Jean-Paul Ducrotoy
Loïc Guézénec

Tidal River Development

Project part-financed by the European Union (European Regional Development Fund)

The Interreg IVB North Sea Region Programme

Managing tidal estuaries in a quickly changing world: our shared responsibility

THE UNIVERSITY OF HULL
Institute of Estuarine & Coastal Studies (IECS)

TIDE – Final conference – Hamburg 25 April 2013

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1. INTRODUCTION

*Introducing the **Seine estuary***

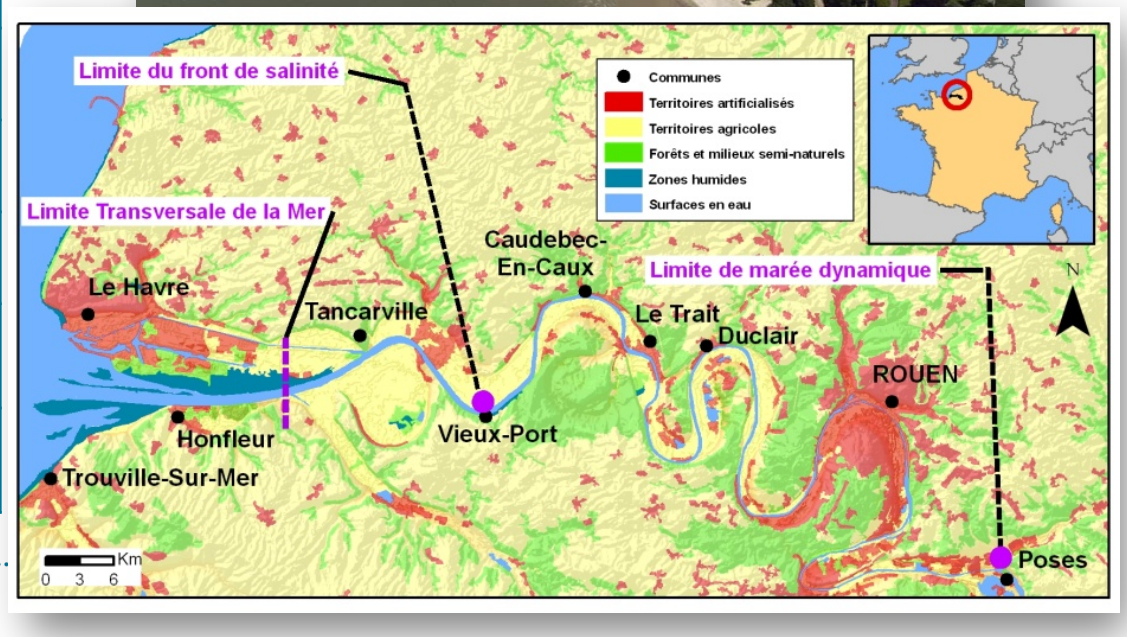
*The **GIP*** *Groupement d'Intérêt Public*

Group in the Interest of the Public

The Seine estuary

Tidal River Development

	Seine
Water catchment area (km^2)	**79 000**
Estuary area (km^2)	**50**
Tidal intrusion (km from sea)	**160** (limited by a dam)
Maximal tidal range (m)	**8**
Mean freshwater discharge ($m^3.s^{-1}$)	**480**
Highest freshwater discharge ($m^3.s^{-1}$)	**2200**
Lowest freshwater discharge ($m^3.s^{-1}$)	**100**
TMZ (t)	**20 000 to 400 000**
Mean water residence time (day)	**25-30**



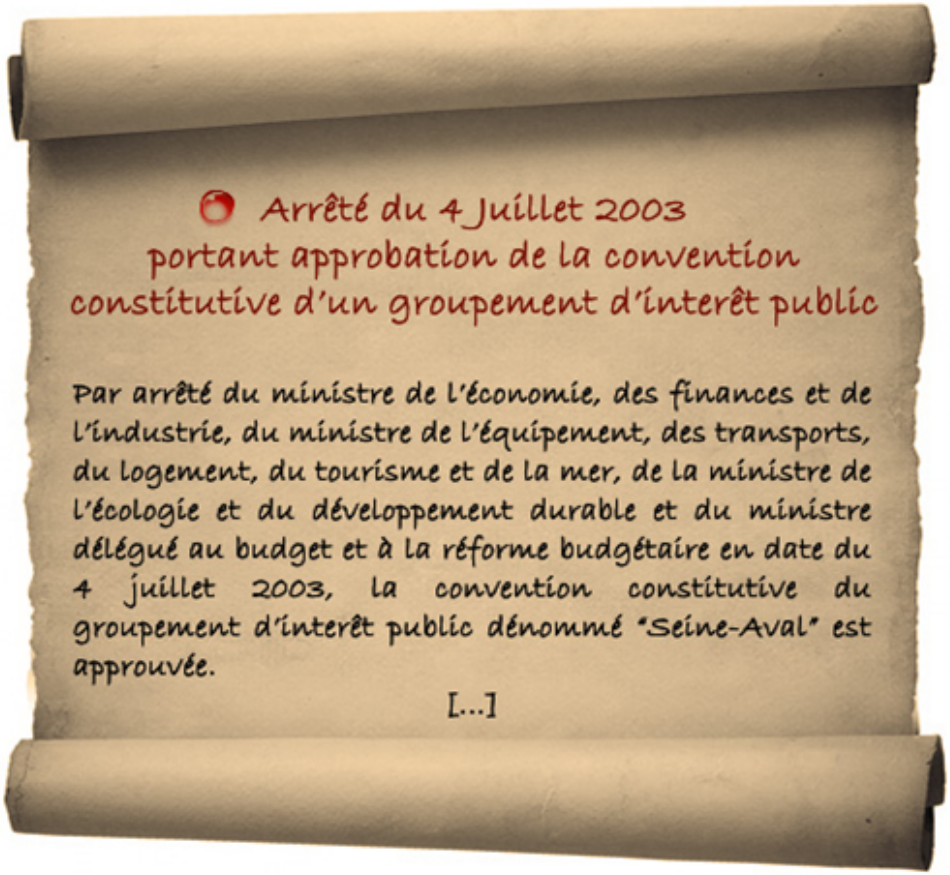
What is the GIP Seine Aval ?

Tidal River Development

1. An applied research programme : a scientific component

   Established in 1995 as a research programme and in 2003 as a GIP

1. A tool for decision making with an operational component
   - Dissemination to the scientific community, the estuary's stakeholders and the public
   - Use of the available scientific information to the benefit of decision makers and managers of the estuary



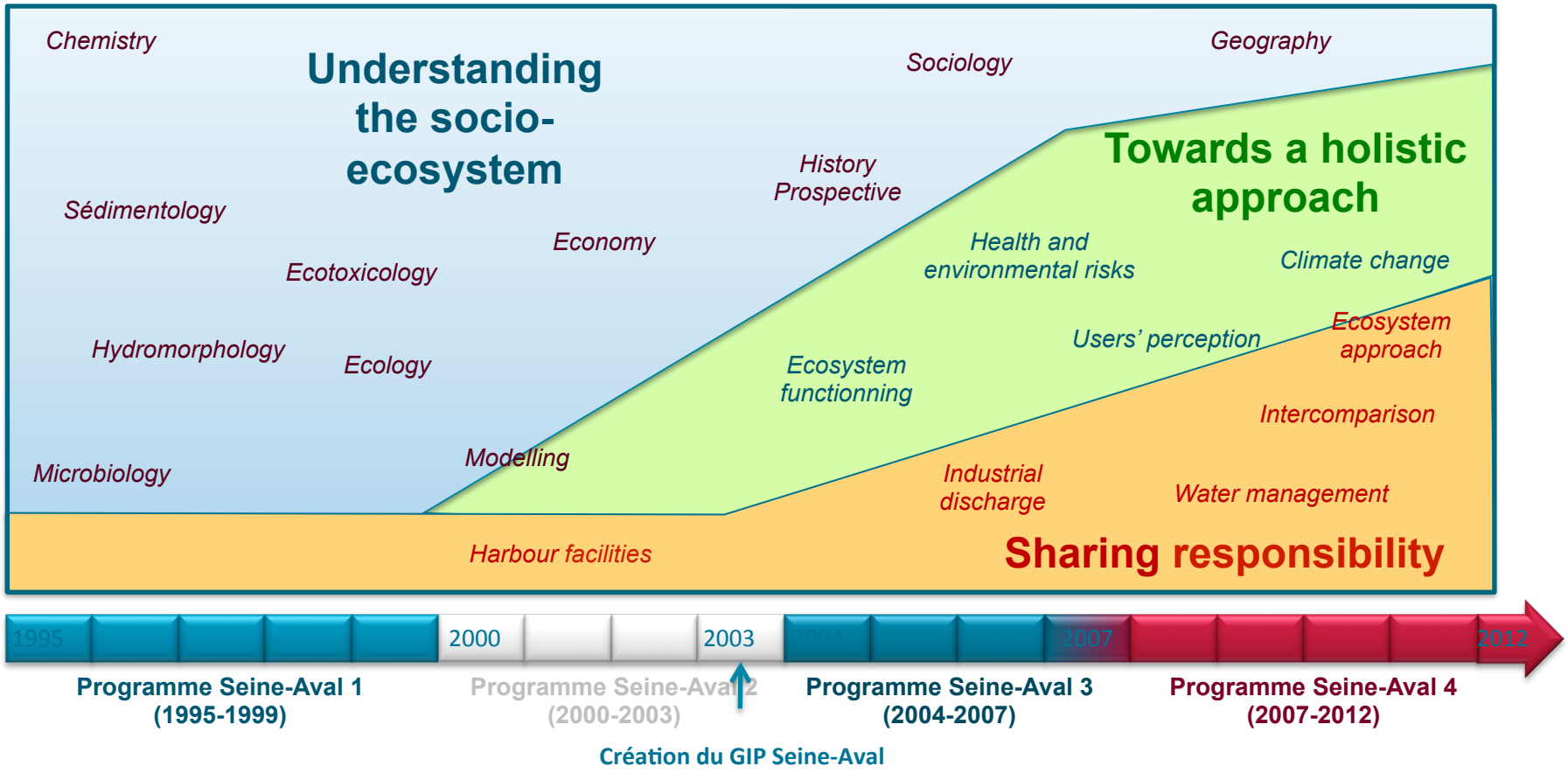
Arrêté du 4 Juillet 2003
portant approbation de la convention constitutive d'un groupement d'interêt public

Par arrêté du ministre de l'économie, des finances et de l'industrie, du ministre de l'équipement, des transports, du logement, du tourisme et de la mer, de la ministre de l'écologie et du développement durable et du ministre délégué au budget et à la réforme budgétaire en date du 4 juillet 2003, la convention constitutive du groupement d'interêt public dénommé "Seine-Aval" est approuvée.

[...]

Disciplines involved

Tidal River Development



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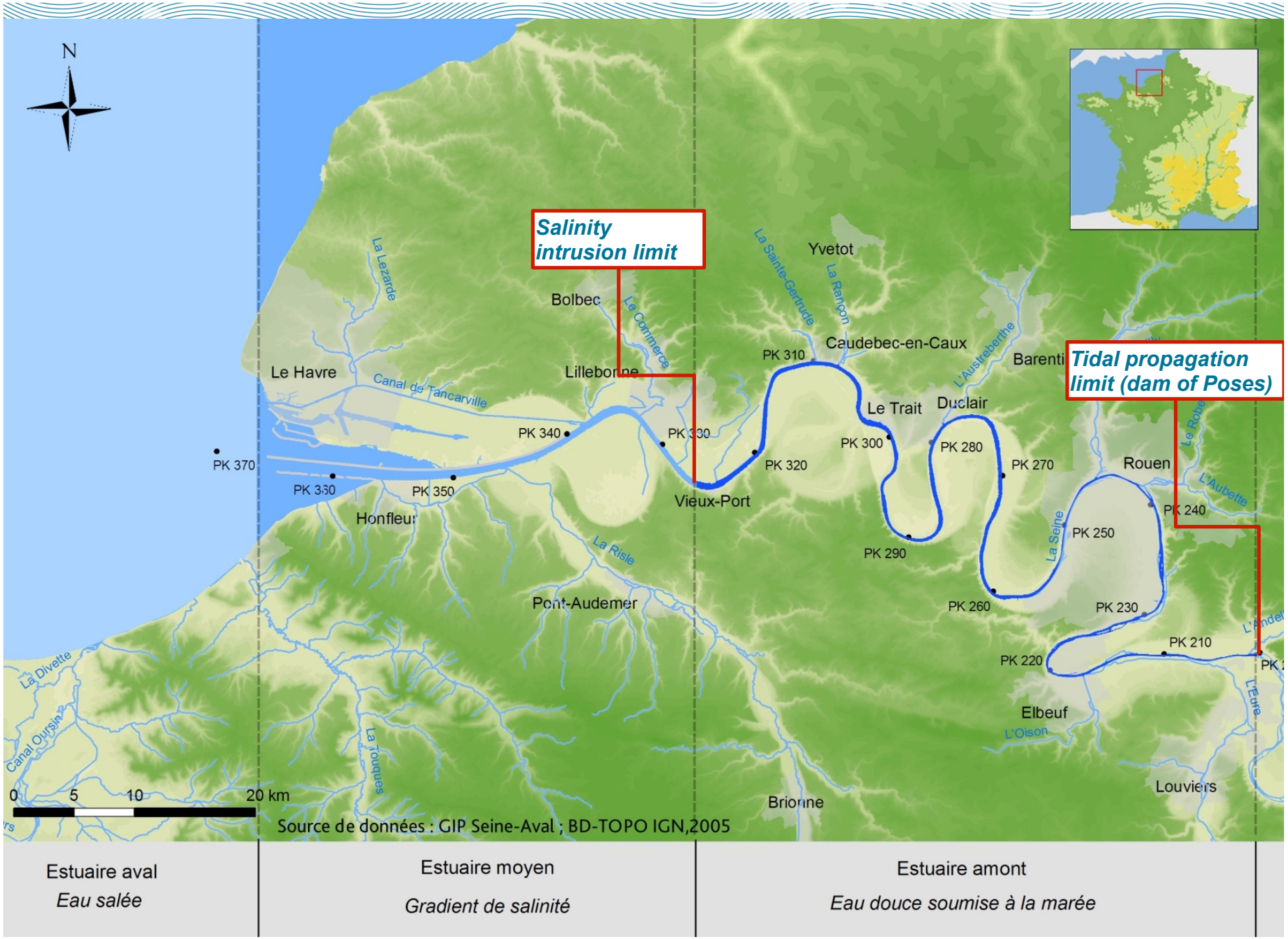
2. Ecosystem Functionning

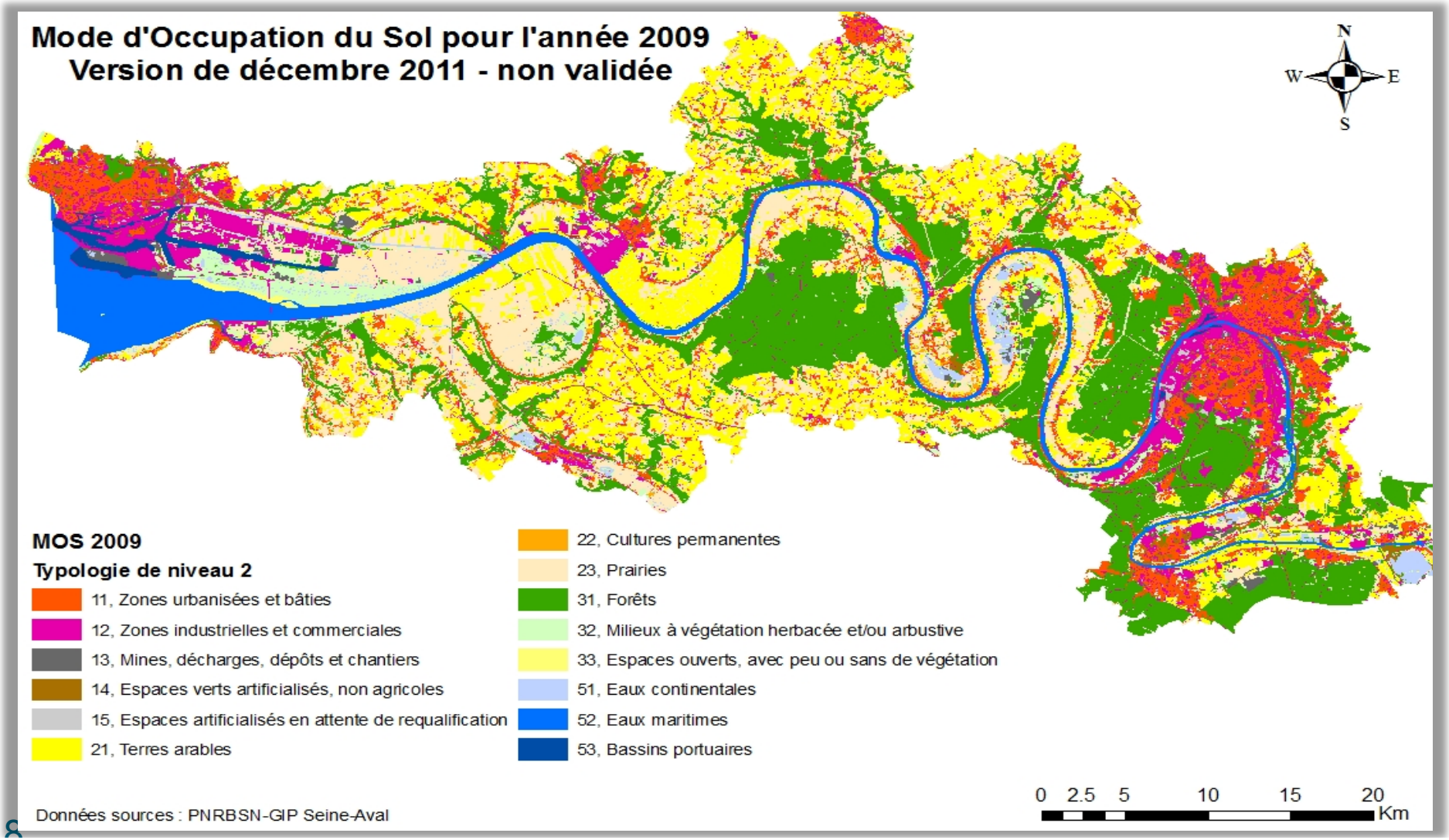
Zonation schemes
Historical development of estuary
Climate change
Carrying capacity and management for habitats and birds
Ecosystem Services
Interestuarine comparison


N
Salinity intrusion limit
Tidal propagation limit (dam of Poses)
Yvetot
Bolbec
Caudebec-en-Caux
Le Havre
Lillebonne
Barenti
Le Trait
Duclair
Rouen
Honfleur
Vieux-Port
Pont-Audemer
Elbeuf
Louviers
Brionne
PK 370
PK 360
PK 350
PK 340
PK 330
PK 320
PK 310
PK 300
PK 290
PK 280
PK 270
PK 260
PK 250
PK 240
PK 230
PK 220
PK 210
La Lezarde
Le Commerce
La Sainte-Gertrude
La Rançon
L'Austrebertne
Canal de Tancarville
Le Robec
L'Aubette
La Seine
La Risle
La Divette
Canal Oursin
La Touques
L'Oison
L'Eure
0 5 10 20 km
Source de données : GIP Seine-Aval ; BD-TOPO IGN,2005
Estuaire aval
Eau salée
Estuaire moyen
Gradient de salinité
Estuaire amont
Eau douce soumise à la marée

Land use mapping

Tidal River Development

- 3 dates:1973, 2000 et 2009
- photo-interpretation.



Tidal River Development

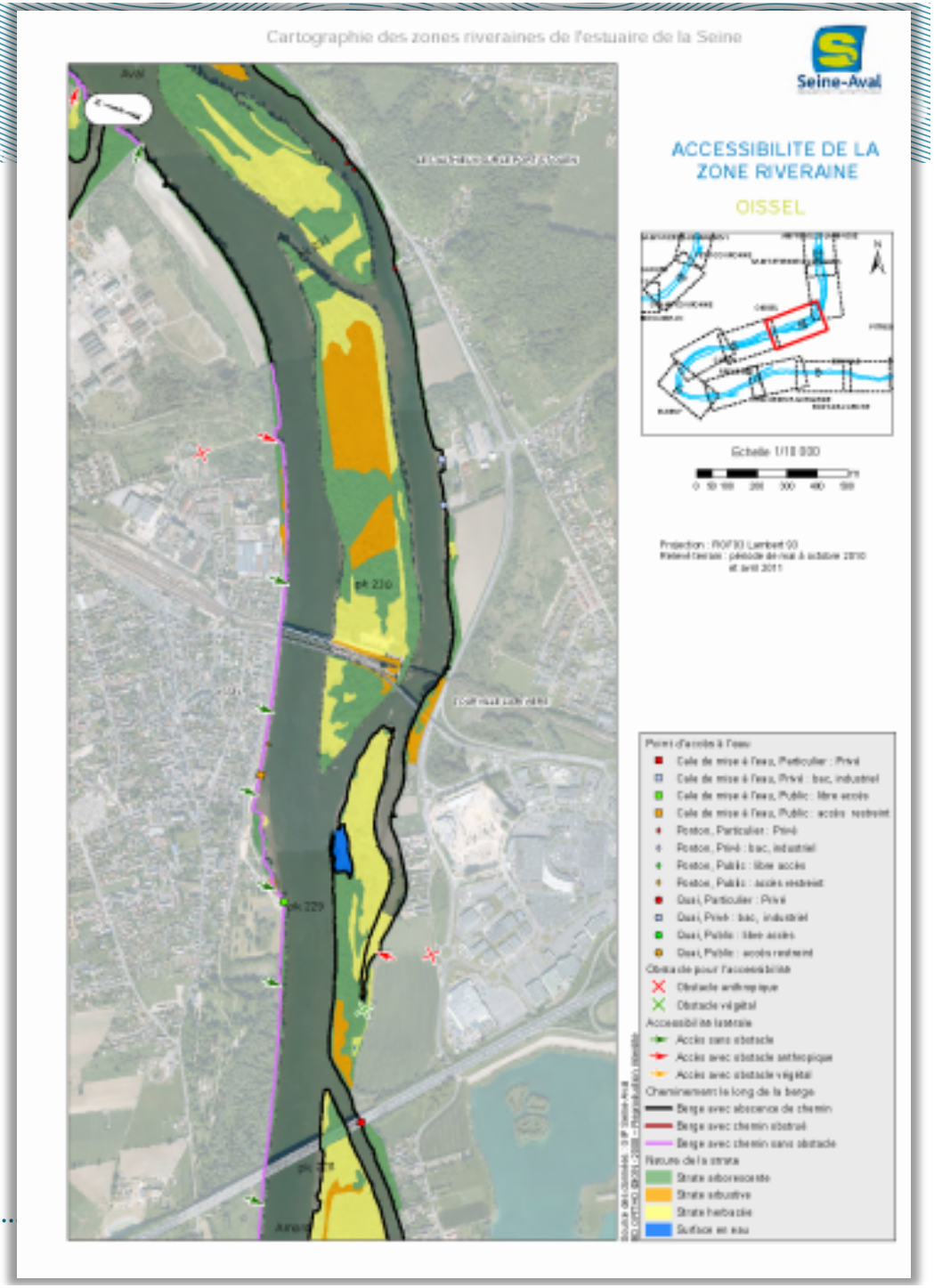
Mapping :

- Banks quality
- Sedimentary substrates
- Intertidal areas
- Vegetation
- Damming and blockades
- Hydraulic connections

Applications diverses

- Blue and green grids
- Banks maintenance
- Fish habitats…

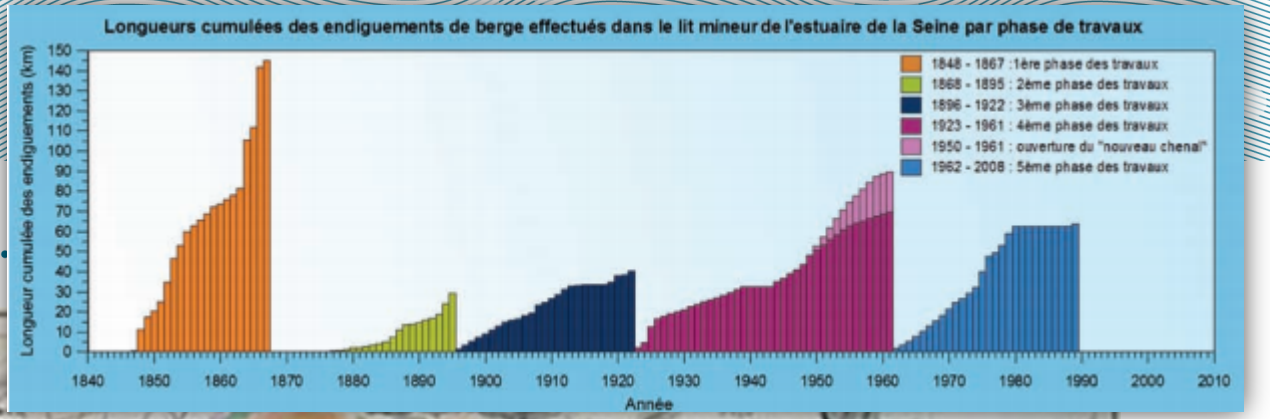
Accessibility to the river

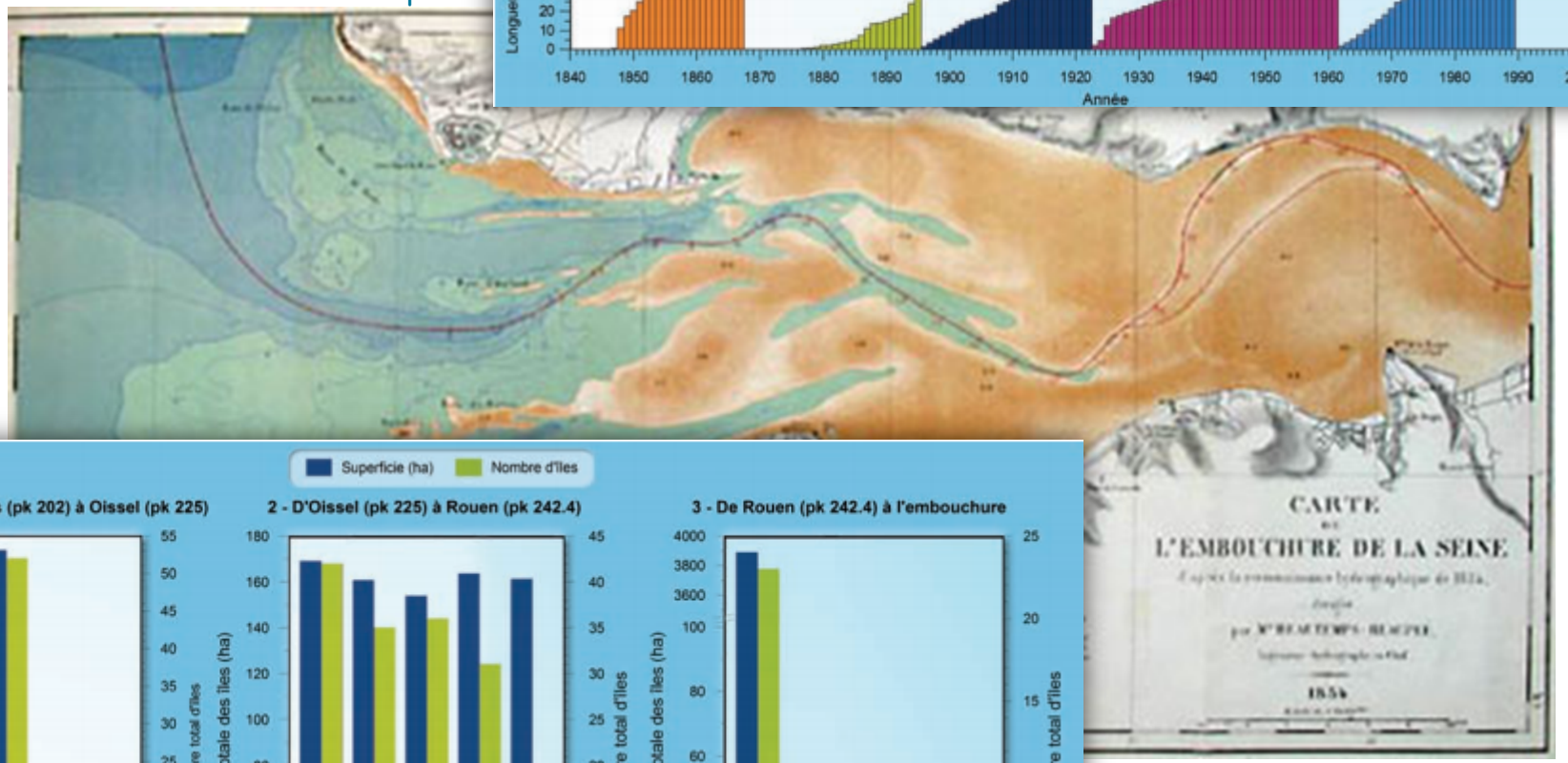


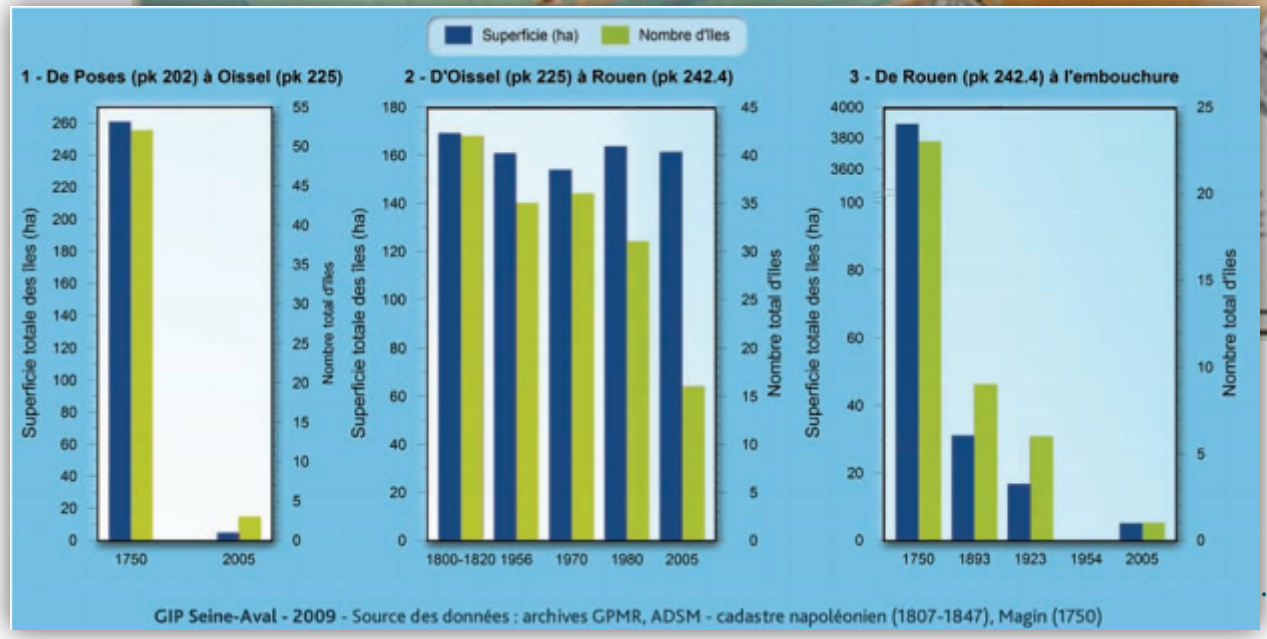
An interdisicplinary approach

Seine-Aval
GROUPEMENT D'INTÉRÊT PUBLIC

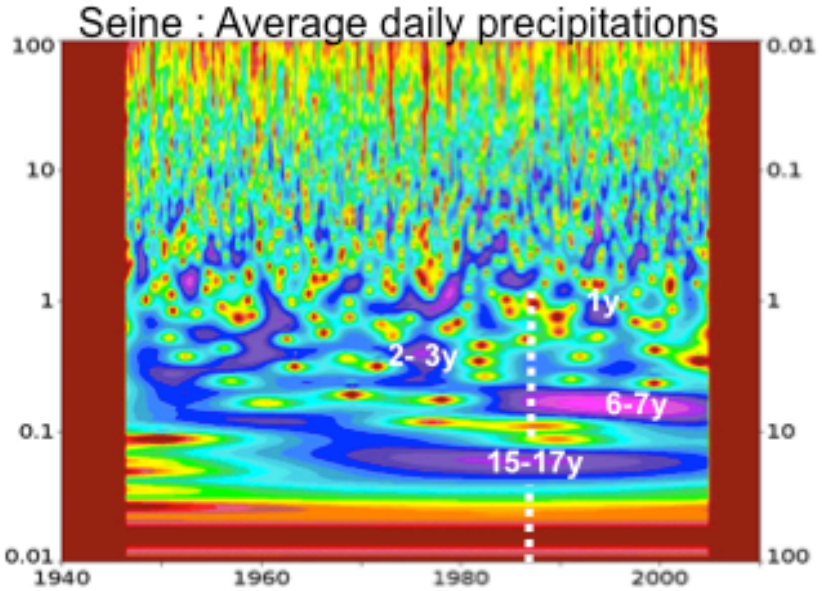
Tidal River Development

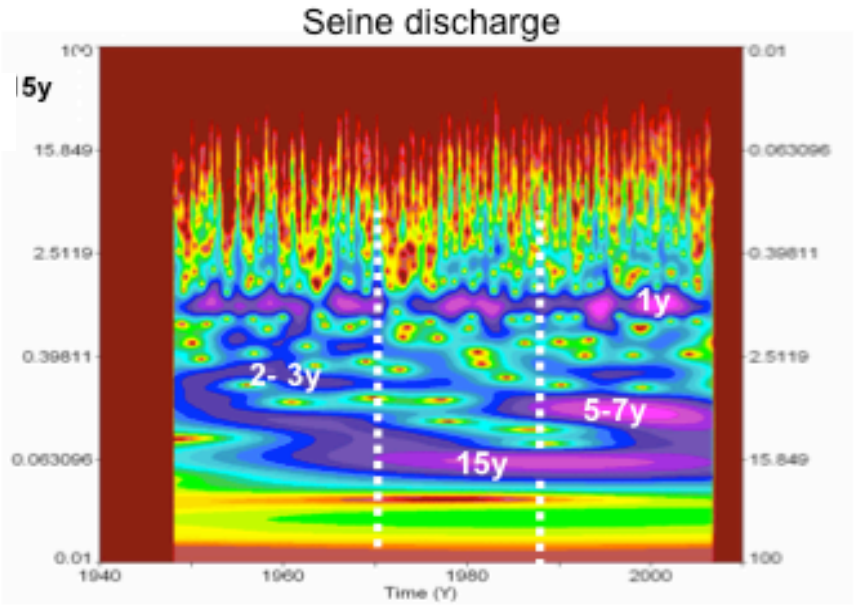


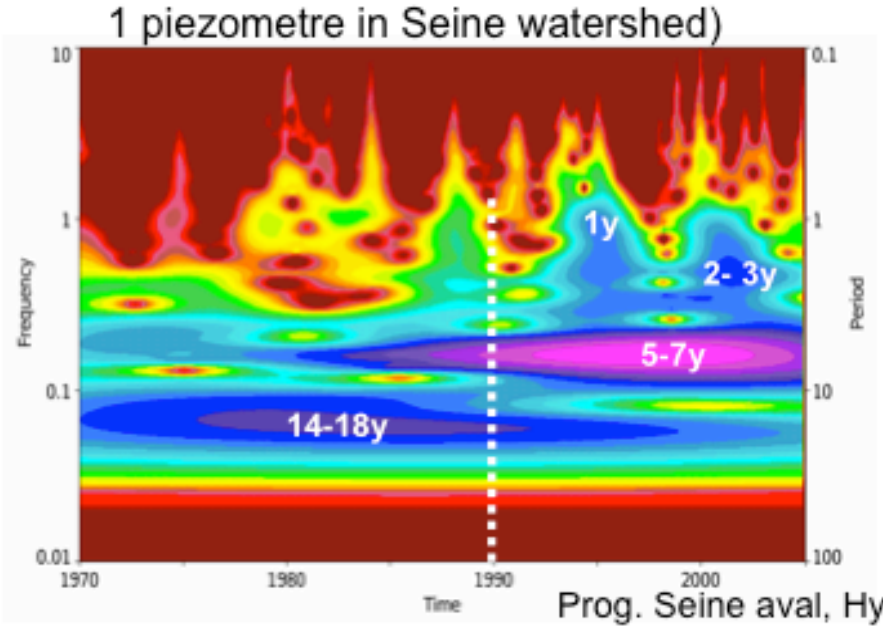




Climate change







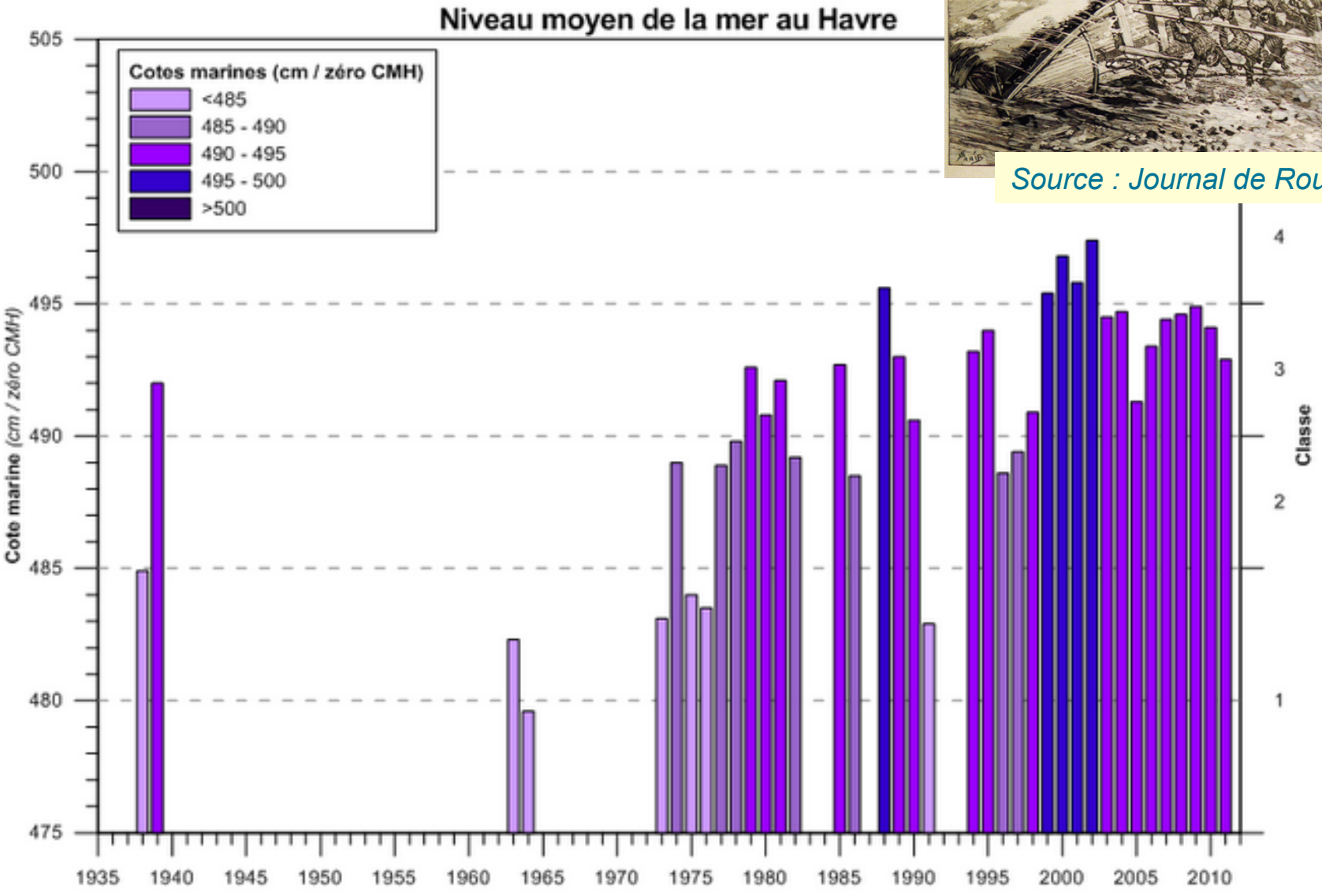
- 1y, 2-3y, 5-7y & 15y EB
Interannual variability synchrone with NAO
- 2 discontinuities 1970 & 1990

...

Prog. Seine aval, Hydroclimat ; Laignel et al., 2008, AGU

Sea level rise

Source : Journal de Rouen



Hydraulic model

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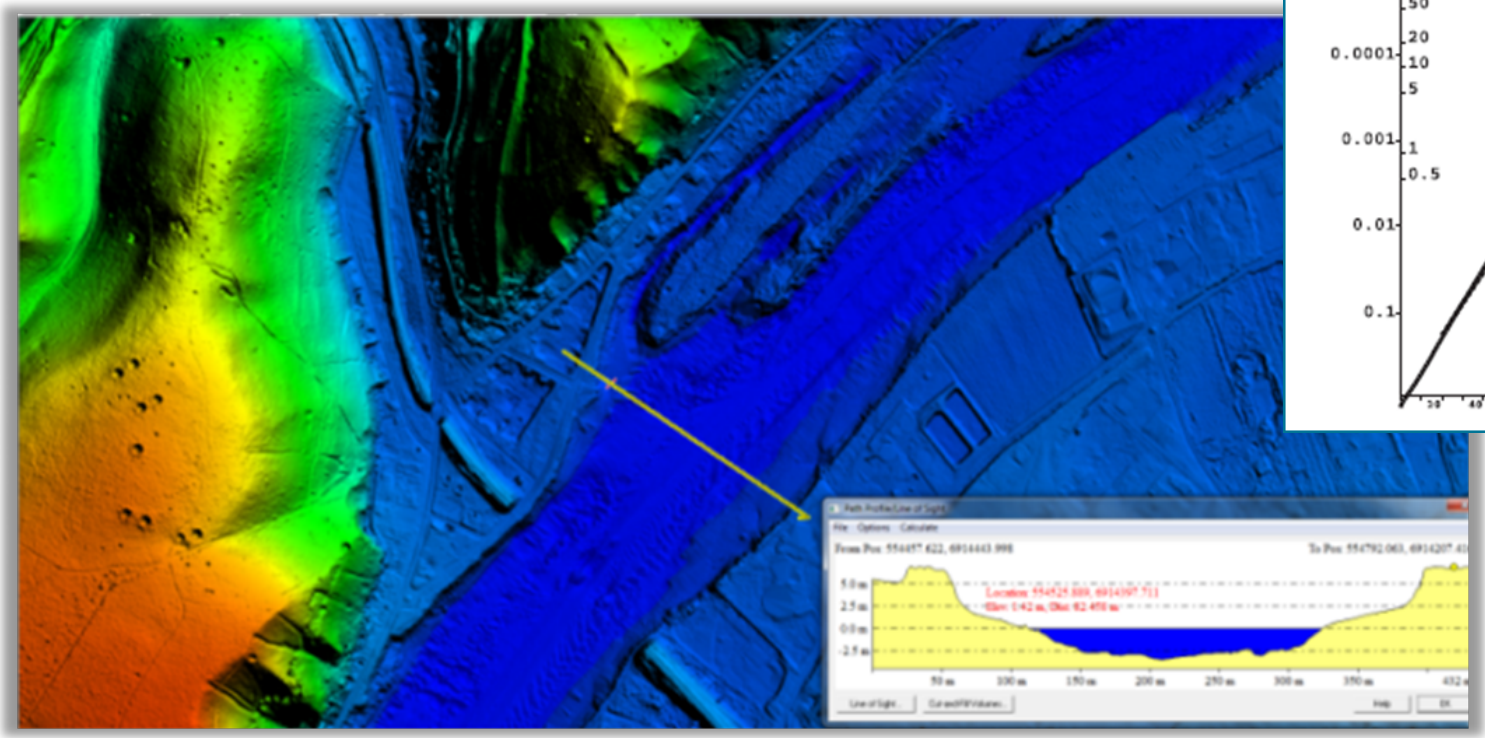
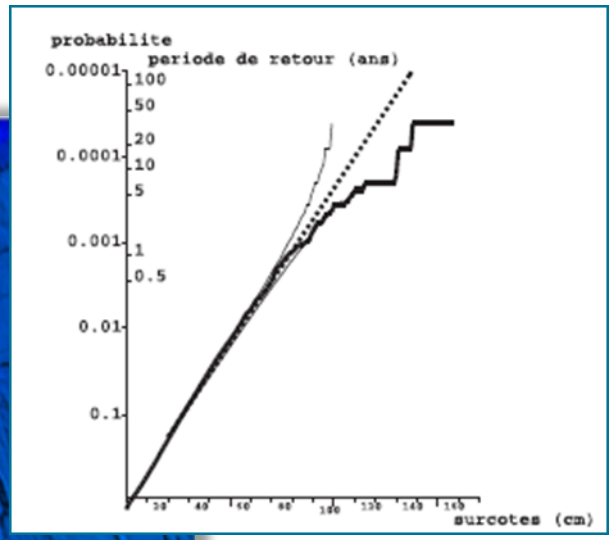




Water level according to different hydrological events

➔Definition of return periods of events triggering floods (flood tide, storm surge)

➔Development of scenarios triggering floods overflow

➔Development of a hydraulic model of the estuary

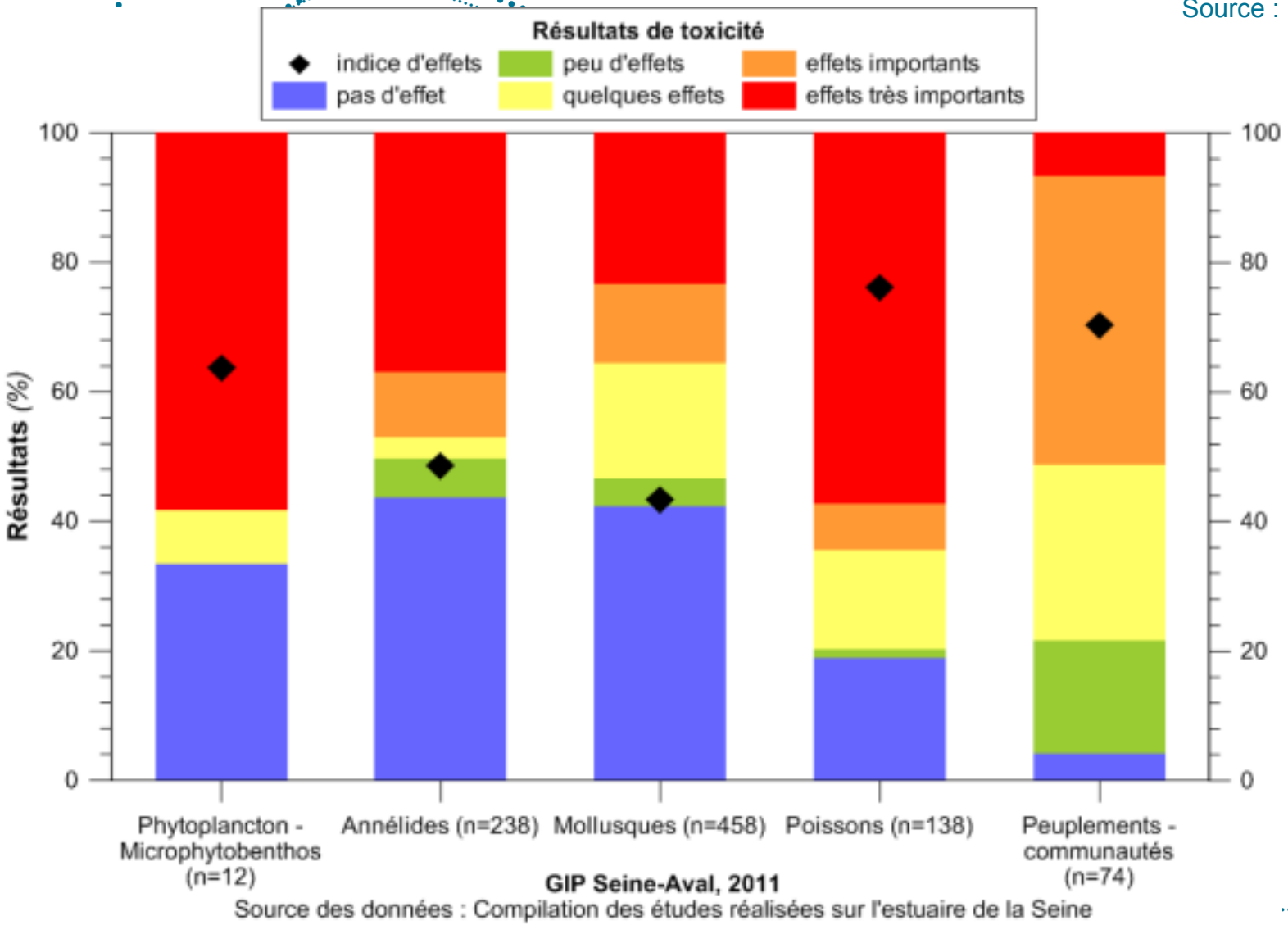
➔Modelling the water level under different scenarios

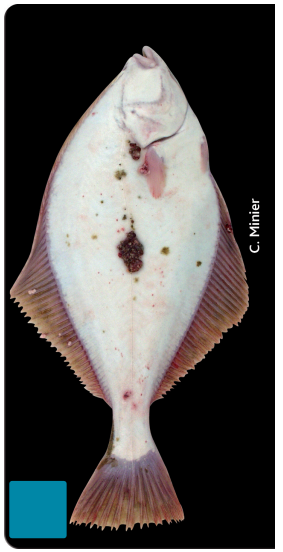
Source : SHOM & CETMEF, 2012

Source : GIP Loire estuaire, 2010

An ecosystem approach to toxicology: up to community level

Source : Poisson *et al.*, 2011



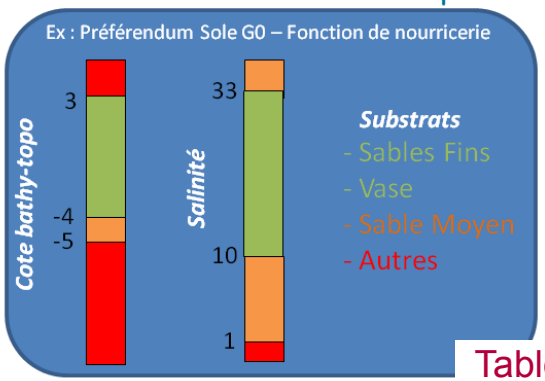


GIS functional habitats

Tidal River Development

Species factsheets

(potentiality for a species to be present depending on different factors)



GIS layers

Table for habitats preferences

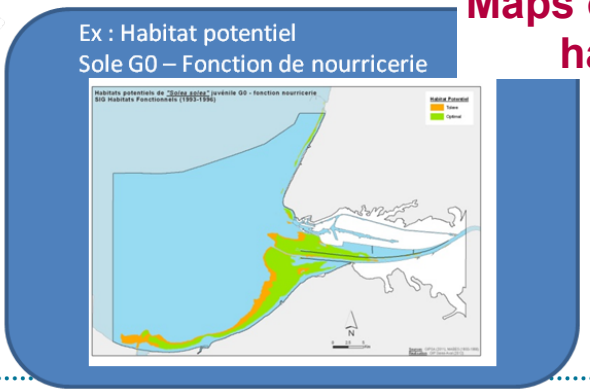
Spatial request

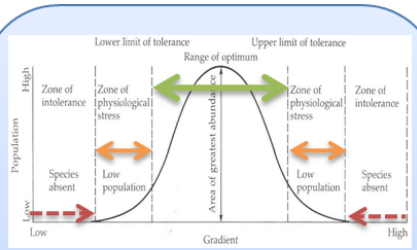
Potential habitats

Other factors ?

Validation

Maps of potential habitats





Bibliographie

Préférendum écologiques

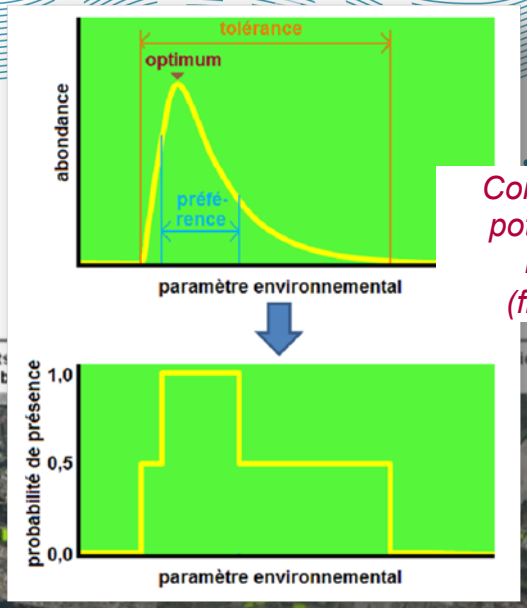
Espèce - Fonctions biologiques

- GEMEL Picardie-T. Ruellet
- MNHN/CRESCO-E. Feunteun
- Univ. Cath. Lille – P. Julve
- Obs. Avifaune Estuaire- P. Provost

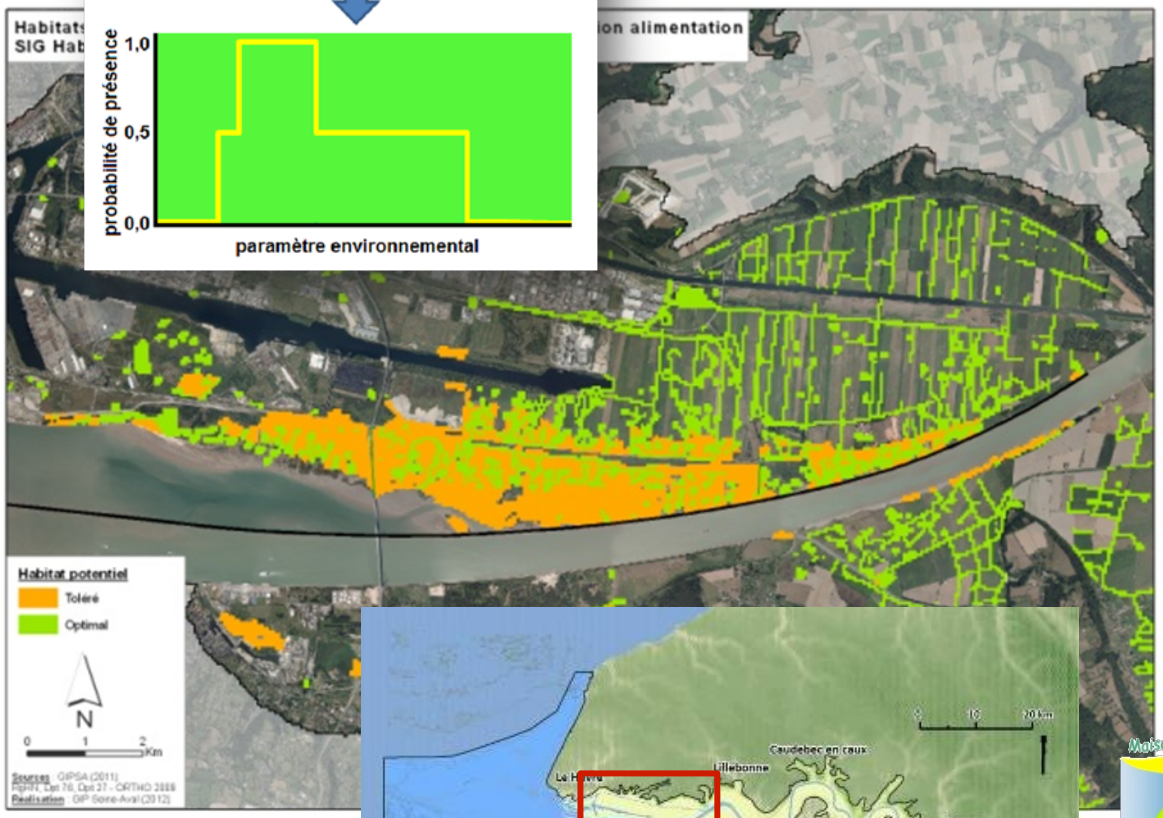
Observations data base

Carrying capacity
GIS functional habitats

Habitat mapping in terms of their role in the ecological functioning of the Seine estuary (feeding, resting, breeding, migration, nursery ...).



Comparisons between potential habitats and realized habitats (field observations)



- Spatial model of the role of estuarine habitats of the Seine for different species
- 50 benthic species, 27 fishes species, 61 birds species

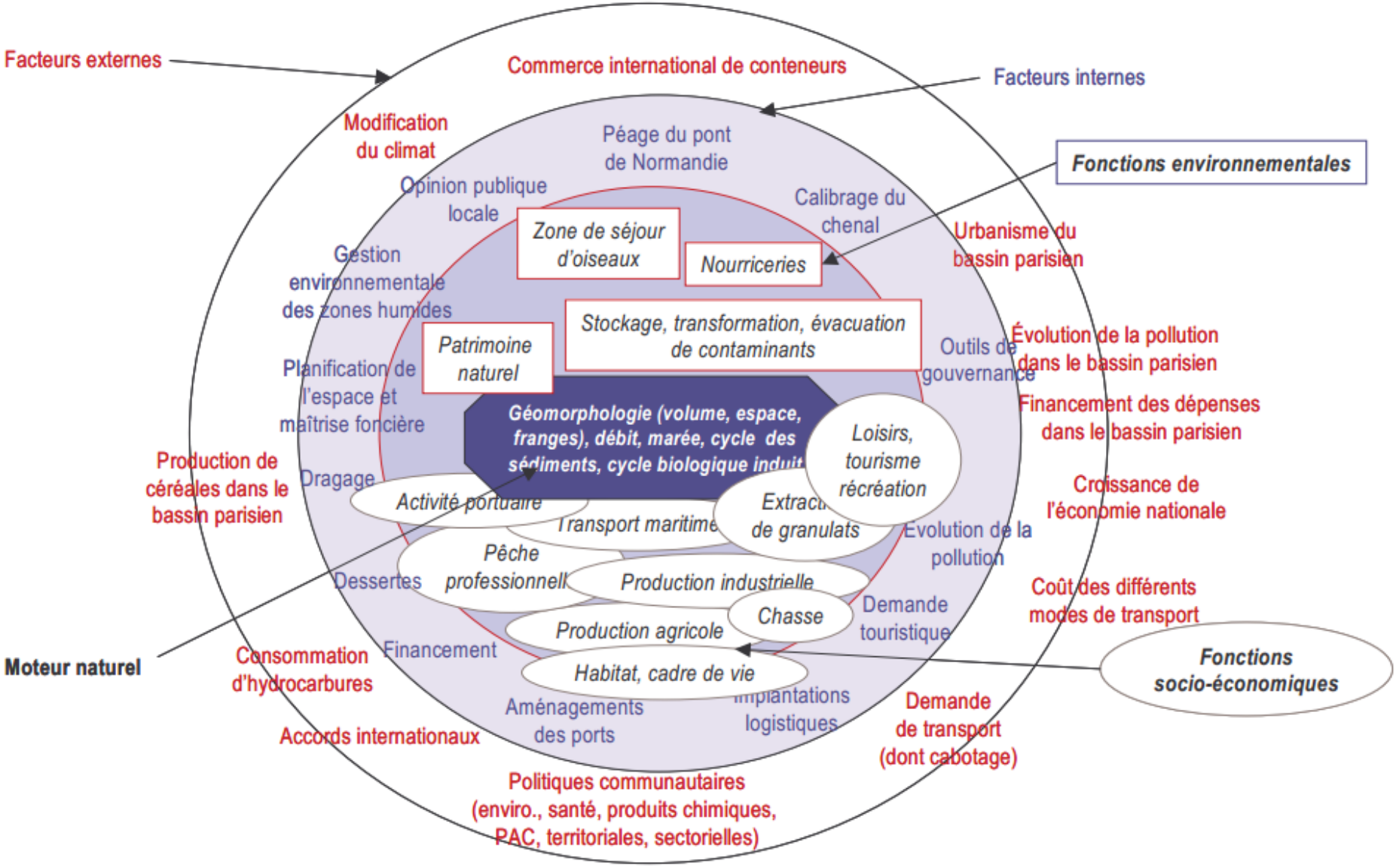
Maison de l'Estuaire

Parc naturel régional des Boucles de la Seine Normande

GIP Loire Estuaire

Cemagref Sciences, eaux & territoires

The Seine estuary "system": functions and services



Goods and services

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. "Natural factory" = geomorphology (volume, space, fringes), flow, tide, sediment cycle, life cycles

. Environmental functions

. Services provided by the estuary to socio-economic activities

. Socio-economic factors that influence the evolution of the estuarine system

*One step towards a comprehensive management plan for the estuary but **questions remain***

What are the best mechanisms for

- Consultation and management?
- Control? Regulation?
- Redistribution?

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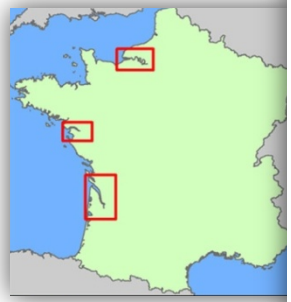
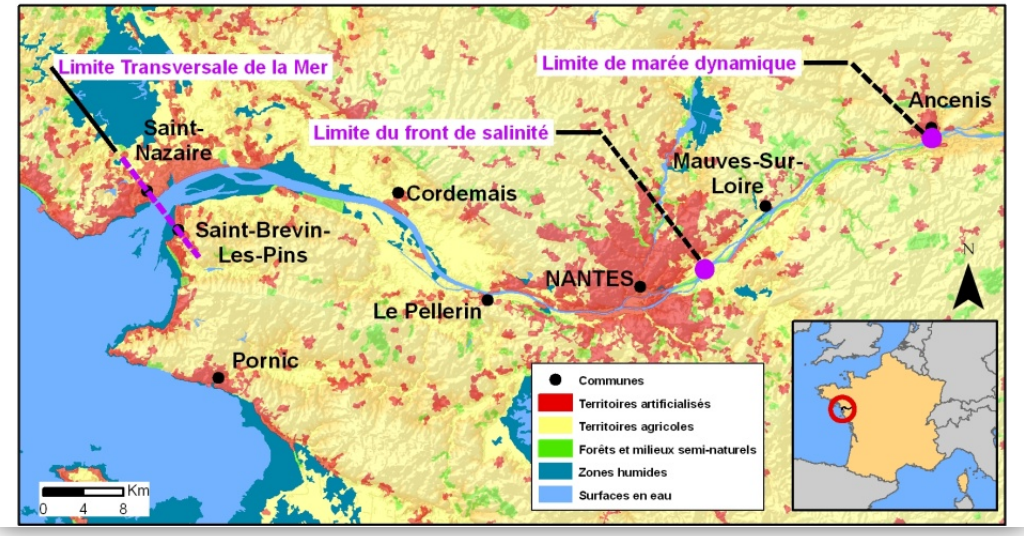
- « Towards a multi-parameter approach to the good ecological status of large estuaries:
- Seine, Loire, and Gironde »

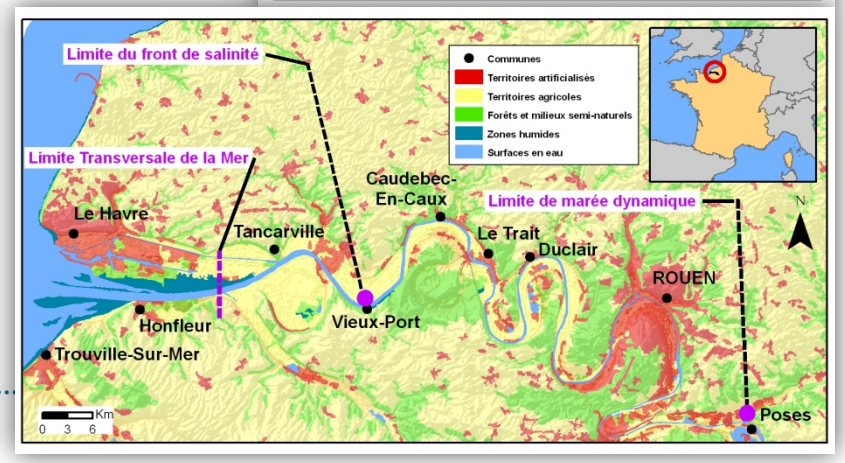
Account for **ecological, economic and societal** needs
Interlink multiple processes, efforts and investments **already taking place**

The three major French estuaries

	Seine	Loire	Gironde
Water catchment area (km2)	79 000	118 000	71 000
Estuary area (km2)	50	60	635
Tidal intrusion (km from sea)	160 (limited by a dam)	95	150
Maximal tidal range (m)	8	6	5
Mean freshwater discharge (m3.s-1)	480	850	800 à 1000
High freshwater discharge (m3.s-1)	2200	1000 to 2000	1000 to 2000
Low freshwater discharge (m3.s-1)	100	200 - 500	100 à 300
TMZ (t)	20 000 to 400 000	800 000 to 1 000 000	4 000 000 to 5 000 000
Mean water residence time (day)	25-30	15 – 40	30 – 80







BEEST main results

Water Framework Directive

- Difficult to define a **reference** based on pristine conditions in present-day disturbed/urbanised estuaries
- More appropriate to identify **trends** rather than thresholds
- Take into account **natural variations** of ecosystem conditions and **human activities**

Good ecological potential *is dynamical and depends on:*

- *Climate*
- *Economic activities*
- *Ecological functions and*
- *Services provided by ecosystem and desired by users*

☼ **should incorporate a social dimension**

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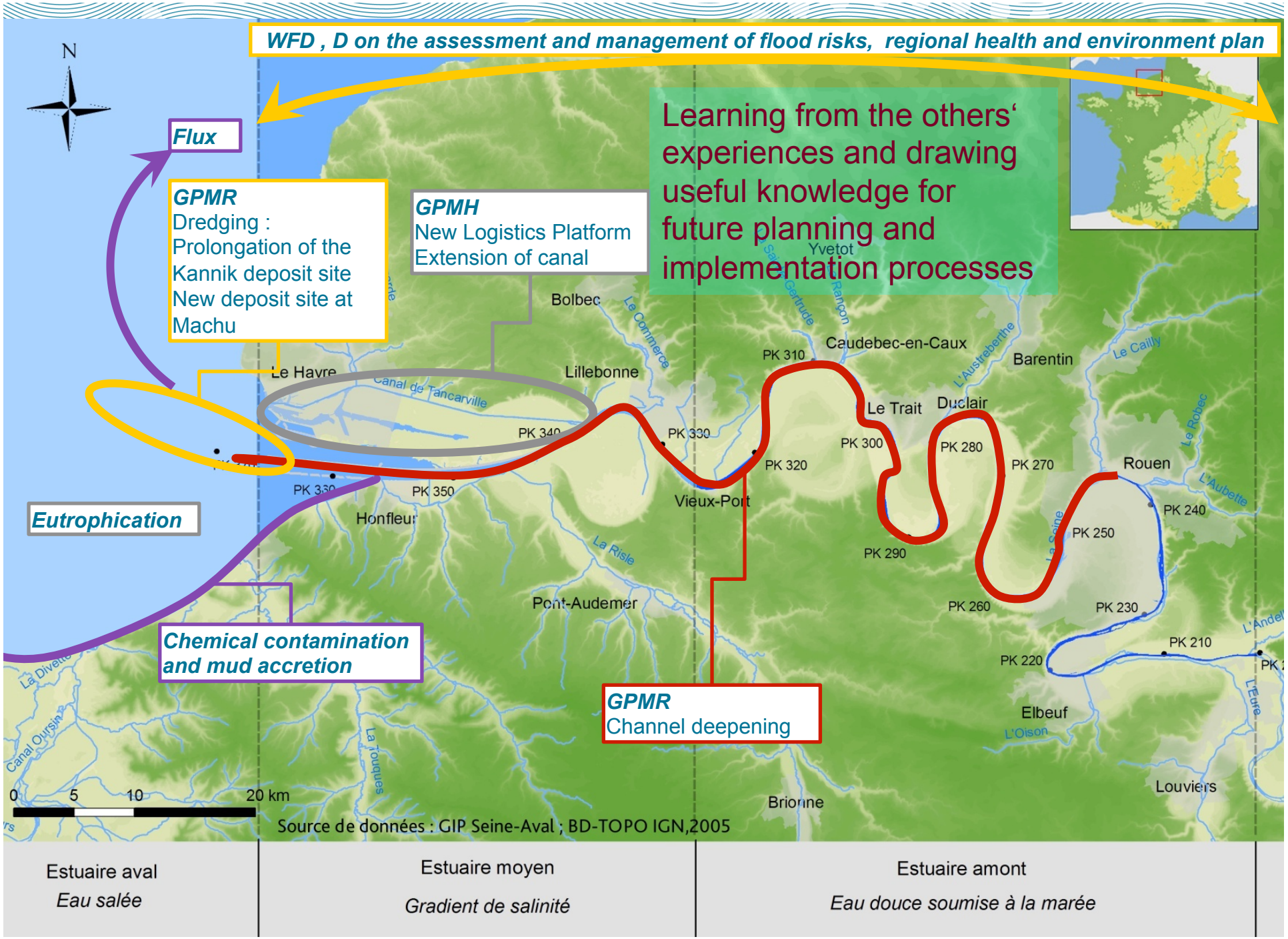
3. ESTUARY GOVERNANCE

Shared responsibility
Inventory of uses / conflict matrix
Communication schemes

Account for ecological, economic and societal needs


WFD , D on the assessment and management of flood risks, regional health and environment plan
Learning from the others' experiences and drawing useful knowledge for future planning and implementation processes
Flux
GPMR
Dredging :
Prolongation of the Kannik deposit site
New deposit site at Machu
GPMH
New Logistics Platform
Extension of canal
Eutrophication
Chemical contamination and mud accretion
GPMR
Channel deepening
N
Yvetot
Bolbec
Le Havre
Lillebonne
Caudebec-en-Caux
Barentin
Le Trait
Duclair
Rouen
Vieux-Port
Honfleur
Pont-Audemer
Elbeuf
Louviers
Brionne
Canal de Tancarville
Le Commerce
L'Austreberthe
Le Cailly
Le Robec
L'Aubette
La Risle
La Touques
La Seine
L'Eure
L'Oison
PK 310
PK 300
PK 290
PK 280
PK 270
PK 260
PK 250
PK 240
PK 230
PK 220
PK 210
PK 350
PK 340
PK 330
PK 320
0 5 10 20 km
Source de données : GIP Seine-Aval ; BD-TOPO IGN,2005
Estuaire aval
Eau salée
Estuaire moyen
Gradient de salinité
Estuaire amont
Eau douce soumise à la marée

What sort of estuary do we want for 2050 and beyond ?

Tidal River Development

Defining a future vision for our estuary

- A vital and complex task
  - understanding and predictive capacity: a necessary starting point for an effective long-term planning process
- Types of actions required to reach the 'best attainable' or optimal situation
  1. Work with long time frames
  2. Re-think transitions to different forms of land use
  3. Establish conservation zones
  4. Restore habitats
  5. Enhance ecosystem services
  6. Increase resilience to future change

The GIP – a working interface

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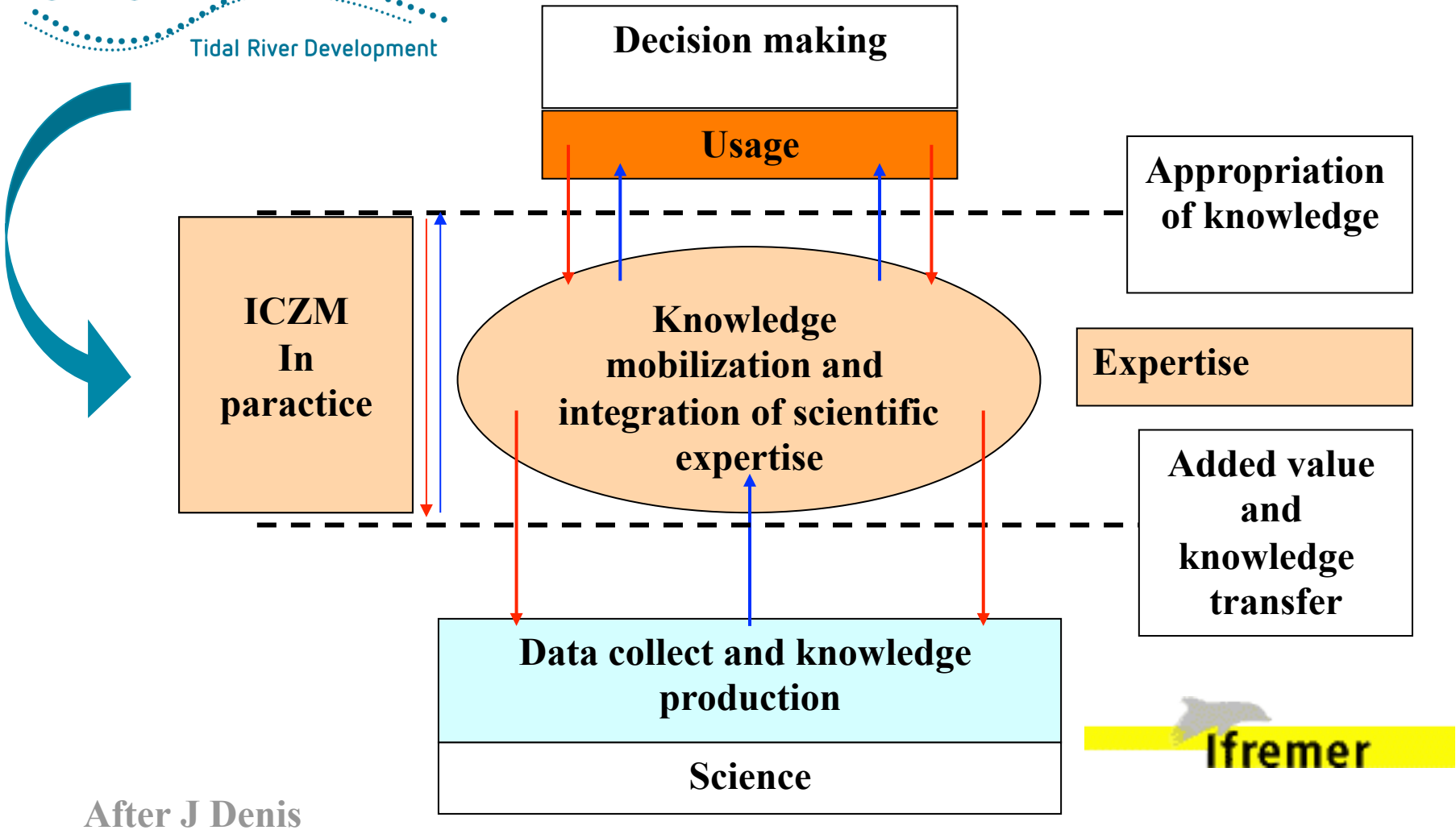

After J Denis

Shared responsibility

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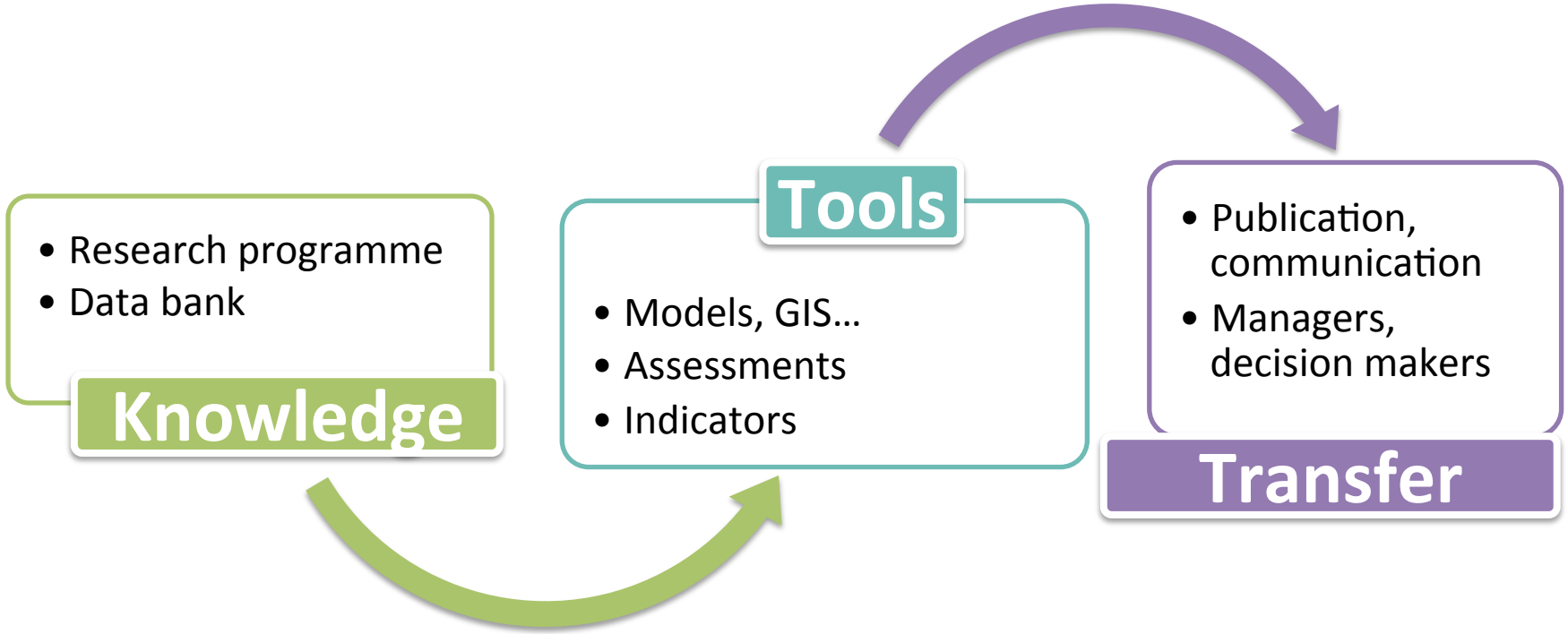
- Strategic environmental change associated with a regional scale for planning and management
  - over-legalisation
  - the remoteness of elected leaders from the concerns and conditions facing local communities
  - an inability to enable ‘fine tuning’ to local social and environmental conditions, and
  - the requirement for effective and costly monitoring
- Towards ‘socialisation’ of environmental governance at the regional level, so that interactive and deliberative forums are increasingly replacing state-directed, monological forms of public consultation

Knowledge platform on the estuary of the Seine

Tidal River Development

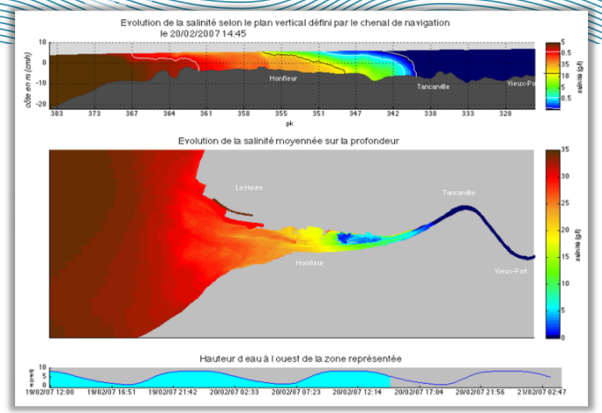
Objective: to establish and publicize the facts in the field of the environment on the estuary of the Seine

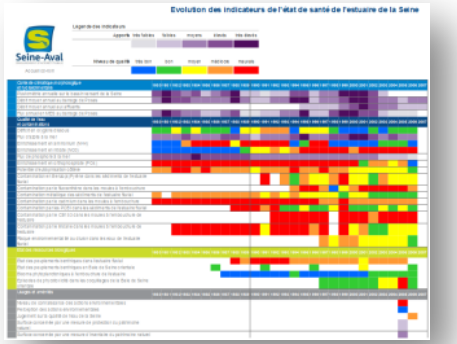


Scientific communication

Tidal River Development

- Tools development
  - Estuarine dashboard
  - Numerical modeling (in Q3 2011)
  - GIS (for links between species, habitats and functionalities: functional habitats)
- Communication
  - 23 booklets (30 to 50 pages)
  - 25 fact sheets (6 pages)
  - Synthesis reports (chemical contamination, PCB's, flooding …)
  - Information letters
  - …





Knowledge transfer and development

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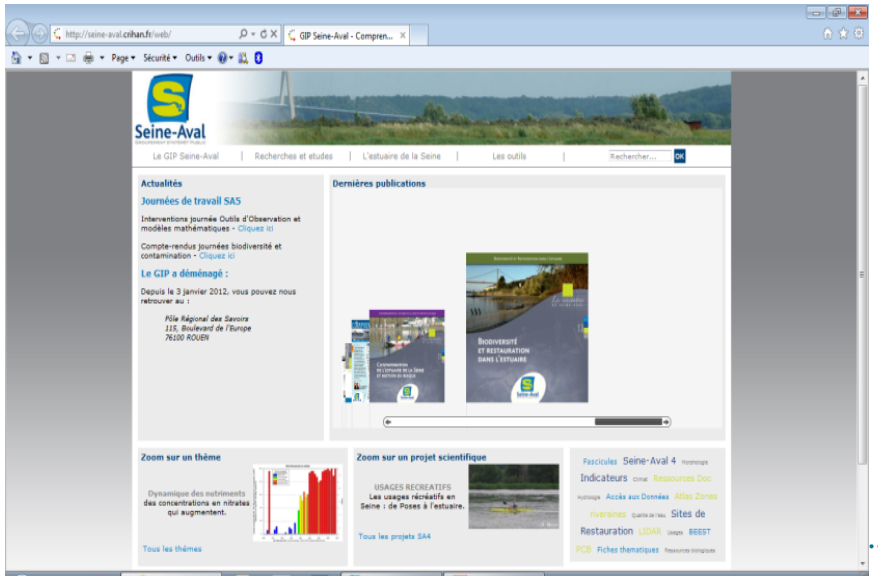
General public

- Illustrated book
- Newsletter
- Scoreboard
- Website (http://seine-aval.fr)
- Press Releases



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4. PRACTICAL MEASURES

Analysis of human interventions: flooding
Comparison of sediment dredging and relocation strategies
Water management
Estuary specific pilot initiatives: ecological restoration

Interlink multiple processes, efforts and investments already taking place

LIDAR Estuaire de Seine

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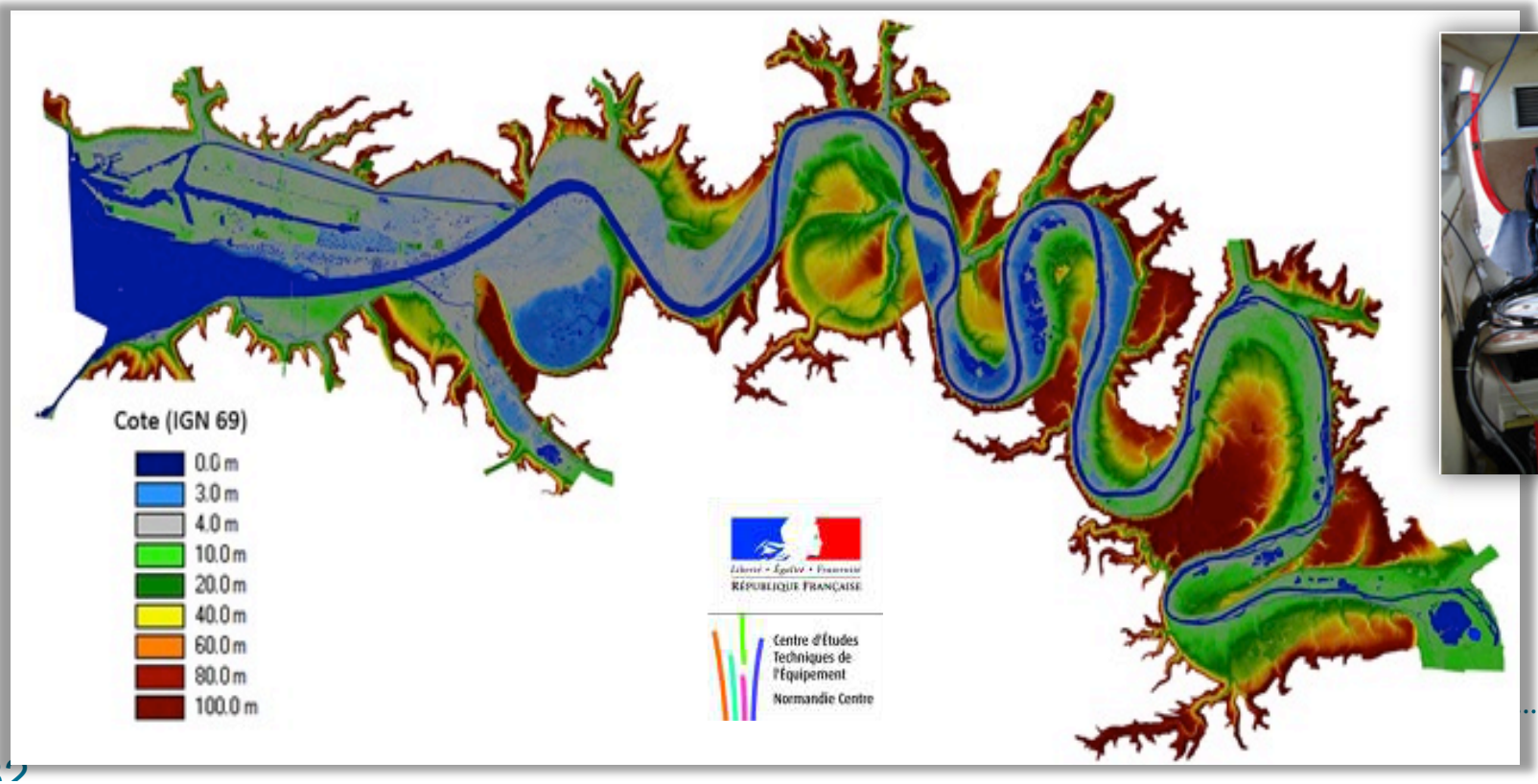
– Acquisition of high-resolution topographic reference by airborne laser system all over the alluvial plain (1160 km2).

– Multiple applications: research support, assessment of potential ecological restoration areas, improving knowledge on floodability ...



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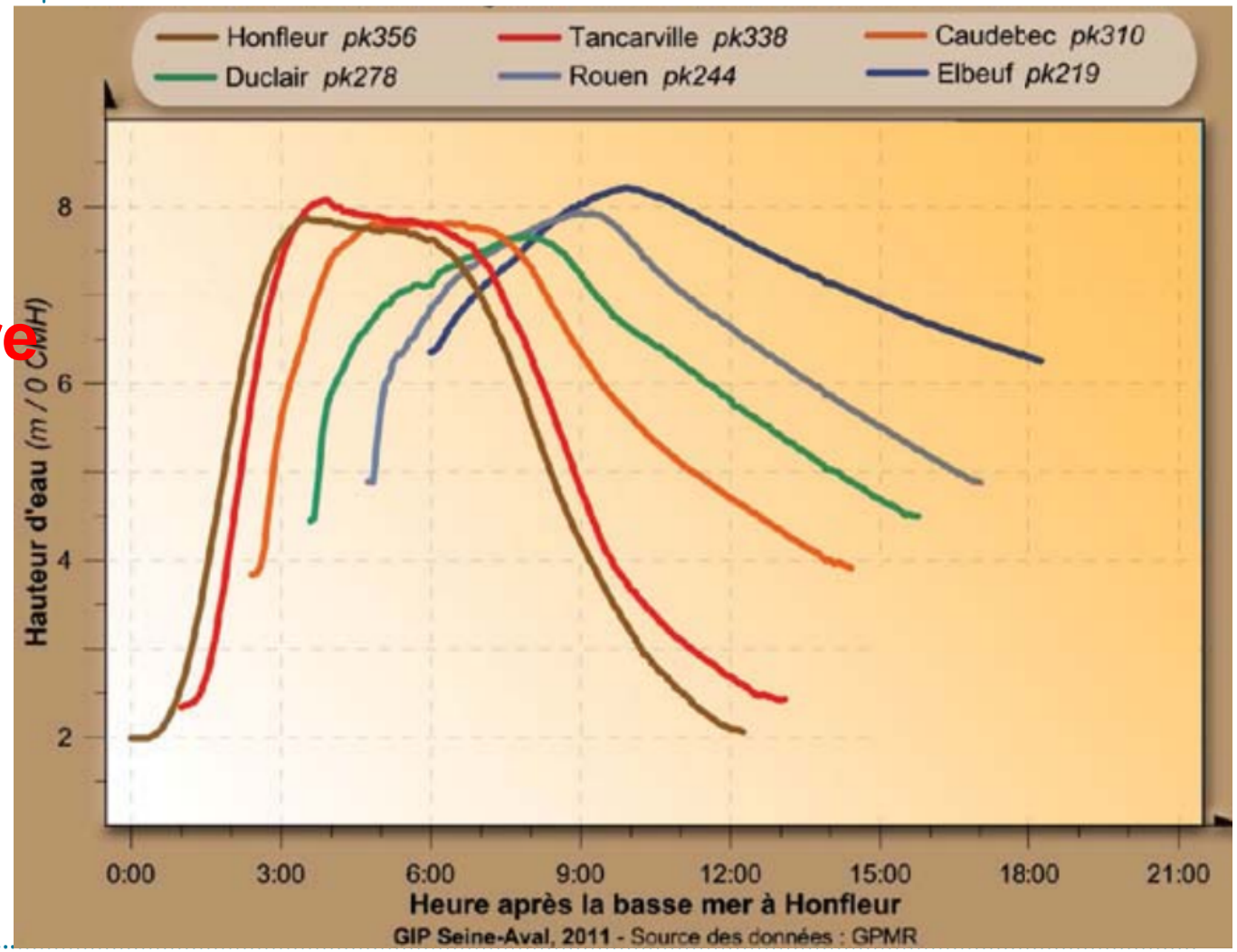
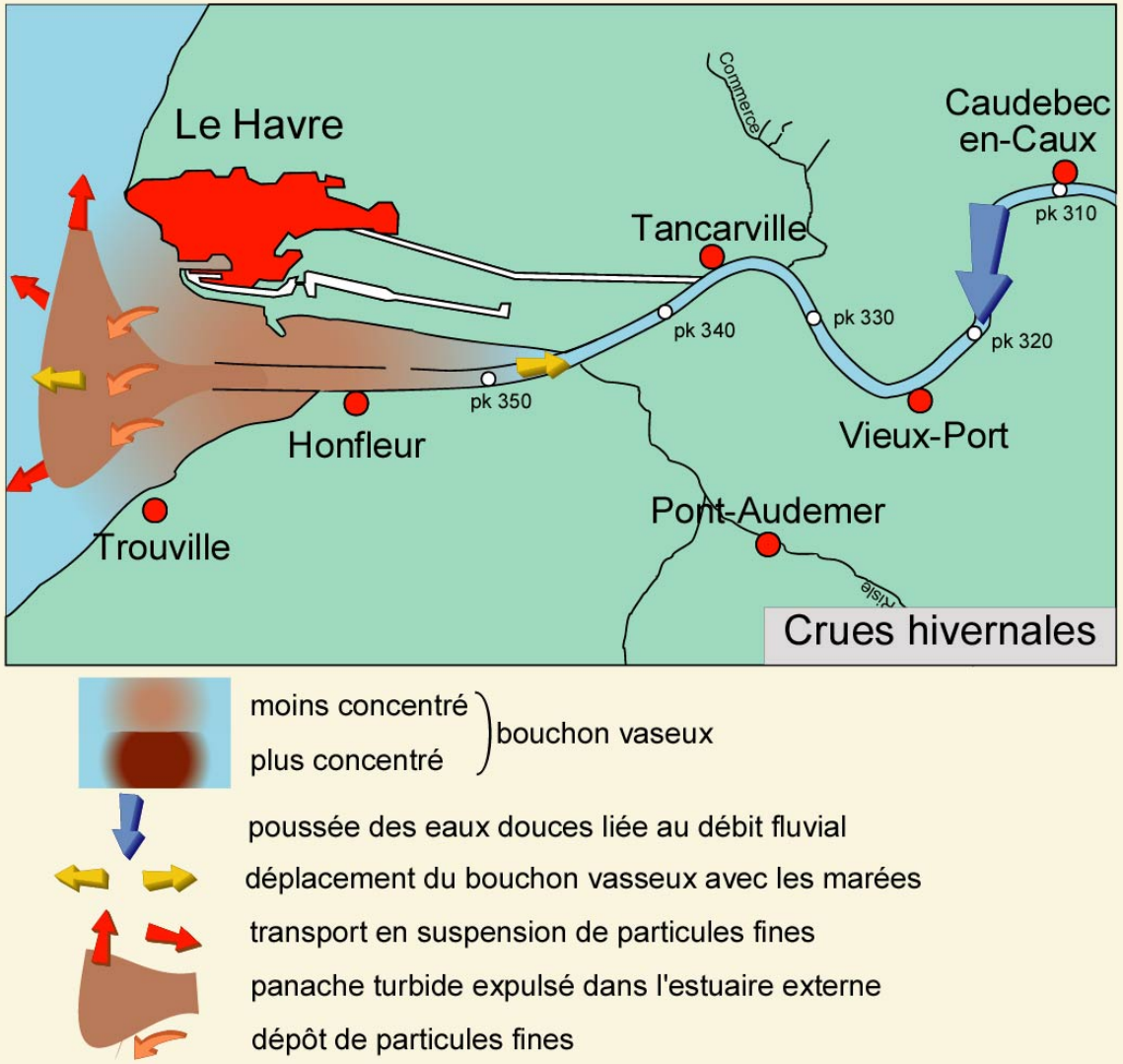
Increasing sediment transport, requiring more maintenance dredging and improved sediment management



Tidal River Development

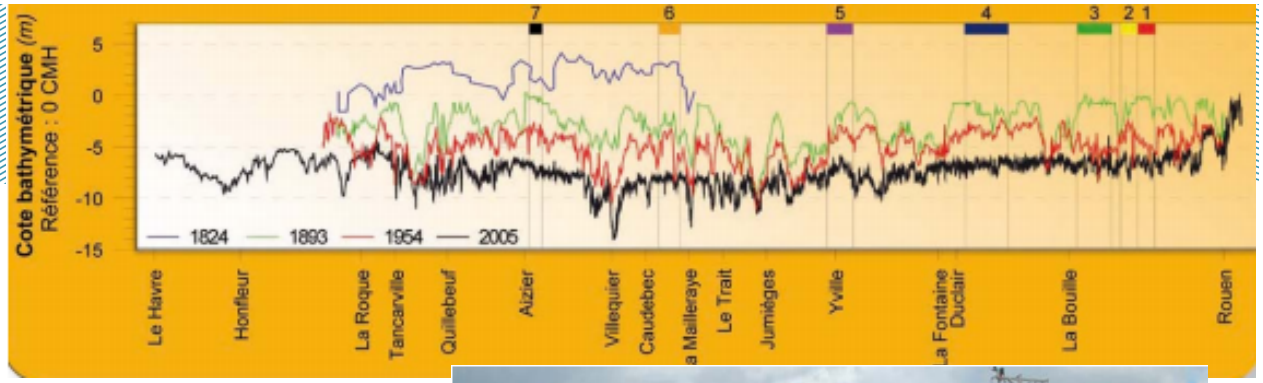
- **macrotidal estuary**
- tidal range> 8 m
- turbidity maximum = average concentration in suspended material: 500 to 1000 $mg.l^{-1}$
- location in estuary changes depending
  - ➢ on excursion of tide
  - ➢ river flow (100 to> 2000 m^3)



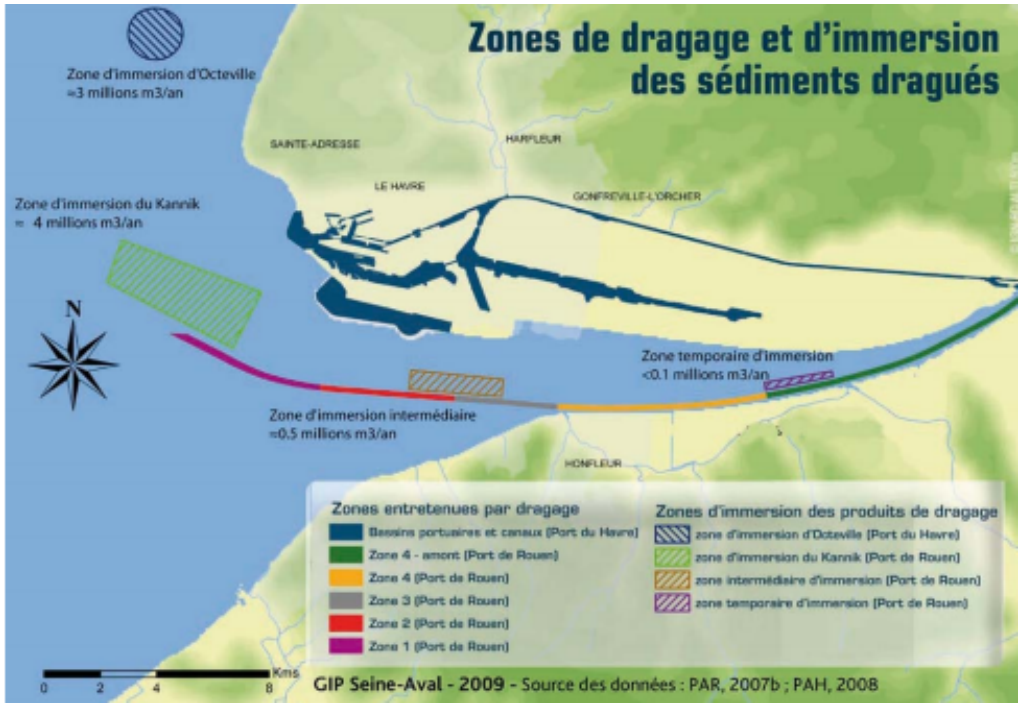
En période de crue de la Seine

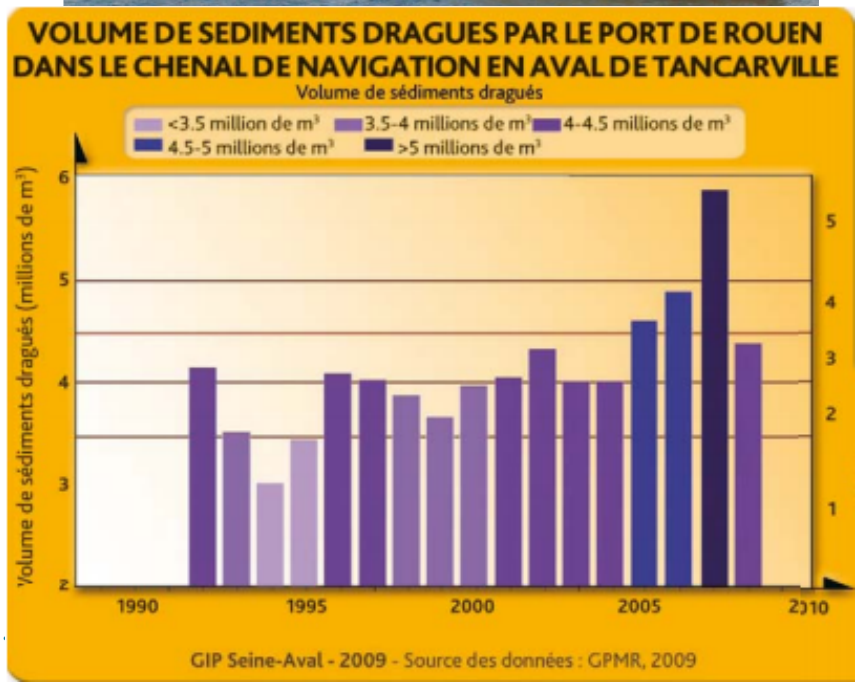
Schéma de synthèse des processus hydrosédimentaires et de dépôt en période de crue de la Seine

Tidal River Development



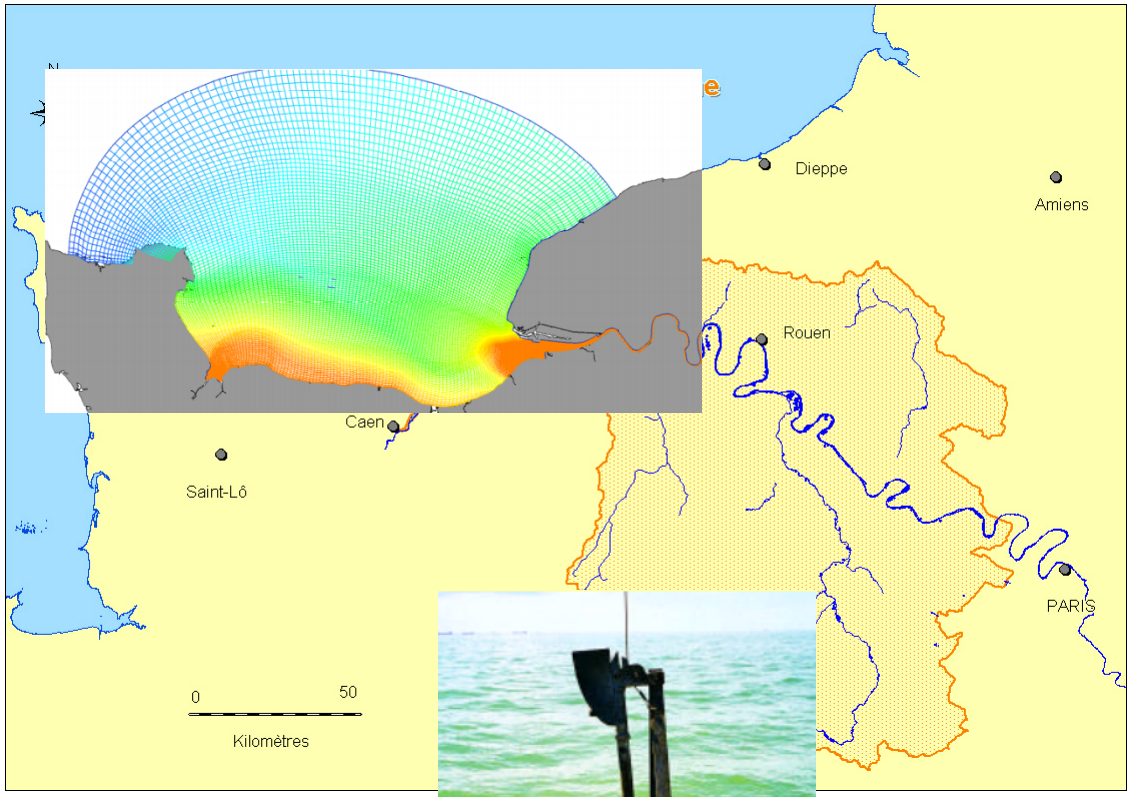
Dredging and sediment disposal





Sediment Dredging and Relocation Strategies

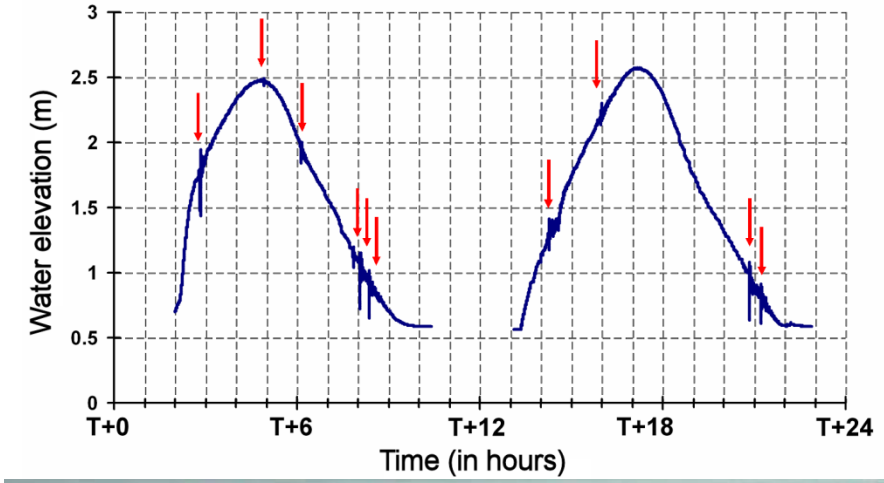
Tidal River Development



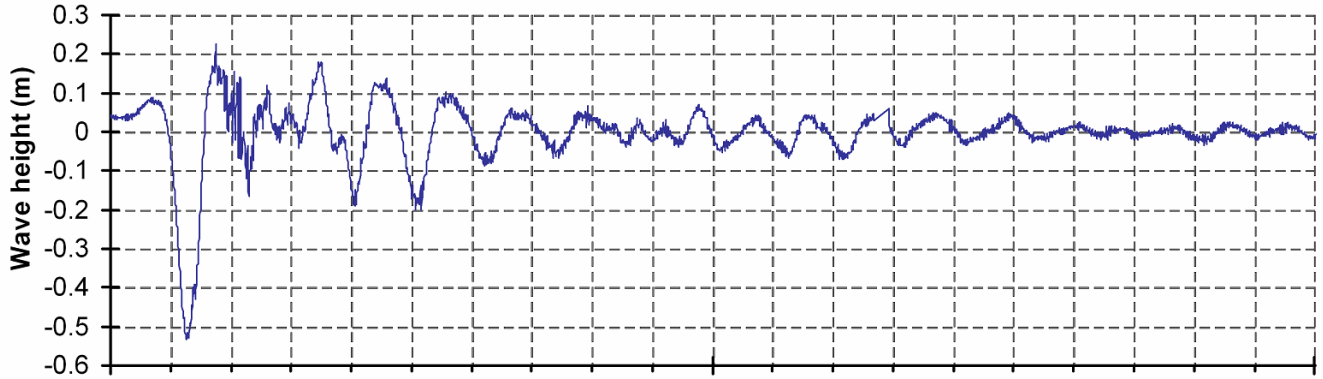
Maintenance, type of dredging, disposal sites, alternative utilisation:

- **containment** downstream of the mouth of the Eure
- extension of **industrial areas** and **ports**
- building **docks** at Oissel
- Normandy **bridge embankment**
- **land storage** for granular sediments (sand, gravel)

TIDE


Water elevation (m)
3
2.5
2
1.5
1
0.5
0
T+0
T+6
T+12
T+18
T+24
Time (in hours)

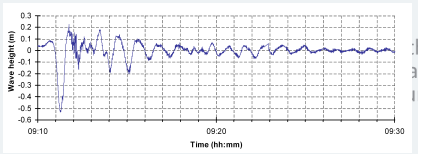

POLARIS
Banks erosion

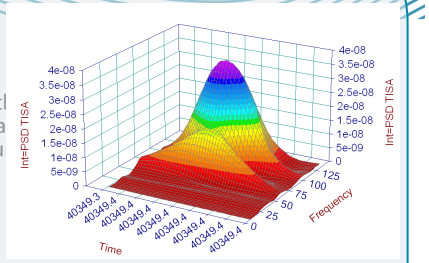

Wave height (m)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
09:10
09:20
09:30
Time (hh:mm)

Turbulences due to shipping

Hydrodynamics

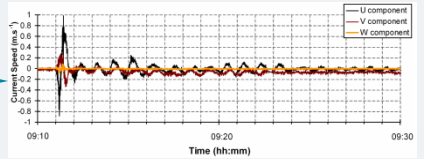
Waves…





Tidal River Development

Current speed/direction



Turbulent shear stress…

$$\tau_{TKE} = \rho C_{TKE} K = 0.5 \rho C_{TKE} \left(\overline{u_t'^2} + \overline{v_t'^2} + \overline{w_t'^2} \right) \quad (1)$$

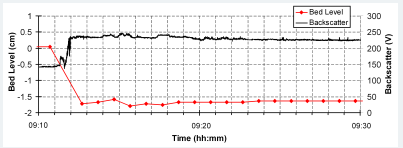
$$\tau_W = 1/2 * r * f_W * U_W^2 \quad (2)$$

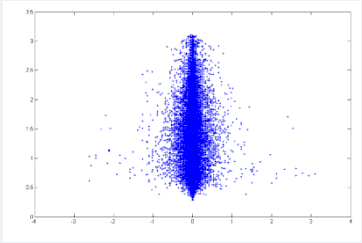
$$f_W = 1.39 * (A/z_0)^{-0.52} \quad (3)$$

$$\tau_{W+C} = \sqrt{(\tau_{TKE})^2 + (\tau_W)^2} \quad (4)$$

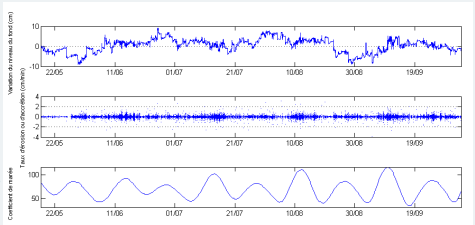
Sediment transport

Topography / SSC





Sediment transport and fluxes

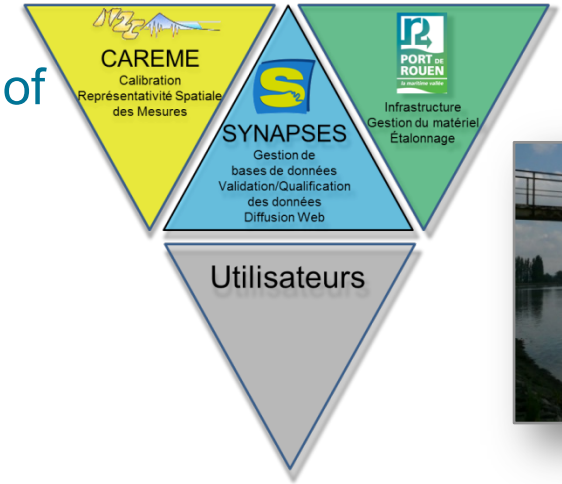


Automated high fequency monitoring

Tidal River Development

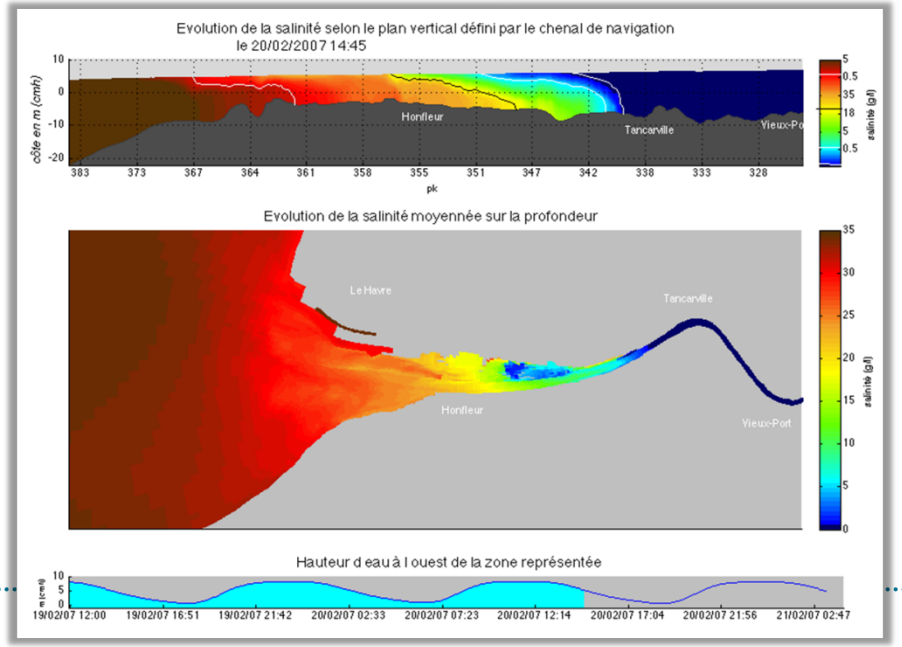
Network for continuous measurement of water quality

- T °, conductivity (salinity), pH, Dissolved Oxygen, Turbidity, Chlorophyll (height of water)
- Frequency: every 5 min
- Depth: 1m below the surface upstream + 1m above the bottom downstream



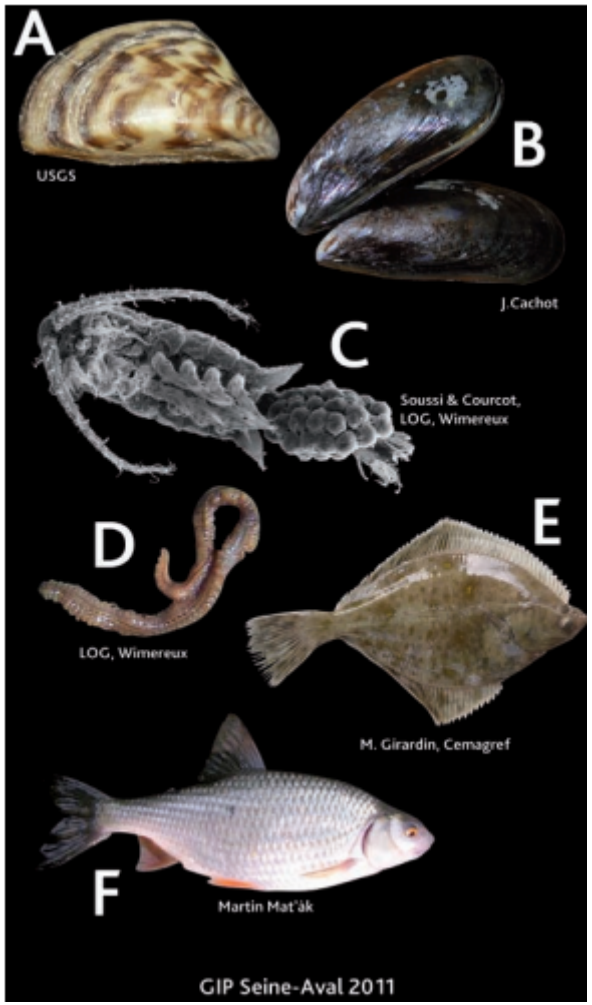
Objectives

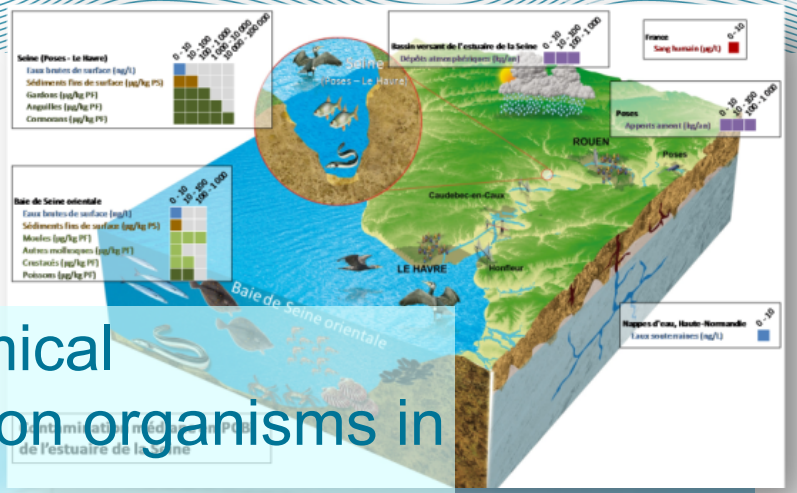
- Estimating solid (sediments) and liquid fluxes
- Monitoring the impact of Rouen on water quality
- Monitoring changes in the anoxic zone and the turbidity maximum
- Calibrating numerical models



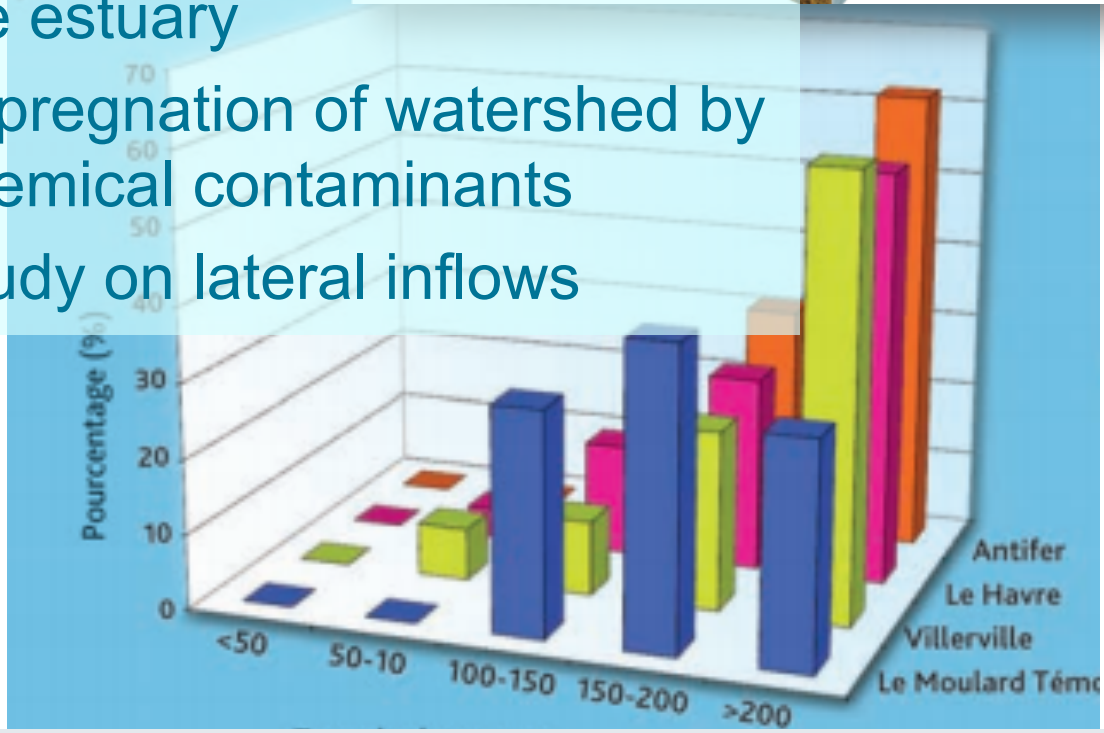
Water quality/ Fluxes / Sediments

Tidal River Development





- Effects of chemical contamination on organisms in the estuary
- Impregnation of watershed by chemical contaminants
- Study on lateral inflows



Rate of broken DNA in *Mytilus edulis*/In relation to carcinogenesis

The mission of the GIP SA in terms of restoration

Tidal River Development

1. To review and classify the main themes for restoration and nature conservation in the Seine estuary (with respect to existing or current scientific research)
2. To propose, locate and put in order of priority monitoring actions and experimentation focused on the understanding of the ecological functioning of the ecosystem or its responses to environmental alterations
3. To support regional restoration operations

Experimental sites for the restoration of estuarine functions in the Seine Estuary - France

Tidal River Development

A pluridisciplinary approach to outline objectives and methods

1. Restoration objectives to focus on **ecosystem functioning** rather than structure description
2. **Interactions** to be understood in terms of morphology, sedimentology and chemistry (silting, transportation, erosion, adsorption, oxydation areas… – sinks and source)
3. **Human activities** to be considered as fully belonging to the ecosystem – social sciences

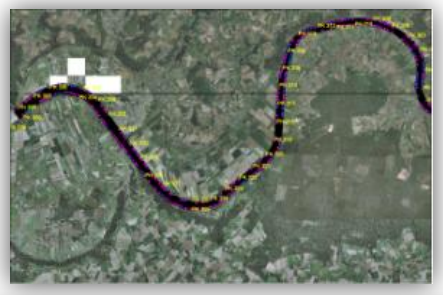
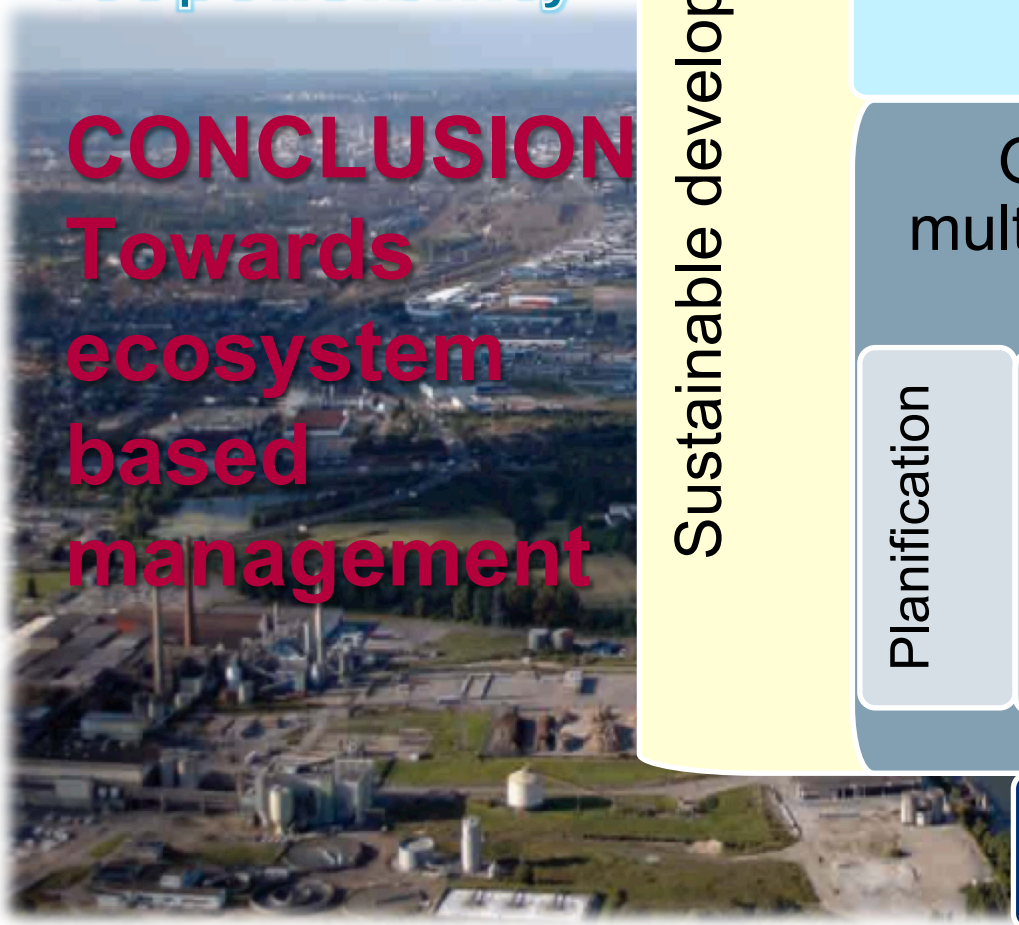


Photo 3 : zone humide à priori en connexion avec la Seine et mondée occasionnellement.
=> Potentiel frayère ?
(Propriété à vérifier car peut-être terrains communaux)

Tidal River Development

Shared responsibility



CONCLUSION Towards ecosystem based management

Sustainable development

Holistic approach

Ecosystemic approach

Multiscale

GIZC - multipartners

- Planification
- Prospection
- Social contract

Ecosystem Based Management

- Ecosystem functioning
- Ecosystems response
- Goods and services

Adaptive management

Shared responsibility

Tidal River Development

- recognition of antecedent societal and policy drivers
- interactions between the various stakeholders
  - community
  - Industry
  - government agencies
  - research institutions
- catchment scale focus
- rather than resource management experience or environmental concern, socio-economic policy to provide a policy shift

Long-term vision

Tidal River Development

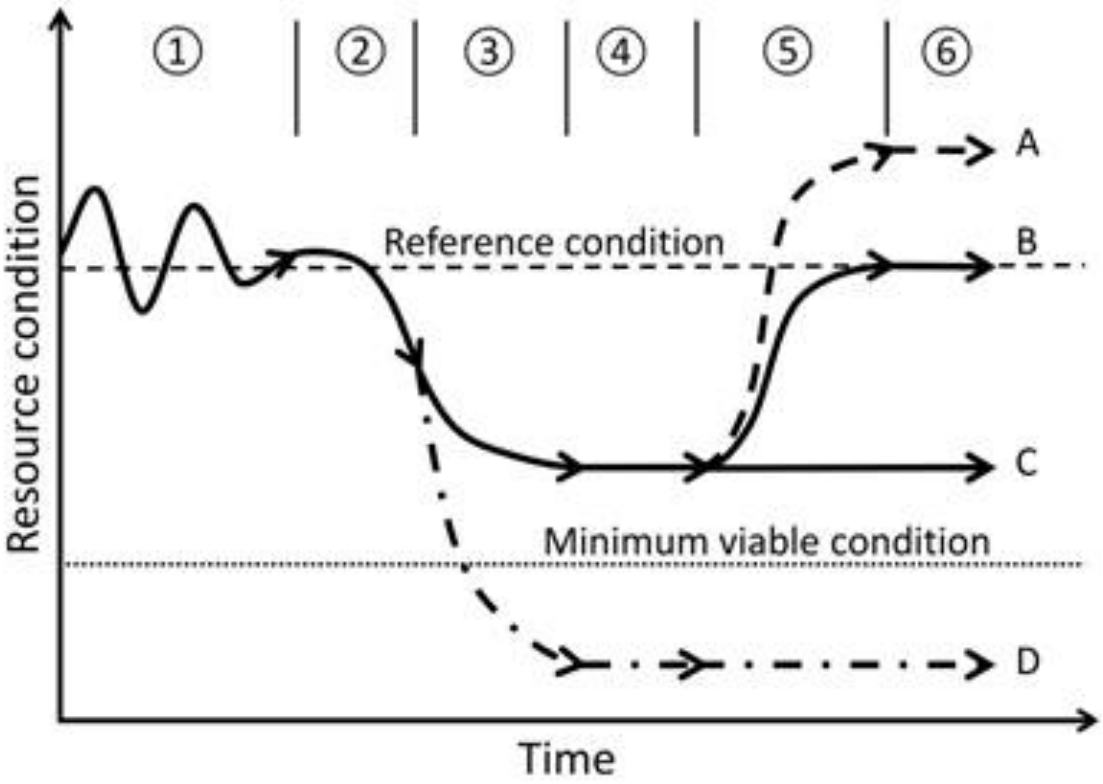
one (or more) reference states
based on models for a rigorous approach

Towards an ecological vision of the estuary

- To promote local actions in harmony with the functioning of ecosystems
- To build an utopian vision of the estuary to 30 or 50 years
- To collect and analyse data through the power of GIS
  - increasing the volume of free estuarine water
  - Understanding the potential of water circulation along longitudinal and transverse directions
- To adopt an historical approach
  - Considering the state of the estuary before major developments (1835)
  - Building on the knowledge of the past to open on prospective attitudes

Tidal River Development

- Ecosystem processes and functions describe biophysical relationships and exist regardless of whether or not humans benefit (Costanza and Daly 1992)
- Various human benefits are obtained through a combination of
  - natural capital (generally built and maintained without humans)
  - built or manufactured capital
  - human capital
  - social or cultural capital (Costanza et al. 1997)



- ① Historical condition with natural fluctuations (often used to define a historical reference condition)
- ② Observation of resource condition decline
- ③ Management intervention to halt the decline
- ④ System stabilisation
- ⑤ Regeneration (augmented regeneration or natural system resilience)
- ⑥ Future condition