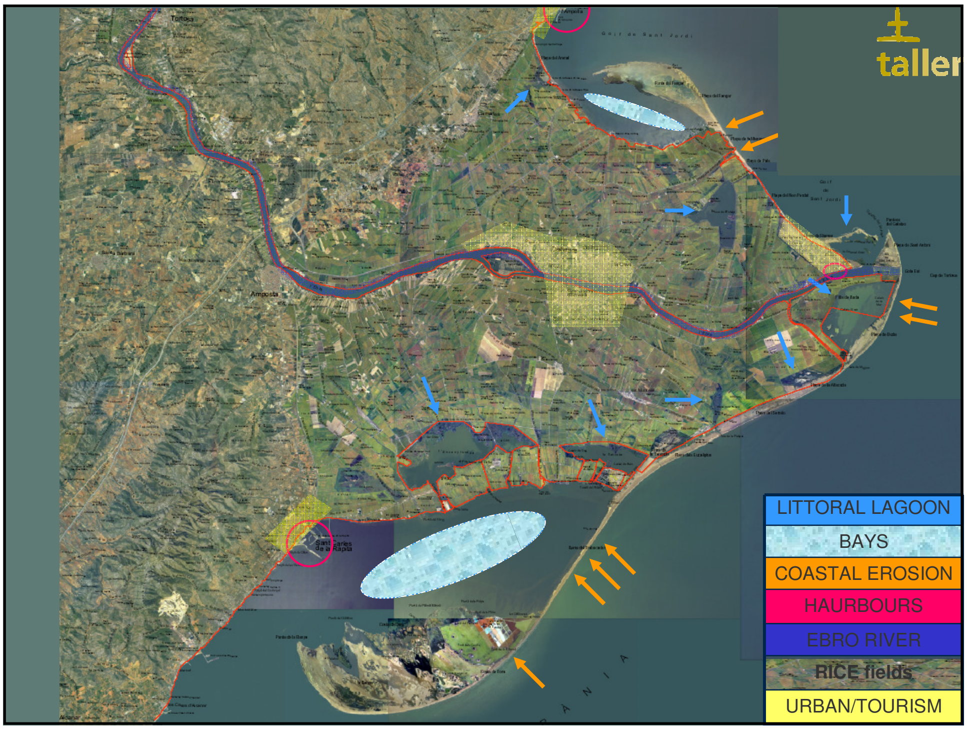
- Coastal erosion and subsidence.
- Eutrophy and loss of ecological potential in saltwater marshes.
- Polluted, eutrophied bays with a high rate of silting.
- Modification of the river flow rate: saline wedge intrusion and loss of water quality.
- Loss of riparian forest and vegetation.
- Reduction and fragmentation of natural areas, habitats and communities.
- Loss in quantity and quality of fishing resources.
- Marine pollution.
- Invasive alien species

Pressures

- Regulation of the Ebro River's water levels.
- Modification of the channel network and influx of water and sediments into the rice fields.
- Excessive use of pesticides and fertilisers.
- Land occupation for urban development.
- Increasing pressure of tourism.
- Deficit of infrastructures and facilities.
- Hydrological management not agreed by all stakeholders

MAIN RISKS

- ❑ Climate Change:
  - Highly sensitive to sea level rise: erosion and subsidence
  - Changes on water and sediment availability could modify environmental and economic structures
- ❑ Loss of Rice Crop Areas (EU's CAP)
  - The whole of the hydraulic system is linked to the rice crops cycle
  - Aquatic ecosystems are highly dependent on rice crops
- ❑ Unplanned and excessive urban growth
- ❑ Risks associated with river dynamics: modification of water flow rates, pollution, riparian degradation
- ❑ Lack of strategic infrastructures planning

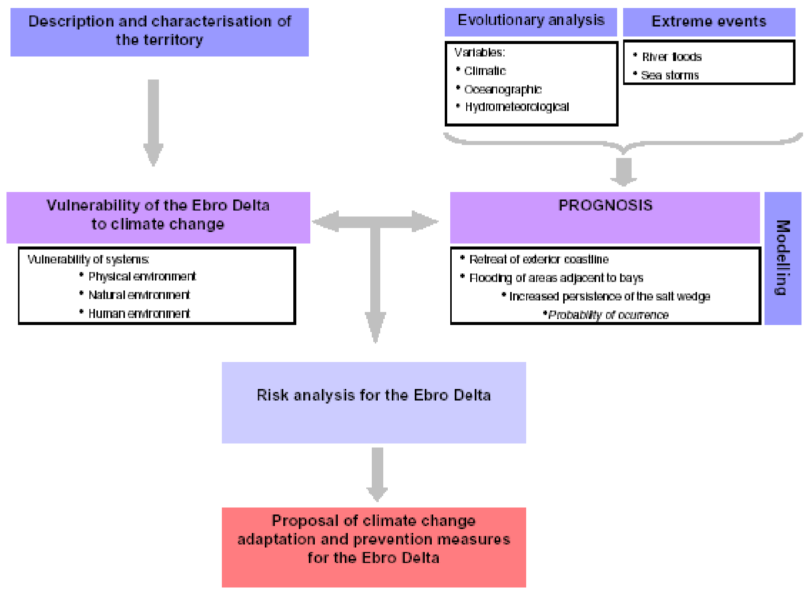


THE MAIN PROBLEM AT THE EBRO DELTA

Coastal erosion:

- It is perceived by the population as alarming
- The most vulnerable areas are flooded lowlands causing the loss of crops
- Process linked to the sedimentary balance and the natural evolution of deltas
- Sea level rise reinforces coastal erosion

METHODOLOGY OF THE STUDY



EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

1. Climatic variables:

- Air temperature
- Sea water temperature
- Precipitation
- Wind
- Evapotranspiration
- Relative humidity

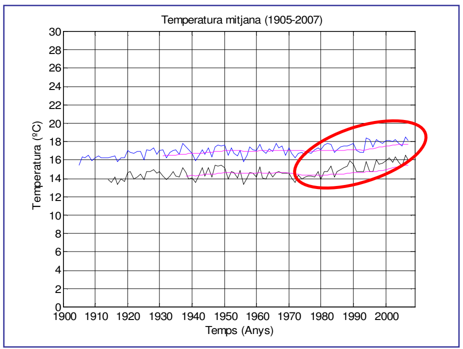
EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

2. Fluvial and maritime climate Variables
   - Fluvial flows
   - Swell
   - Sea wind
   - Meteorological tides
   - Sea level
3. Catalogue of historical episodes
   - Sea storms
   - Fluvial floods
4. Calibrating the models of prediction from the datum of historical extreme events

EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

AIR TEMPERATURE

Datum: Observatory of Ebro (1905-2007), Observatory Fabra (1914-2008)



In the Ebro:

The **average increase** of temperature between the beginning and the end of the temporary series is **1,14ºC**, which corresponds to an **increase of 0,12ºC per decade**

The average increase of temperature between **1980 and 2007** (upward period) is 0,76ºC, which corresponds to an **increase of 0,28ºC per decade**

EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

SEA WATER TEMPERATURE

Datum: l'Estartit (1969/1973-2006), Cape of Tortosa (1990-2007, non complete at the central years)

L'Estartit

The increase of temperature between **1973-2006 is 0,45 ºC**, that supposes an increase of **0,14ºC per decade** and the increase of temperature between **1973- 2006 is 1,17ºC**, which corresponds to an increase of **0,35ºC per decade**

Cap Tortosa

The increase of temperature between the average value of the four last years of the series (2003-2007) and the first four years (1990-1994) is 0,86 ºC, that corresponds to an **increase of 0,51ºC per decade** along period **1990-2007**

Highest increases of temperature recorded at Cap Tortosa correspond to autumn months, while at l'Estartit they correspond to summer months

EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

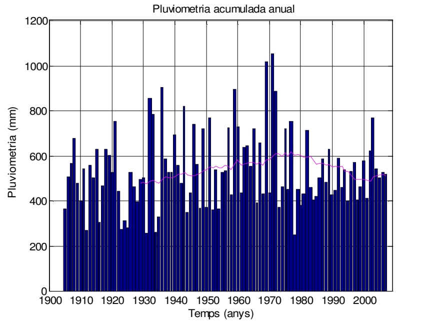
PRECIPITATION

Datum: Observatory of Ebro (1905-2007), stations of Els Alfacs, Amposta and El Fangar(1992-2008)

Datum of Observatory of Ebro

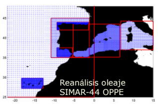
The increase of the annual accumulated precipitation along 1905-2007 is due to the increases of the precipitation in winter and autumn, while the precipitation in summer and spring is reduced

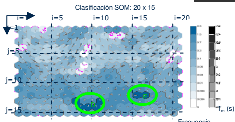
The trends are statistically not significant, neither the linear adjustments are good, due to the highly variable nature of the precipitation in Mediterranean bioclimatic regions

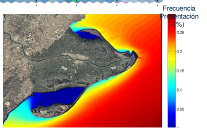


MARITIME CLIMATE VARIABLES

SWELL AND TIDES ANALYSIS





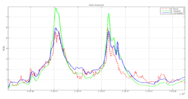


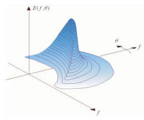
Historic and numeric data bases

Calibration

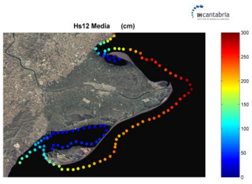
Classification

Propagation



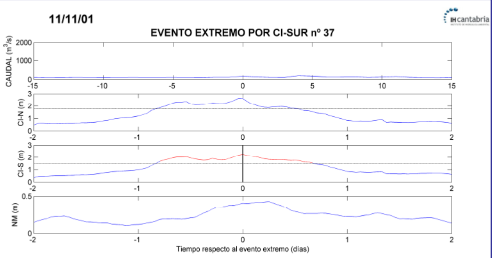


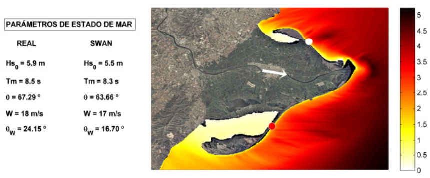
Reconstruction of temporal series in the Ebro's Delta



EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

CALIBRATING THE MODEL





EL PAÍS, lunes 12 de noviembre de 2001 — ESPAÑA / 31

Pujol suspende su visita a Tortosa por las protestas contra el trasvase del Ebro

Los vientos, nieves y lluvias remiten tras un fin de semana de destrozos, atascos y apagones

El temporal se cobra su sexta víctima mortal y arrasa multitud de playas del Mediterráneo

CATALOGUE OF EPISODES

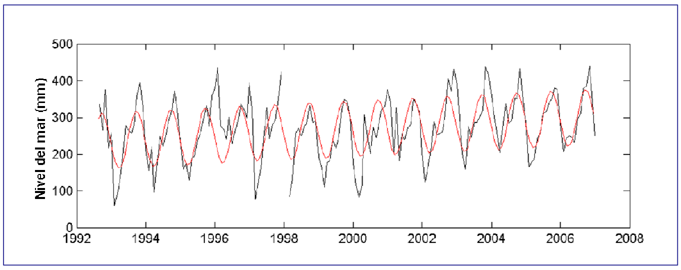
- FLOODS
- SEA STORMS
- BREAKING OF SPIT BARS

They have been used for calibrating the model of prediction

EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

SEA LEVEL

Sea level series for the Barcelona tide gauge



The analyses made of the sea level variable indicate an **increase of 4.5 mm/year** for the **period 1992-2007** and a significant correlation with the Scandinavian pattern (SCA index).

EVOLUTIONARY ANALYSIS OF CLIMATIC VARIABLES AND EXTREME EVENTS

CLIMATE MARINE VARIABLES

- Extreme Swell Hs (T=100 years) = 5.5 m exterior/ 0.5 m interior
- There is a link between climate patterns and the magnitude and structures of swell
- The analysis of long-term trends affecting th e size of wave height indicates very small changes. A slight positive trend has been detected ti the south of the river mouth together with a slight decrease to the north which is only visible during the winter season and only affects the average regime
- The study of persistency of wave heights of 1m shows a long-term positive trend in swells in the northeast and a negative trend in the southeast

CHARACTERIZATION OF THE EBRO DELTA: VULNERABILITY

The Ebro Delta is vulnerable to the climate change effects mainly due to:

- Extremely simple relief of the delta's surface, with heights near to the sea level
- Subsidence of its terrains and reduction in of transported sediments by the Ebro river.
- Presence of urbanized zones in coastal areas.
- High needs of water to sustain the rice crops
- Nature zone of international importance: habitats and species protected in vulnerable zones

CHARACTERIZATION OF THE EBRO DELTA : FACING CLIMATE CHANGE

The Ebro Delta shows some characteristics that allow to face the climate change effects:

- The surface of the Delta plain is extensive enough to allow the adaptation to the phenomena produced by climate change.
- The coastline is little urbanized and little modified. This allows a great capacity of remodelling the beaches that operate as barriers against sea level rise
- The main urban centres are located on the highest areas of the delta near the fluvial margins and therefore far from the zones of risk.
- The diversity of environments of the delta can favour a better possibility of conservation of its natural values

PROGNOSIS: PREDICTION FOR 3 SCENARIOS

In order to evaluate the expected impacts on the Ebro Delta the study carries out a prognosis of the trends and predictions of evolution of:

- The exterior coastline of the Delta
- The coastline of the bays
- The presence and persistence of salt wedge

The prognosis is carried out for 3 different scenarios:

- Scenario A1B of the IPCC (average scenario) by the year 2050: a rise of 15 cm in sea level
- Stage A1B of the IPCC (average scenario) by the year 2100: a rise of 40 cm in sea level
- Scenario considered pessimistic (in the long term) by the year 2100: a rise of 100 cm in sea level

PROGNOSIS: The exterior coastline of the Delta

CONCLUSIONS:

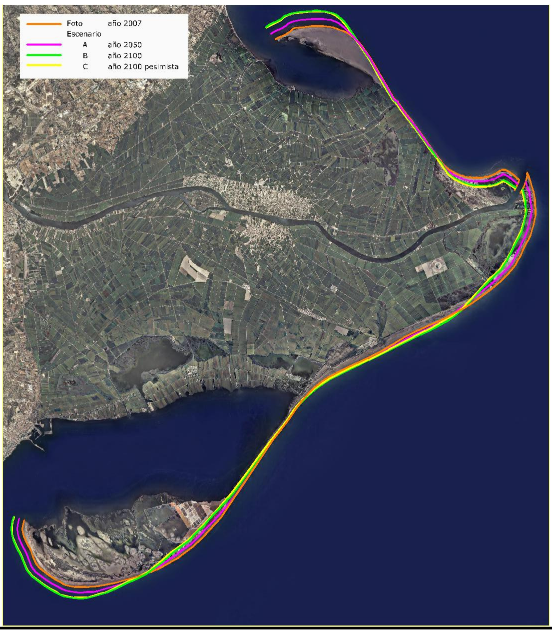
1. **Two main agents are linked to the backward movement or advance of the coastline in the Ebro Delta: the oblique incidence of the waves and the sea level rise.**
2. **Waves are the main cause of the longitudinal transport of sediments and also the sediment redistribution that changes the morphology of the delta. This phenomenon is the main responsible of the predictable changes of the coastline in the delta.**

PROGNOSIS: The exterior coastline of the Delta

CONCLUSIONS:

3. **The phenomenon most linked to the climate change is the retreat of the coastline associated with the rise in average sea level.**
4. **In short the trend of the delta is to become eroded in its central part (Cap Tortosa) and to grow up in the two lateral lobules (The Fangar Peninsula and Punta de la Banya), while the intermediate zones work as zones of sediments transition**

PROGNOSIS: The exterior coastline of the Delta



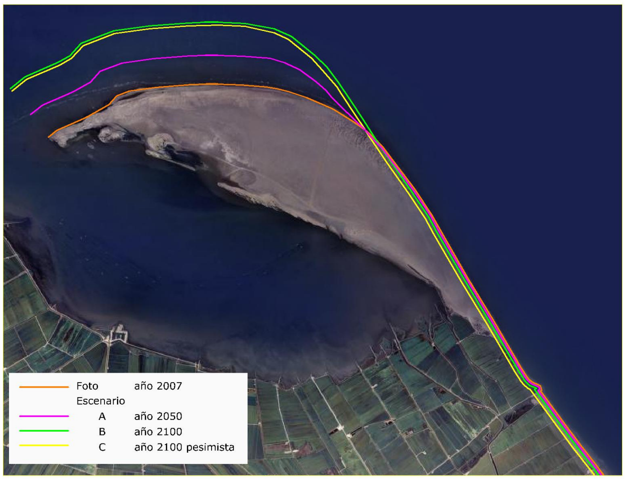
Scenario A:
- Year: 2.050
- Rise: 15 cm S.L:.

Scenario B:
- Year: 2.100
- Rise: 40 cm S.L.

Scenario C:
- Year: 2.100
- Rise: 100 cm S.L..

Reference:
- Photo 2007

PROGNOSIS: The exterior coastline of the Delta



Fangar Peninsula and la Marquesa Beach

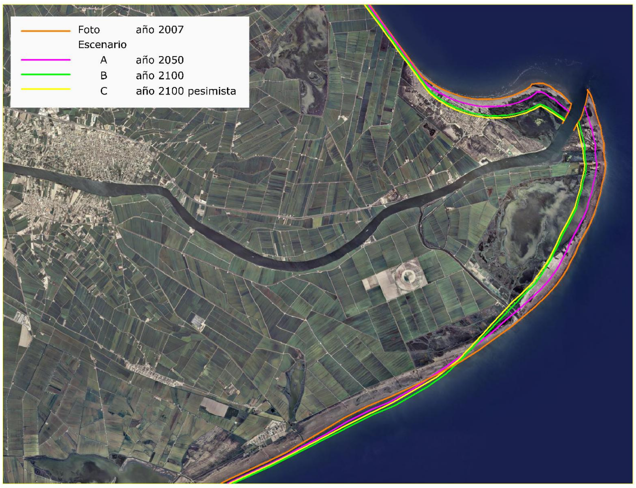
Scenario A:
- Year: 2.050
- Rise: 15 cm S.L:.

Scenario B:
- Year: 2.100
- Rise: 40 cm S.L.

Scenario C:
- Year: 2.100
- Rise: 100 cm S.L..

Reference:
- Photo 2007

PROGNOSIS: The exterior coastline of the Delta



Riumar Beach and Tortosa Cape.

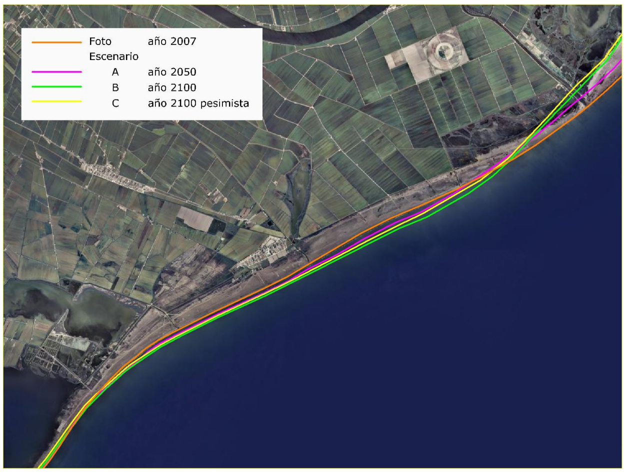
Scenario A:
- Year: 2.050
- Rise: 15 cm S.L:.

Scenario B:
- Year: 2.100
- Rise: 40 cm S.L.

Scenario C:
- Year: 2.100
- Rise: 100 cm S.L..

Reference:
- Photo 2007

PROGNOSIS: The exterior coastline of the Delta



Beaches of Eucaliptus, Migjorn and Serrallo.

Scenario A:
- Year: 2.050
- Rise: 15 cm S.L:.

Scenario B:
- Year: 2.100
- Rise: 40 cm S.L.

Scenario C:
- Year: 2.100
- Rise: 100 cm S.L..

Reference:
- Photo 2007

PROGNOSIS: The exterior coastline of the Delta

Trabucador Beach

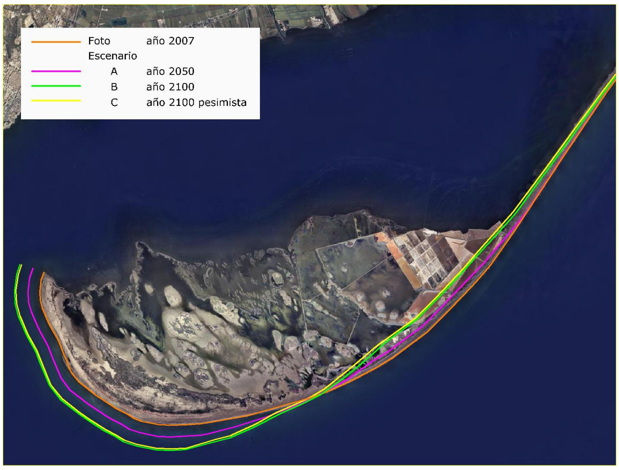
Scenario A:
- Year: 2.050
- Rise: 15 cm S.L:.

Scenario B:
- Year: 2.100
- Rise: 40 cm S.L.

Scenario C:
- Year: 2.100
- Rise: 100 cm S.L..

Reference:
- Photo 2007

PROGNOSIS: The exterior coastline of the Delta



La Trinitat Salt works and Punta de la Banya.

Scenario A:
- Year: 2.050
- Rise: 15 cm S.L:.

Scenario B:
- Year: 2.100
- Rise: 40 cm S.L.

Scenario C:
- Year: 2.100
- Rise: 100 cm S.L..

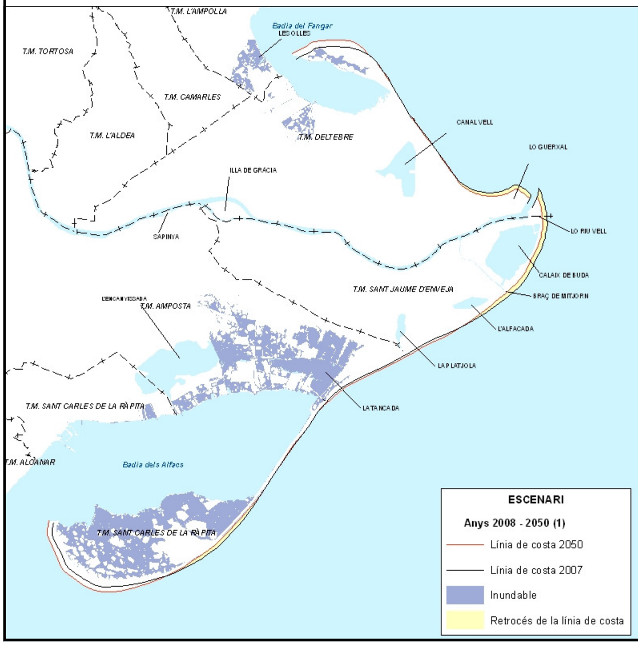
Reference:
- Photo 2007

PROGNOSIS: coastline of Delta's bays

CONCLUSIONS:

- **The sea level rise in the inner zone of the bays, where there is not any beach protection provokes a direct flood of the adjacent terrains.**
- **The results shown only indicate trends for different scenarios of sea level rise, due to the inaccuracy of the current available topographic data.**
- **The zones detected that offer the easiest point of entry for seawater are inlets and pumping stations .**
- **There is a lack of detailed and suitable cartography to carry out analysis with better spatial accuracy.**

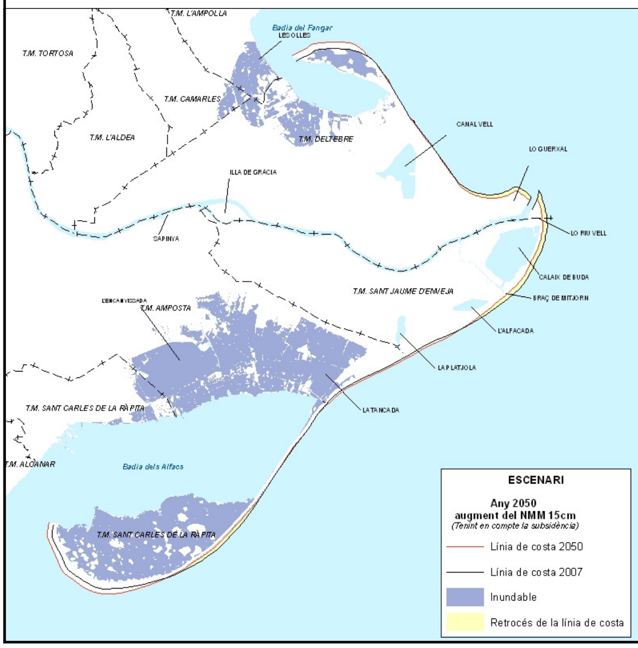
PROGNOSIS: coastline of Delta's bays



Prognosis of the floodable zones before year 2050, with heights under 15 cm of rise in sea level average

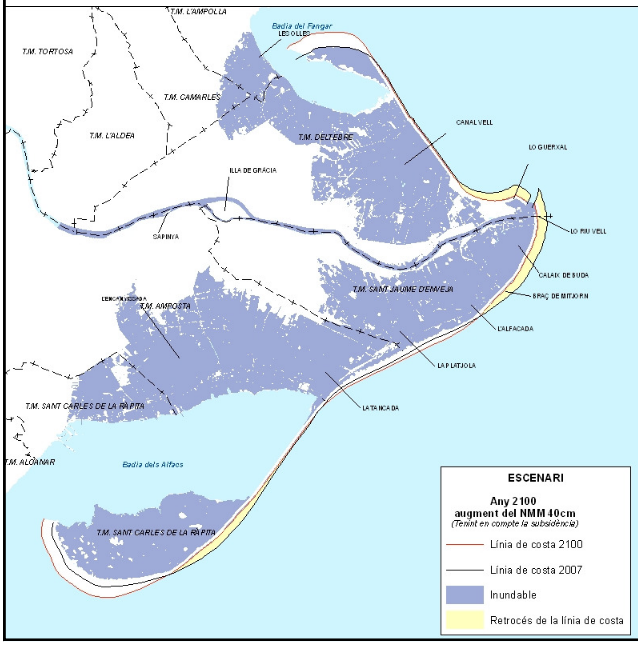
It is observed where sea water starts flooding (zones between heights of 0 to +15 cm)

PROGNOSIS: coastline of Delta's bays



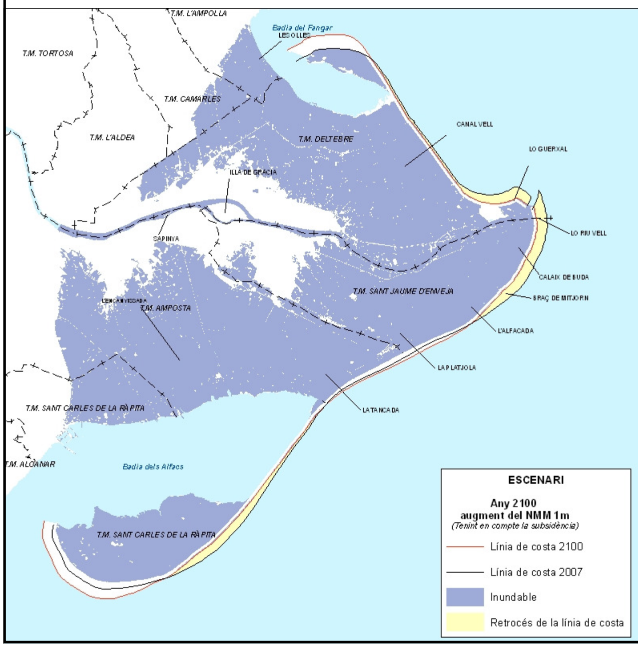
Prognosis of the floodable zones before year 2050 considering a rise of 15 cm on the sea level average and a subsidence of 0,2 cm/year

PROGNOSIS: coastline of Delta's bays



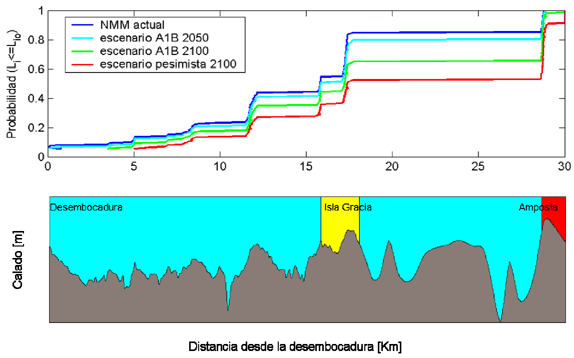
Prognosis of the floodable zones before year 2100 considering a rise of 40 cm on the sea level average and a subsidence of 0,2 cm/year

PROGNOSIS: coastline of Delta's bays



Prognosis of the floodable zones before year 2100 considering a rise of 100 cm on the sea level average and a subsidence of 0,2 cm/year

PROGNOSIS: presence and persistence of the salt wedge

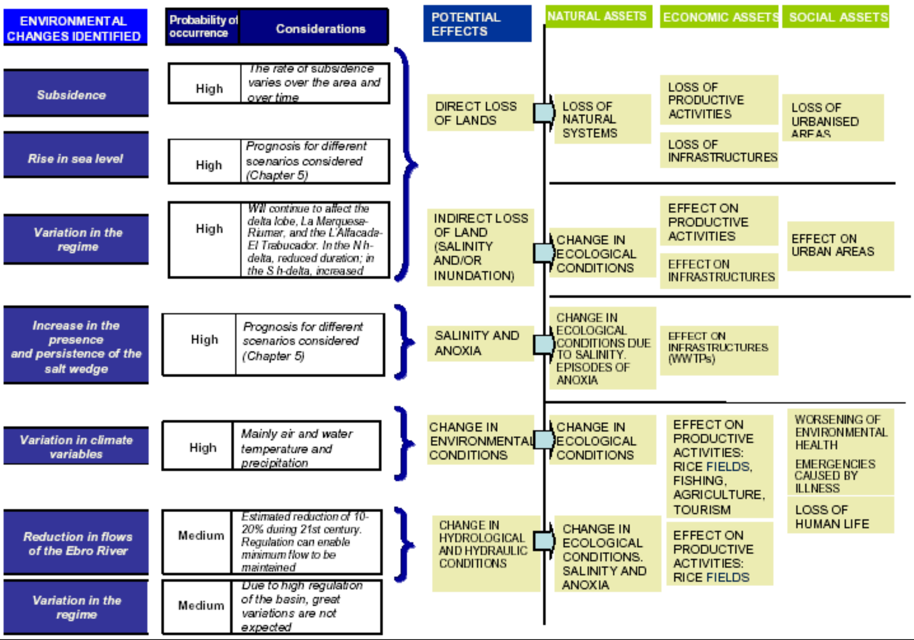


- The rise in average sea level encourages the existence of the salt wedge over a greater area and for a longer period of time.
- The wedge currently reaches Gracia Island 20% of the time; in scenario A1B (40 cm) for 2100 this would be the case 40% of the time.
- The worst-case scenario anticipates that the salt wedge would be present in this zone 50% of the time.

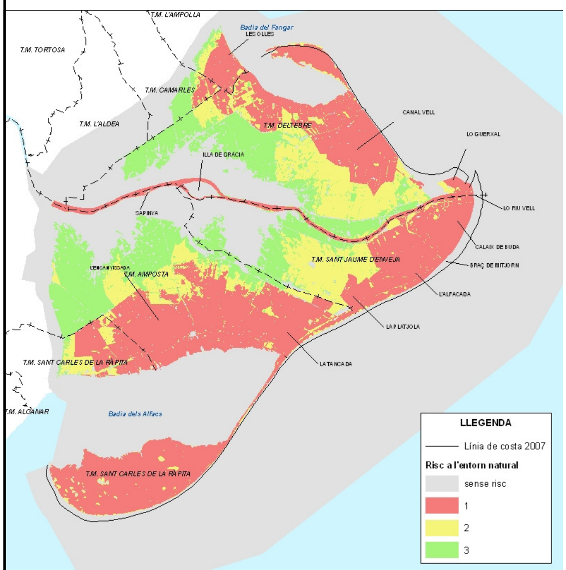
RISK ANALYSIS

Area	*Foreseen risks on a 50-year horizon*	*Foreseen risks on a 100-year horizon*
La Marquesa Beach-Nen Perdut area	Reduction and retreat of the beach	Reduction of the beach. Indirect effects on the delta plain from the bays
Riumar area	Effect on urbanised area due to the rise in sea level	Increase of the effect. Indirect effects on the delta plain from the bays
El Garxal – Sant Antoni Island – Buda Island- L'Alfacada	Reduction of natural areas	Increase of the effect. Indirect effects on the delta plain from the bays
La Platjola – Els Eucaliptus	No effect is foreseen	Indirect effects on the delta plain from the bays (effect on the urbanised area)
Le Punta del Fangar and La Punta de la Banya and El Trabucador bar	Evolution of the systems according to the coastal dynamic. The interior of La Punta de la Banya and La Punta del Fangar is reduced, while at the same time these spits lengthen.	Continuation of processes of change in the coastline. The spits may lengthen more and the internal parts will flood more but will not disappear
Northern hemi-delta	Flooding of the hemi-delta firstly from the Les Olles inlets and the El Port de L'Illa pumping station and later from other low points.	Flooding from the rest of the hemi-delta towards the spit with different probabilities depending on the scenario.
Southern hemi-delta	Flooding of the southern hemi-delta firstly from the inlets. Risk to the village of El Poblenou del Delta.	Flooding from the rest of the hemi-delta towards the spit with different probabilities depending on the scenario.

RISK ANALYSIS



RISK ANALYSIS: NATURAL ASSETS

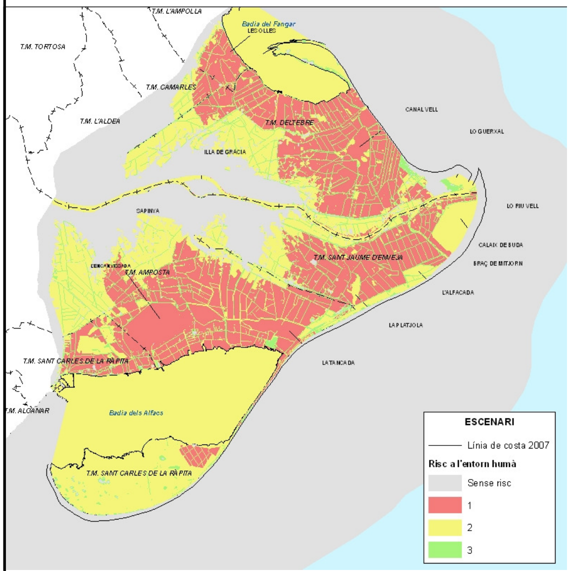


LOSS OF NATURAL SYSTEMS

RISk 1: the **coastal lagoons** (Les Olles, El Canal Vell, El Garxal, El Calaix de Buda, L'Alfacada, La Platjola, La Tancada, L'Encanyissada), **other wetland areas** (Sant Antoni Island, Buda Island and the Migjorn River), **the beaches, the dune systems, the halophyte systems** (including the uninhabited areas of La Tancada, Casablanca and Vilacoto and the old Sant Antoni **salt works**), and **rice field areas**. It should be noted that all of the natural systems located on the delta lobe and the El Fangar and La Banya spits have a risk level of 1.

Risks 2 and 3 apply to the banks of the Ebro River at the lowest stretch, the associated marshes and springs and the rice field areas.

RISK ANALYSIS; ECONOMIC ASSETS

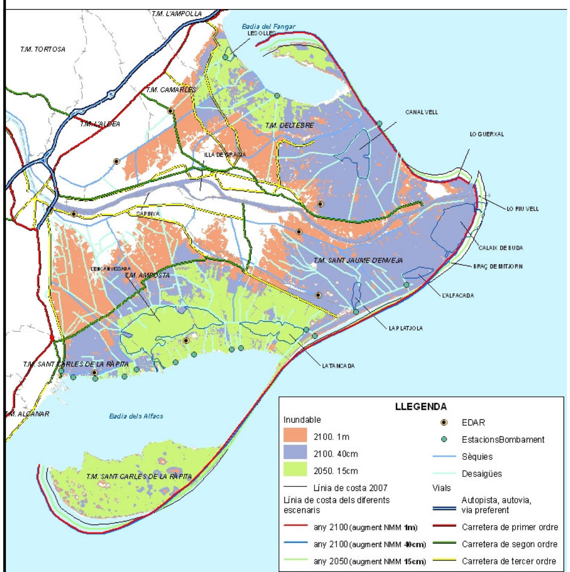


MAP OF RISK TO PRODUCTIVE ACTIVITIES DUE TO:

- Sea level rise
- Salinisation and/or inundation
- Changes in climate conditions

RISK 1: productive activities such as rice crops, inland fishing and salt works of la Trinitat

RISK ANALYSIS: INFRASTRUCTURES



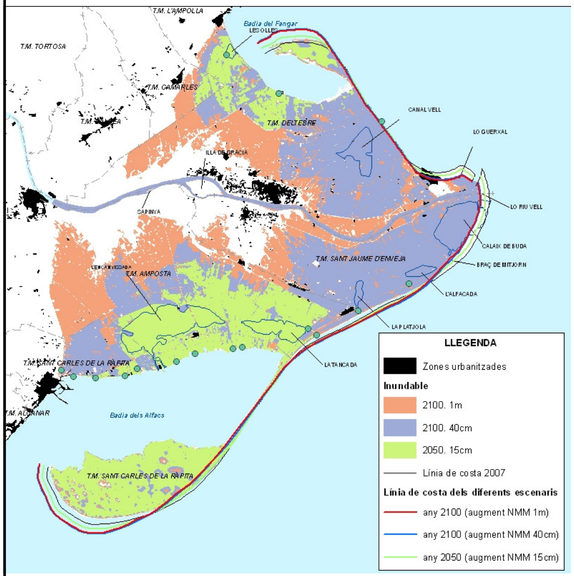
MAP OF RISK TO INFRAESTRUCTURES DUE TO:

- Sea level rise

There is a risk of effects to different types of infrastructure: roads, wastewater treatment facilities (WWTPs, collectors and outfalls) and hydraulic infrastructures.

Other affected infrastructures are roads and ports

RISK ANALYSIS: URBAN ZONES



The following population centres in the Ebro Delta are at risk:

Riumar. At risk due to changes in the coastline, which are already present in the scenario projected for 2050 and which will increase towards the end of the century.

El Poblenou del Delta. There is a high risk to this centre in the scenario projected for 2050 due to the rise in the sea level in Els Alfacs Bay.

Els Muntells. At risk in the worst-case scenario: considering the horizon year of 2100 and a rise in sea level of 1 m.

Els Eucaliptus. In the coastal area of Els Eucaliptus there is no risk, since the forecast is for growth of the coastline. However, flooding from Els Alfacs Bay could affect the area between 2050 and 2100.

RISK ANALYSIS: URBAN ZONES
RIUMAR

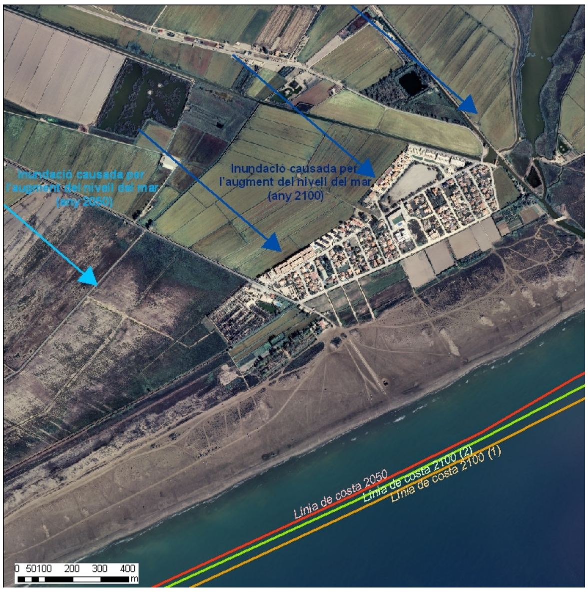
Enlarged image of the coastlines at Riumar::

Scenario AB1 – 2050 (15 cm S.L.)

Scenario AB1 – 2100 (40 cm S.L.)

Worst-case scenario – 2100 (100 cm S.L.)

RISK ANALYSIS: URBAN ZONES
EUCALIPTUS



Enlarged image of the situation for Els Eucaliptus:

Scenario AB1 – 2050 (15 cm S.L.)
Scenario AB1 – 2100 (40 cm S.L.)
Worst-case scenario – 2100 (100 cm S.L.)

FLOODING RISK FROM BAYS

DESIGN OF ADAPTATION AND PREVENTION MEASURES

APPLYING THE PRECAUTIONARY PRINCIPLE

Broad lines of adaptation measures:

1. Managing, planning and regulatory measures
2. Public information and awareness-rising measures
3. Data collection and implementation of studies
4. Direct intervention measures:
   - Measures of planned backward step
   - Measures of protection and prevention
   - Measures of adaptation

→

OBJECTIVES

1. Improve the measurement, data collection and information processing systems.
2. Reduce vulnerability and the risk to people.
3. Adapt economic activities and protect economic assets that are potentially affected.
4. Protect and restore the integrity of environmental systems under threat.

DESIGN OF ADAPTATION AND PREVENTION MEASURES

- A set of potential measures indicating their advantages and inconveniences are proposed
- Often it is necessary a broaden knowledge and datum
- A process of reflection and debate is opened

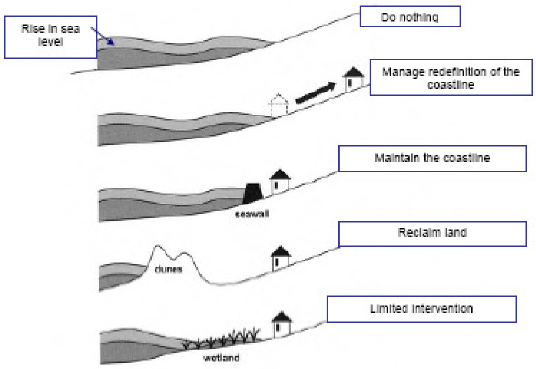
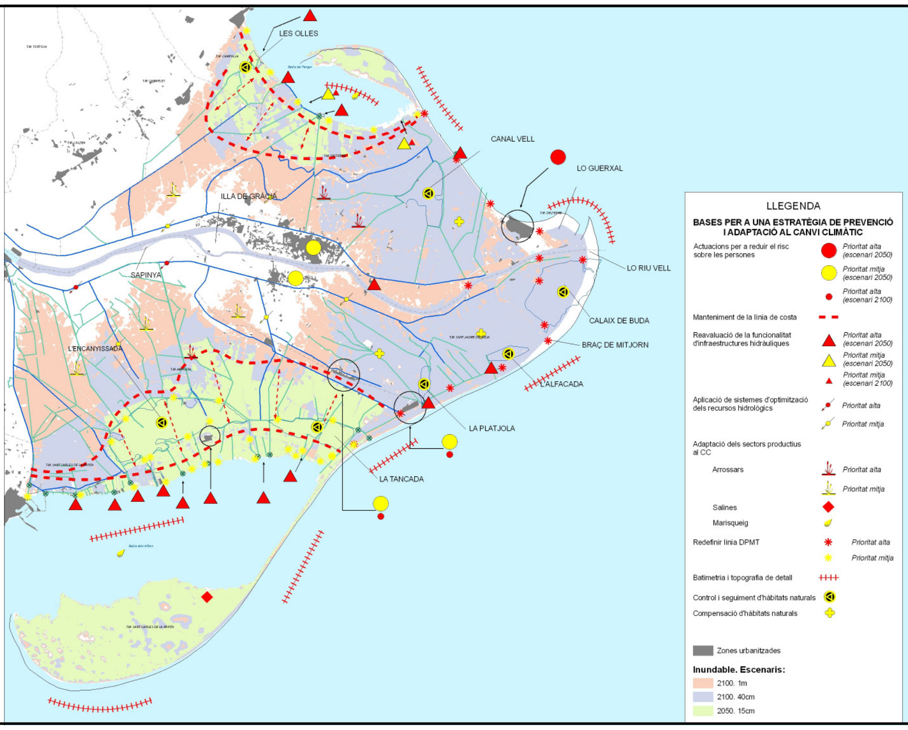


Figure 8.1.1. Generic coastline management policies, according to the definition of the UK Department for Environment, Food and Rural Affairs (DEFRA)

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