Inter-relationships among Salt Marsh, Tidal Inlets, Barrier Islands and Tidal Delta Sand Reservoirs

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Ioannis Georgiou *University of New Orleans*

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Peter Phippen *Merrimack Valley Planning Comm.*

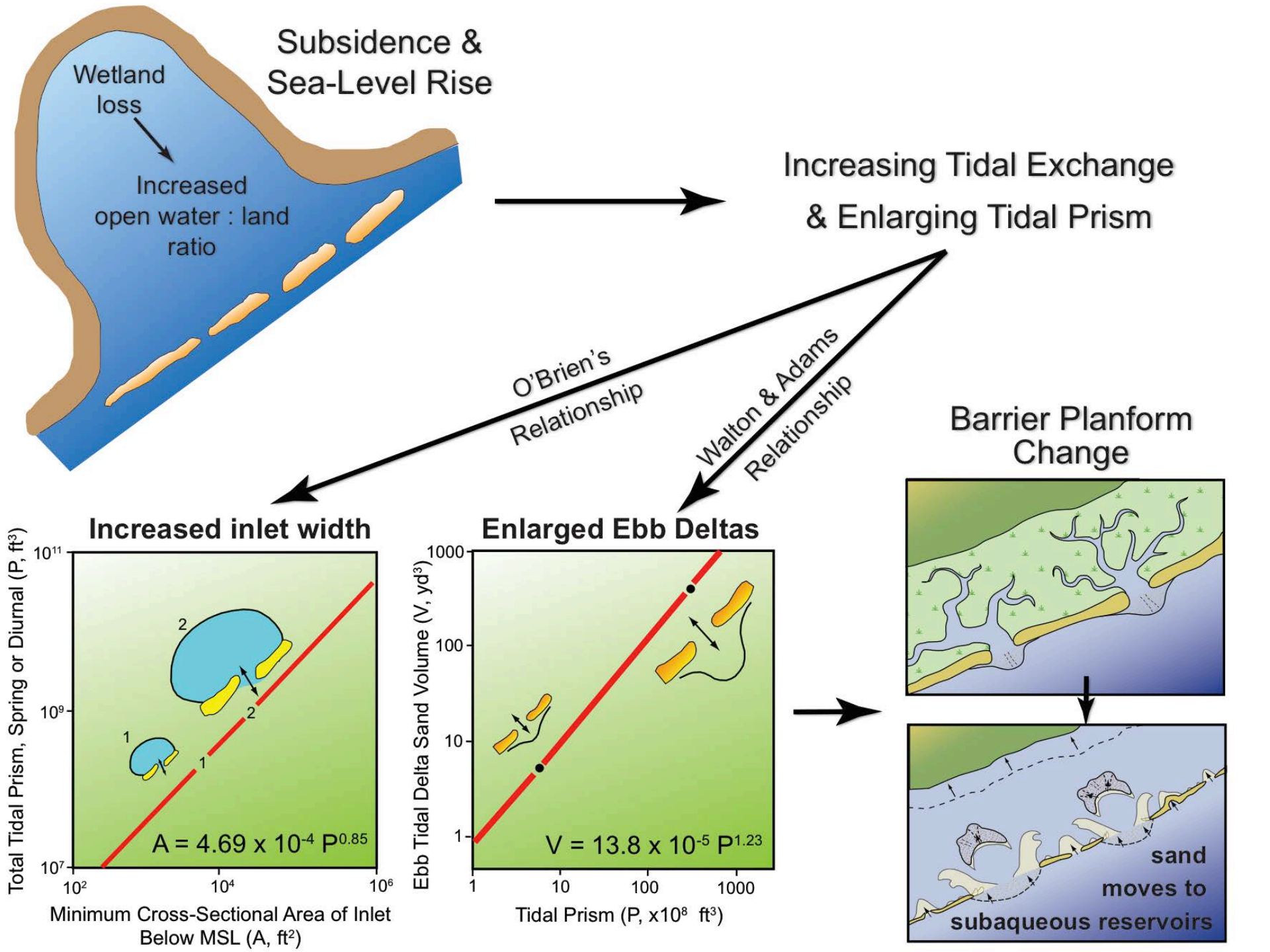
Geof Walker, *Town of Newbury*

BOSTON UNIVERSITY

THE UNIVERSITY of NEW ORLEANS

VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

Merrimack Valley Planning Commission


Subsidence &
Sea-Level Rise
Wetland
loss
Increased
open water : land
ratio
Increasing Tidal Exchange
& Enlarging Tidal Prism
O'Brien's
Relationship
Walton & Adams
Relationship
Barrier Planform
Change
Increased inlet width
Total Tidal Prism, Spring or Diurnal (P, ft³)
10¹¹
10⁹
10⁷
10²
10⁴
10⁶
1
2
2
1
A = 4.69 x 10⁻⁴ P^0.85
Minimum Cross-Sectional Area of Inlet
Below MSL (A, ft²)
Enlarged Ebb Deltas
Ebb Tidal Delta Sand Volume (V, yd³)
1000
100
10
1
1
10
100
1000
V = 13.8 x 10⁻⁵ P^1.23
Tidal Prism (P, x10⁸ ft³)
sand
moves to
subaqueous reservoirs

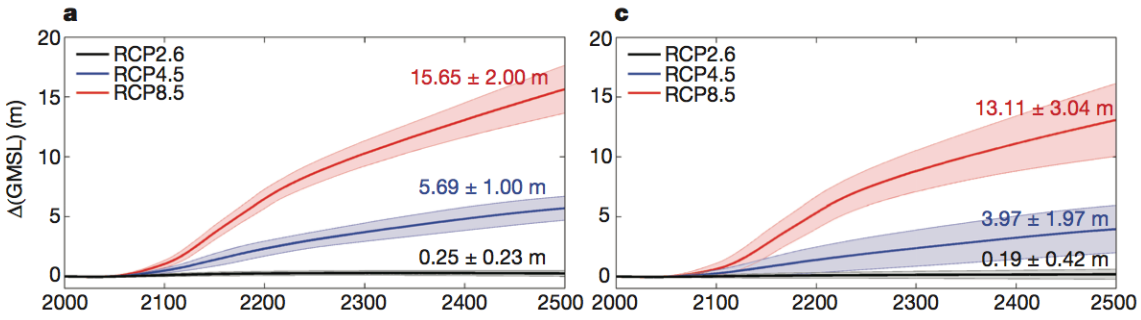
ARTICLE

doi:10.1038/nature17145

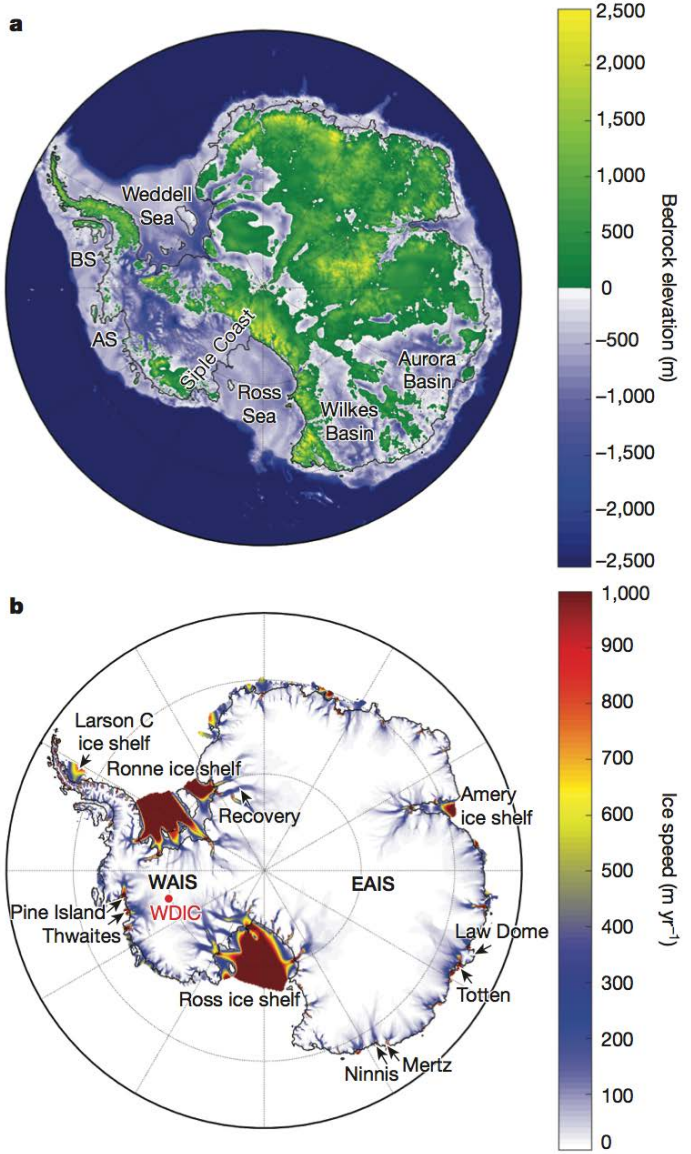
Contribution of Antarctica to past and future sea-level rise

Robert M. DeConto[1] & David Pollard[2]

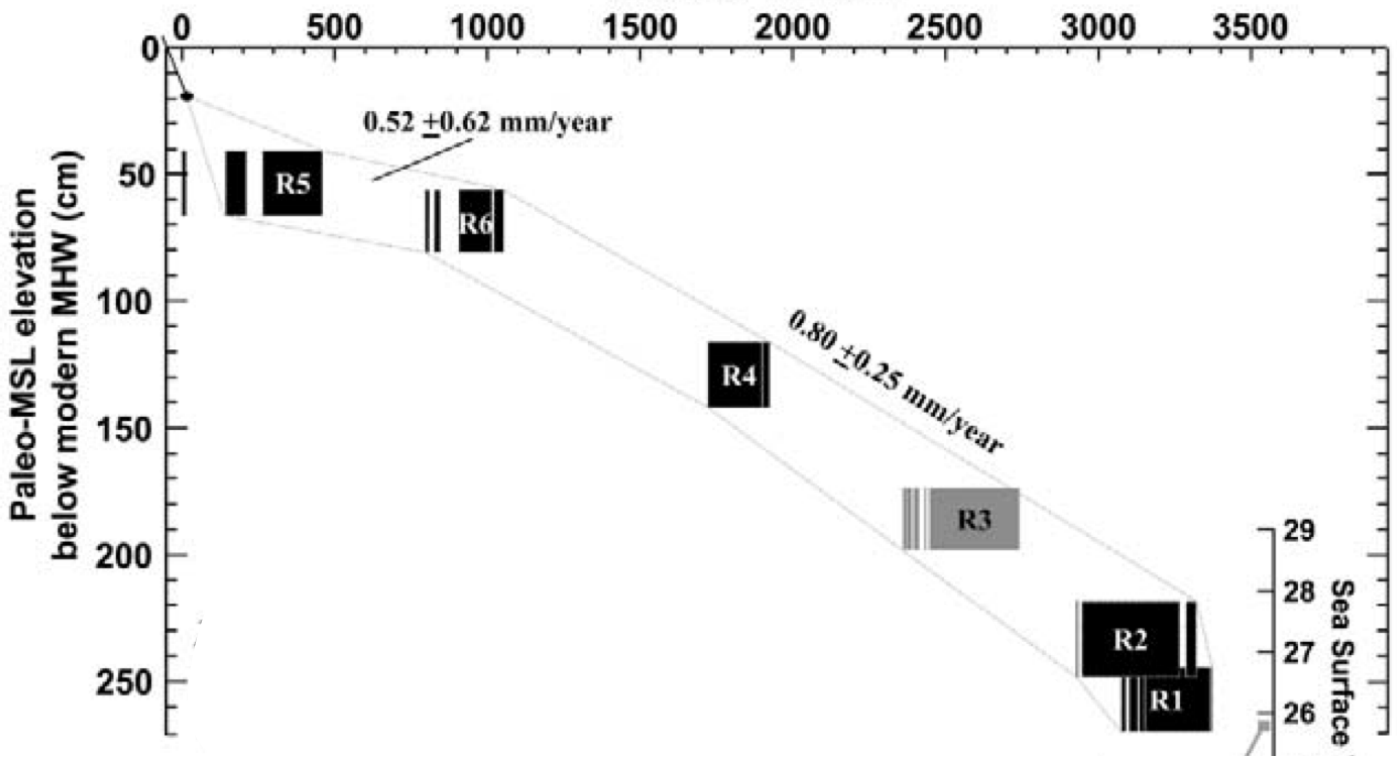
Polar temperatures over the last several million years have, at times, been slightly warmer than today, y sea level has been 6–9 metres higher as recently as the Last Interglacial (130,000 to 115,000 years ago) and during the Pliocene epoch (about three million years ago). In both cases the Antarctic ice sheet has been ir primary contributor, hinting at its future vulnerability. Here we use a model coupling ice sheet and clim including previously underappreciated processes linking atmospheric warming with hydrofracturing of shelves and structural collapse of marine-terminating ice cliffs—that is calibrated against Pliocene and l sea-level estimates and applied to future greenhouse gas emission scenarios. Antarctica has the potenti more than a metre of sea-level rise by 2100 and more than 15 metres by 2500, if emissions continue ur case atmospheric warming will soon become the dominant driver of ice loss, but prolonged ocean war its recovery for thousands of years.



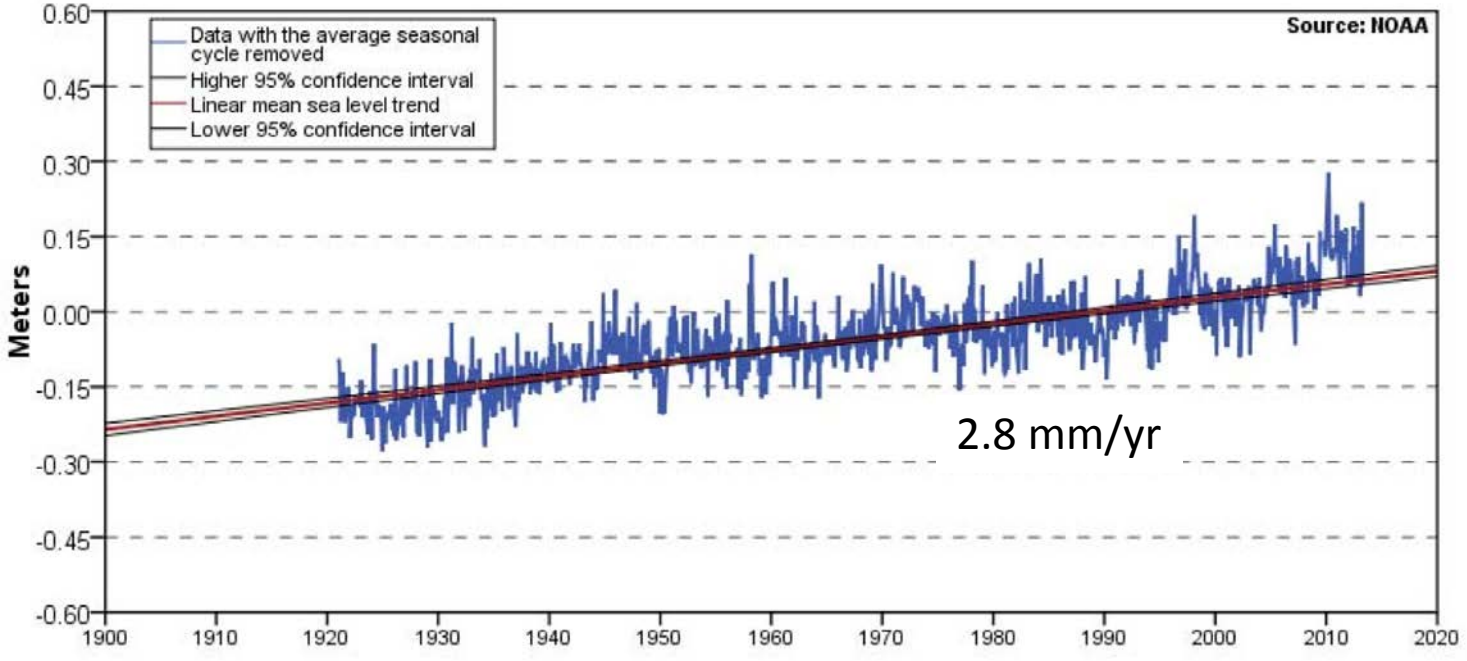
"When applied to future scenarios with high greenhouse gas emissions, our paleo-filtered model ensembles show the potential for **Antarctica to contribute >1 m of GMSL** rise by the end of this century."



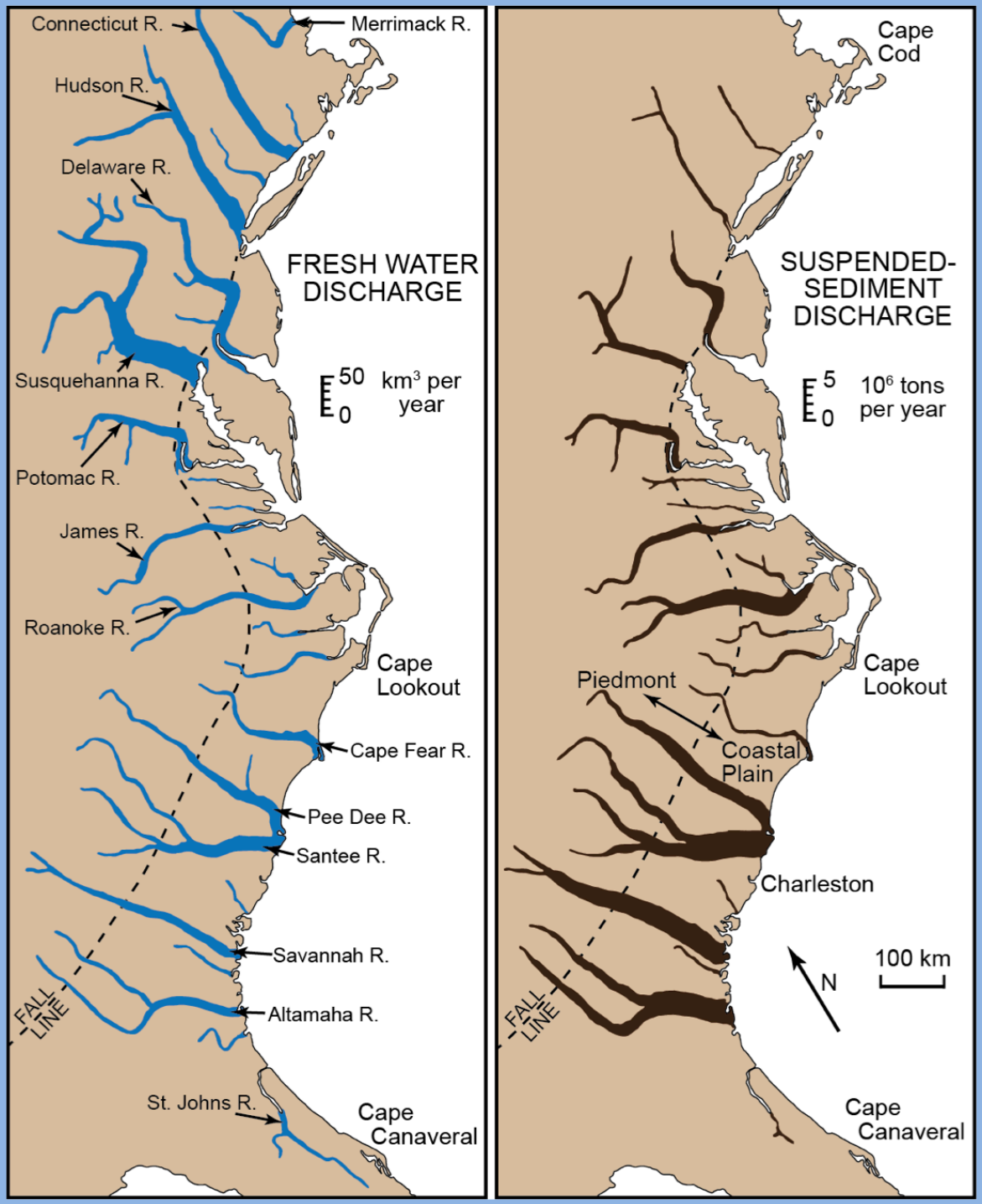
Sea Level Curves



(Donnelly 2006)
Romney marsh



Boston Harbor
Tide gage record

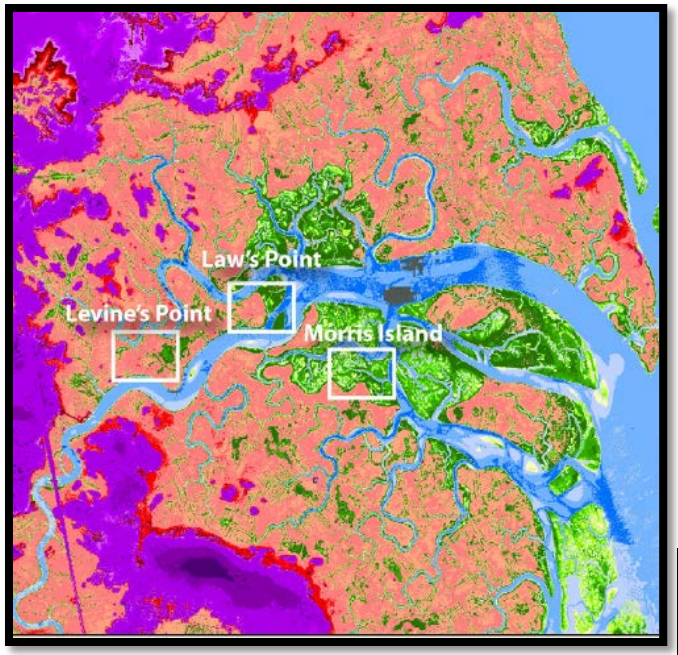


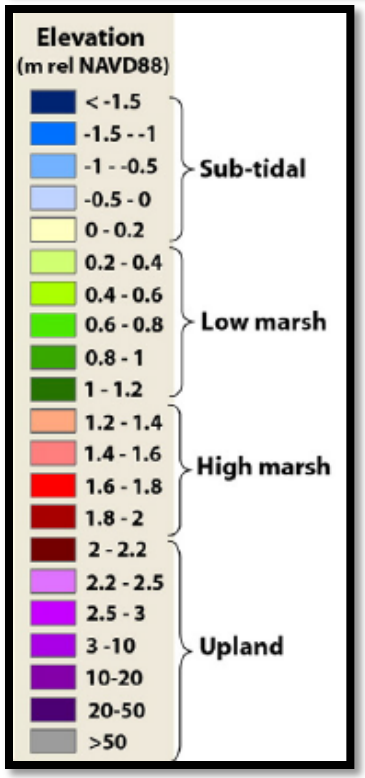
Inverse Relationship

- *Northern rivers* high Q_w and low Q_s
- *Southern rivers* low Q_w and high Q_s

(Meade, 1975)

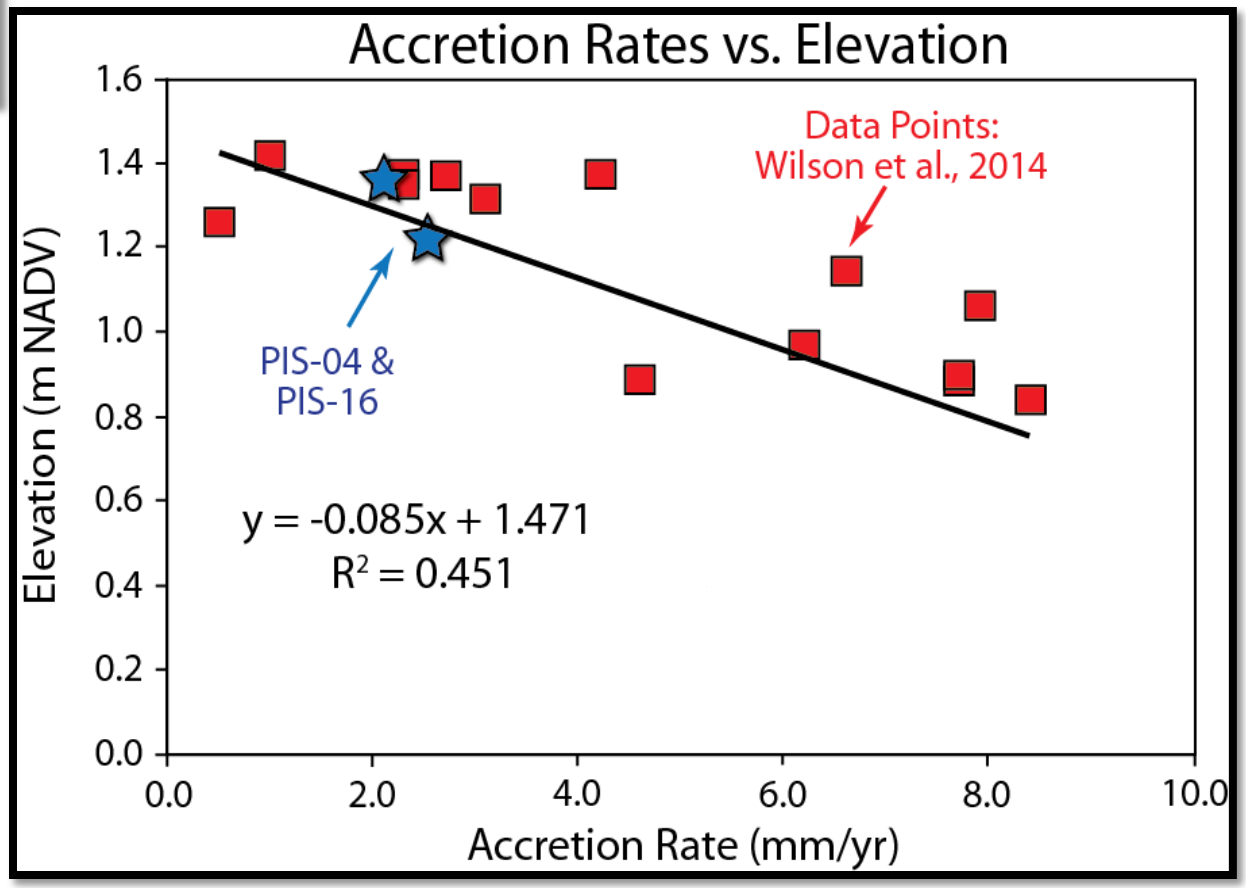
Preliminary Results:
Accretion Rates





Wilson et al., 2014

- PIS-16 (Merrimack River mouth) accretion > PIS-04 (south of PI Airport); BUT, different elevations
- Two preliminary data points match well with published data
- Apparent trend: accretion rates in high marsh (1- 4.2 mm/yr) and accretion rates in low marsh (5-9 mm/yr)

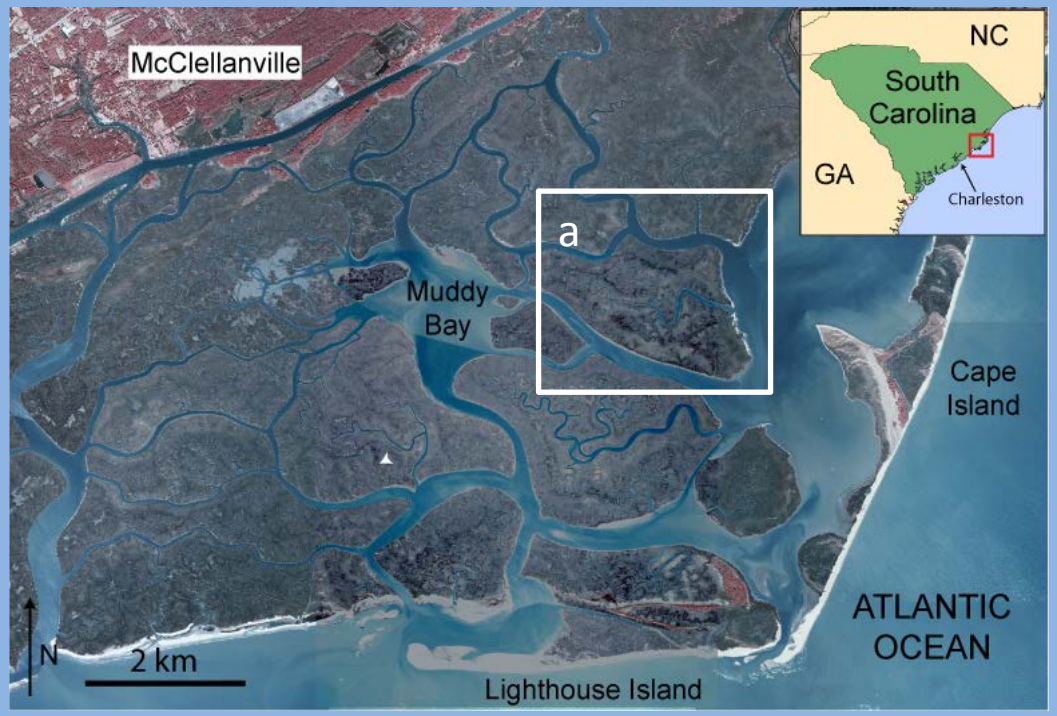


Increased Flooding and Draining of the Marsh

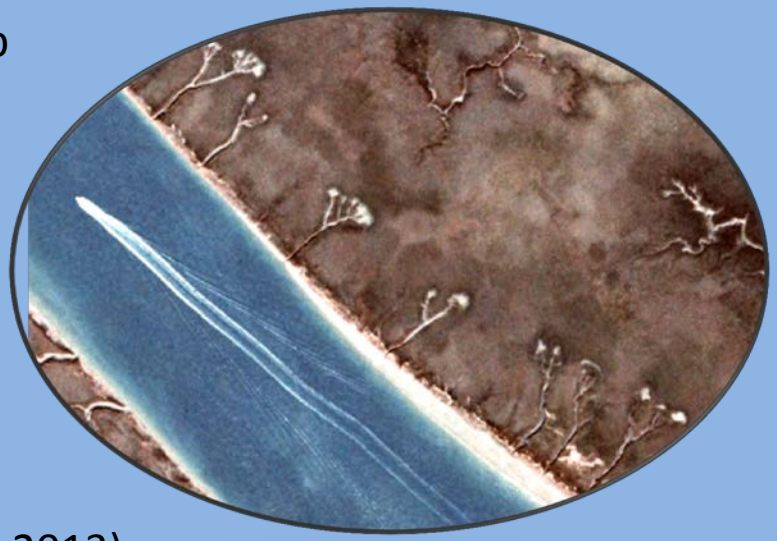
Wilson et al (2014):

- Natural systems show slight headward erosion
- Drainage ditches no headward, some filling

Cape Romain, SC



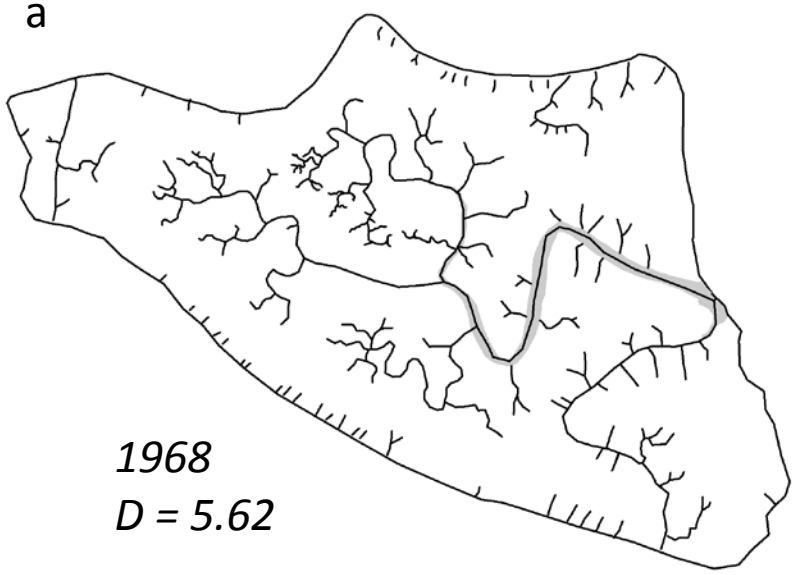
b



(Wilson, 2013)

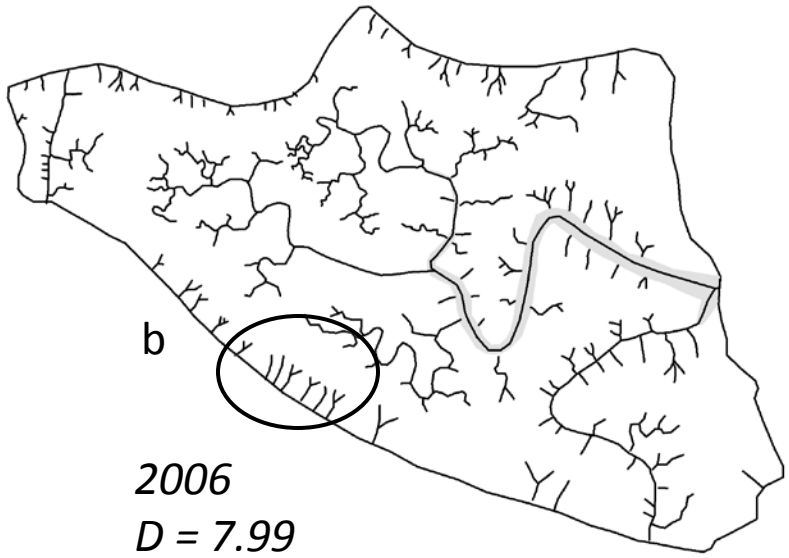
Drainage Density

a



1968

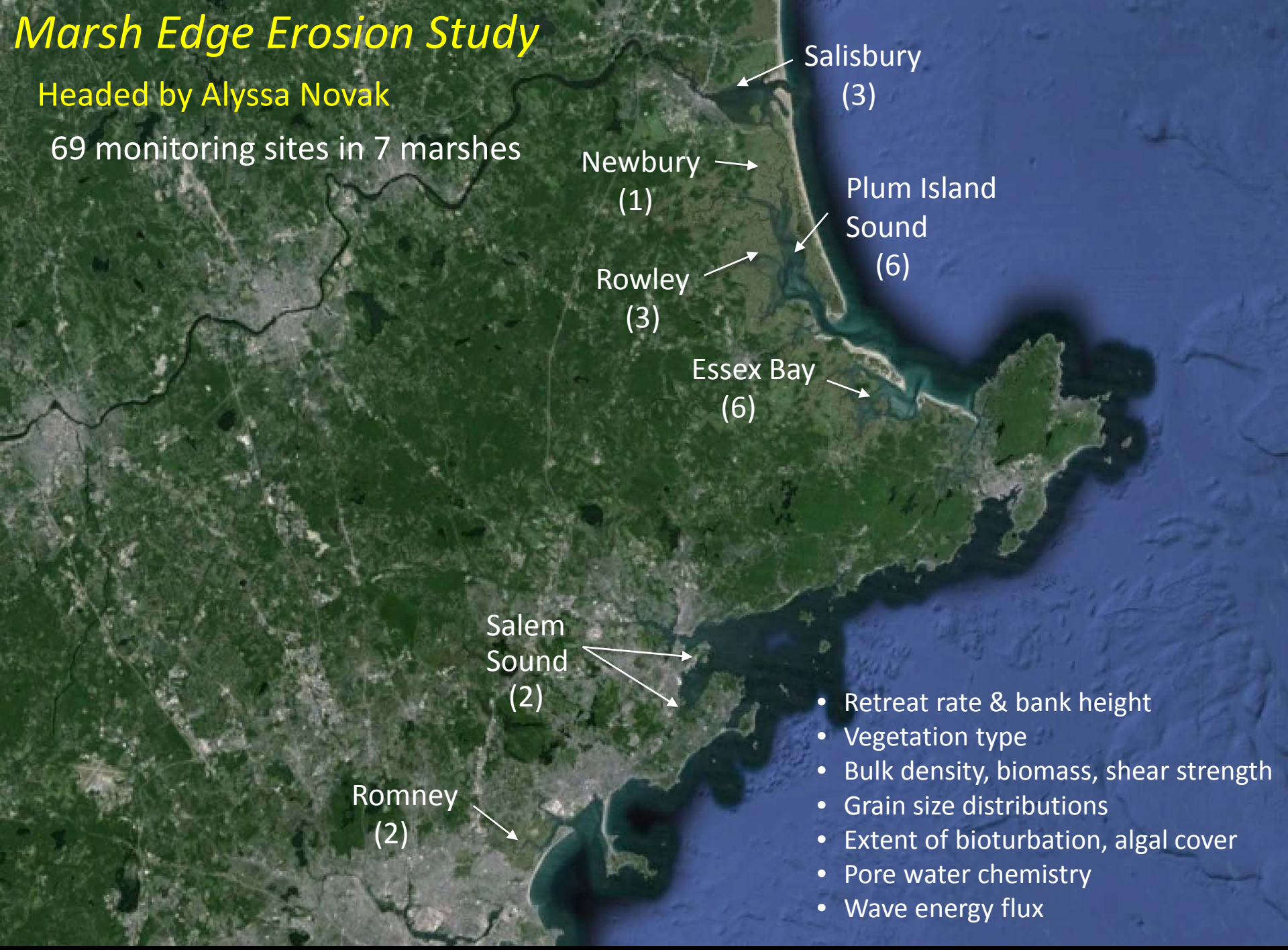
D = 5.62

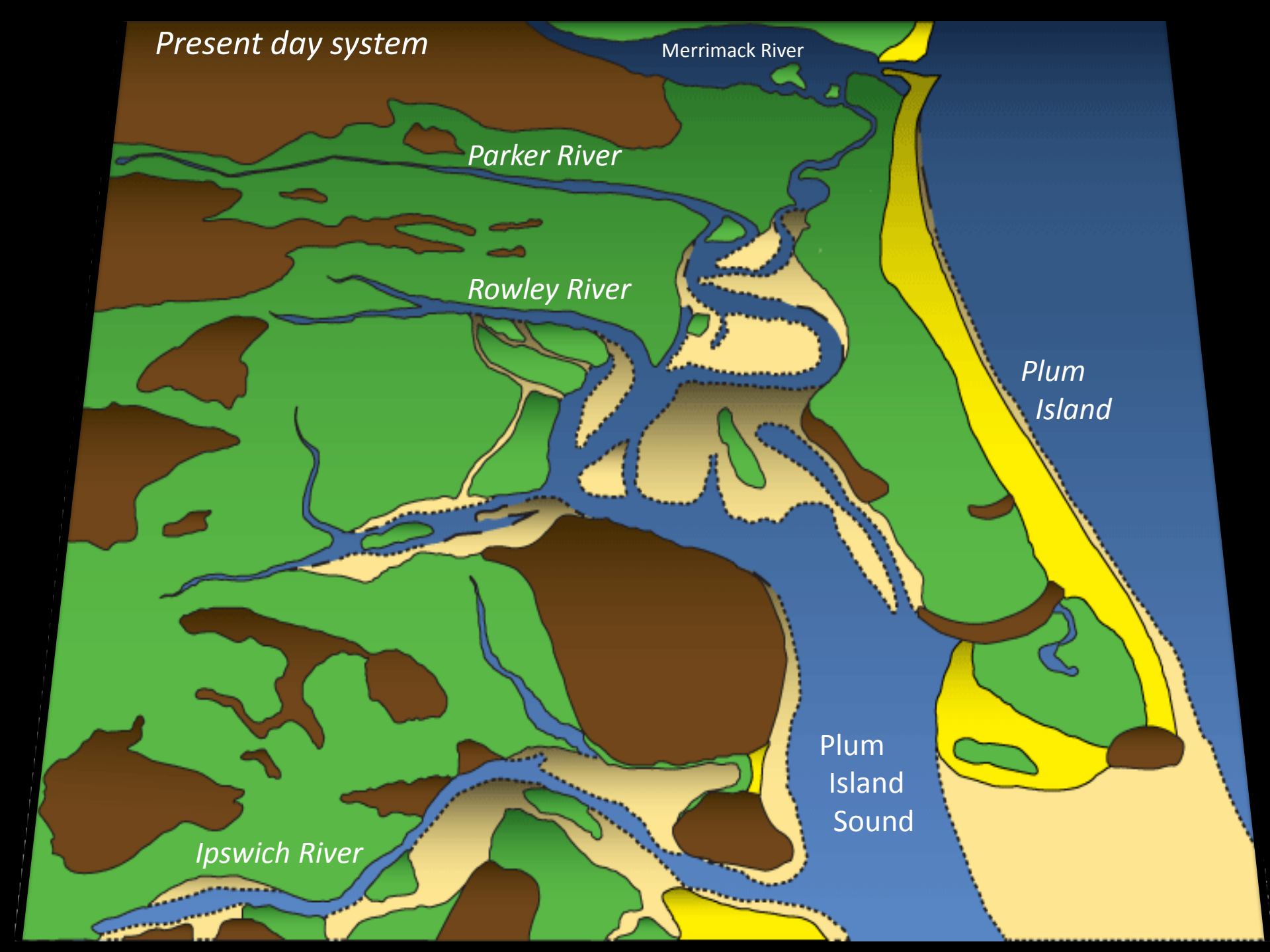


2006

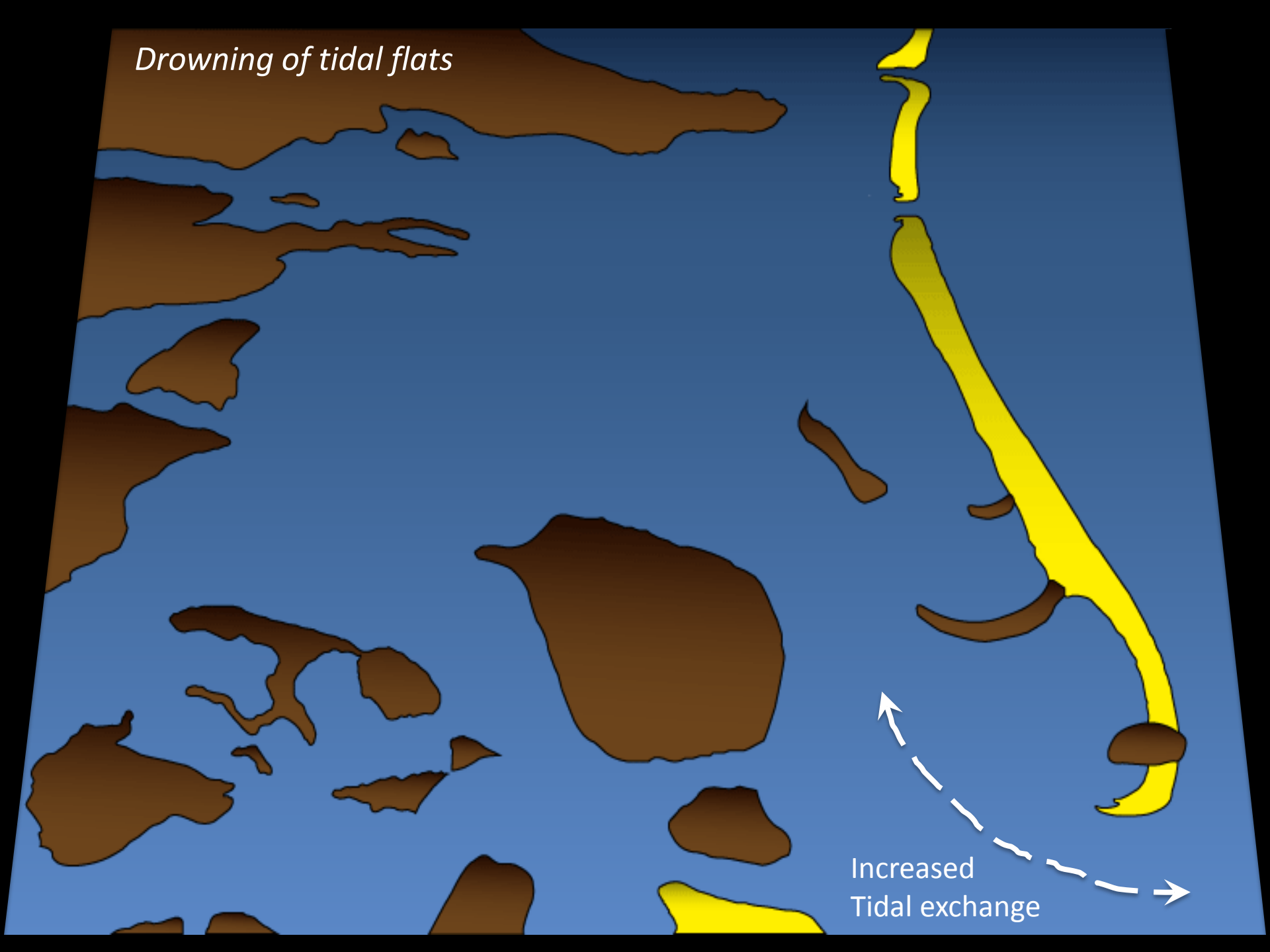
D = 7.99

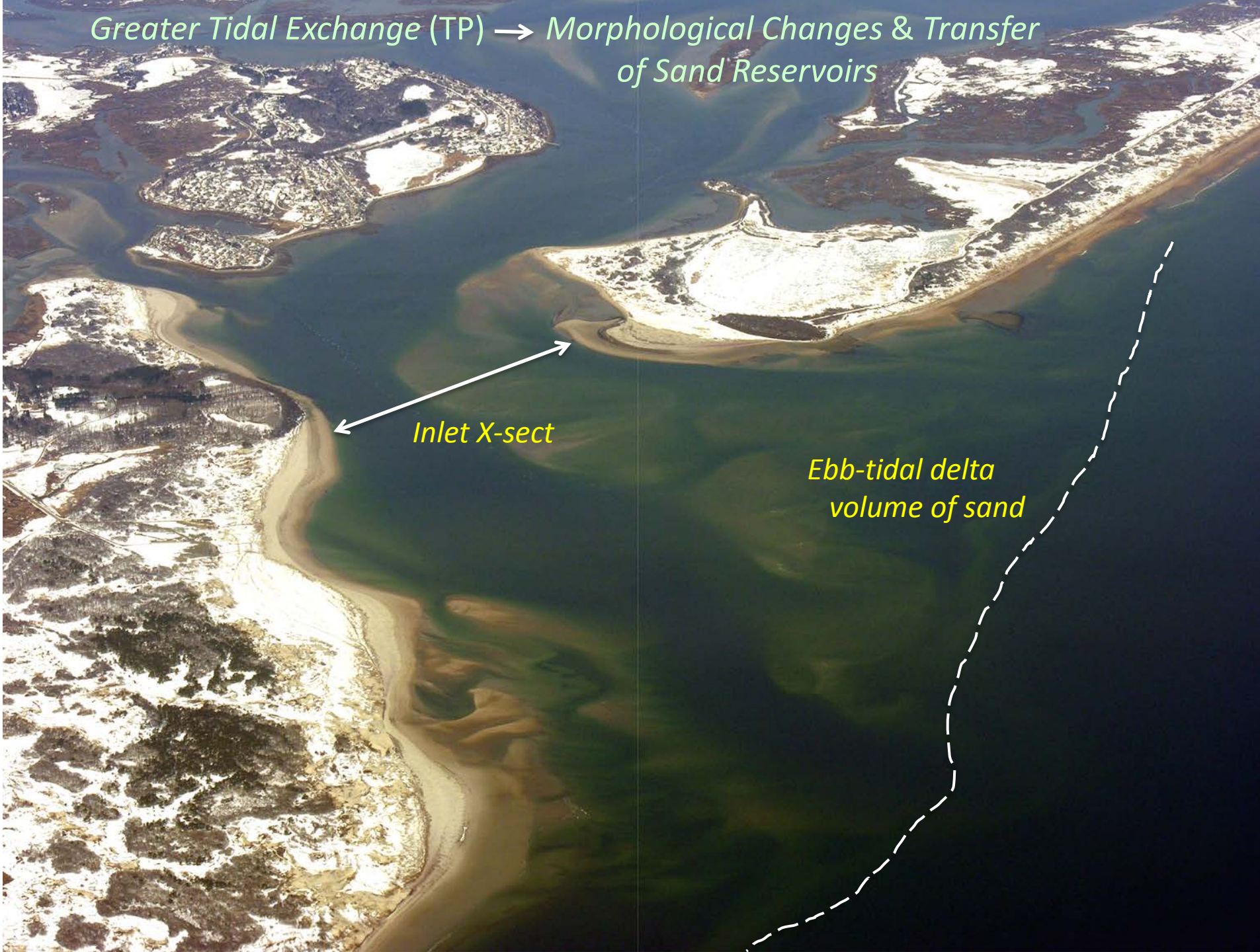
Essex Bay

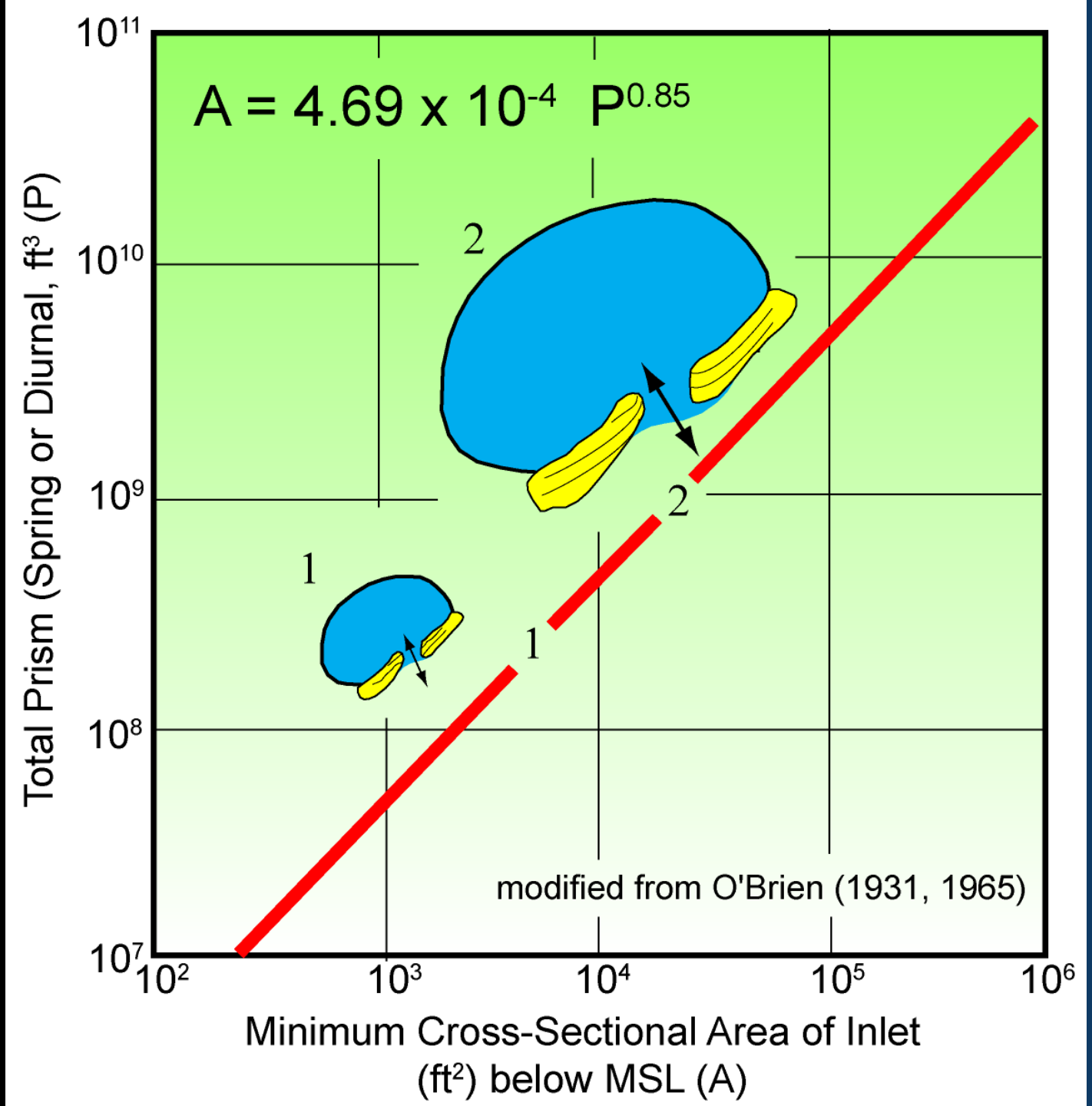

Marsh Edge Erosion Study
Headed by Alyssa Novak
69 monitoring sites in 7 marshes
Salisbury (3)
Newbury (1)
Plum Island Sound (6)
Rowley (3)
Essex Bay (6)
Salem Sound (2)
Romney (2)
• Retreat rate & bank height
• Vegetation type
• Bulk density, biomass, shear strength
• Grain size distributions
• Extent of bioturbation, algal cover
• Pore water chemistry
• Wave energy flux

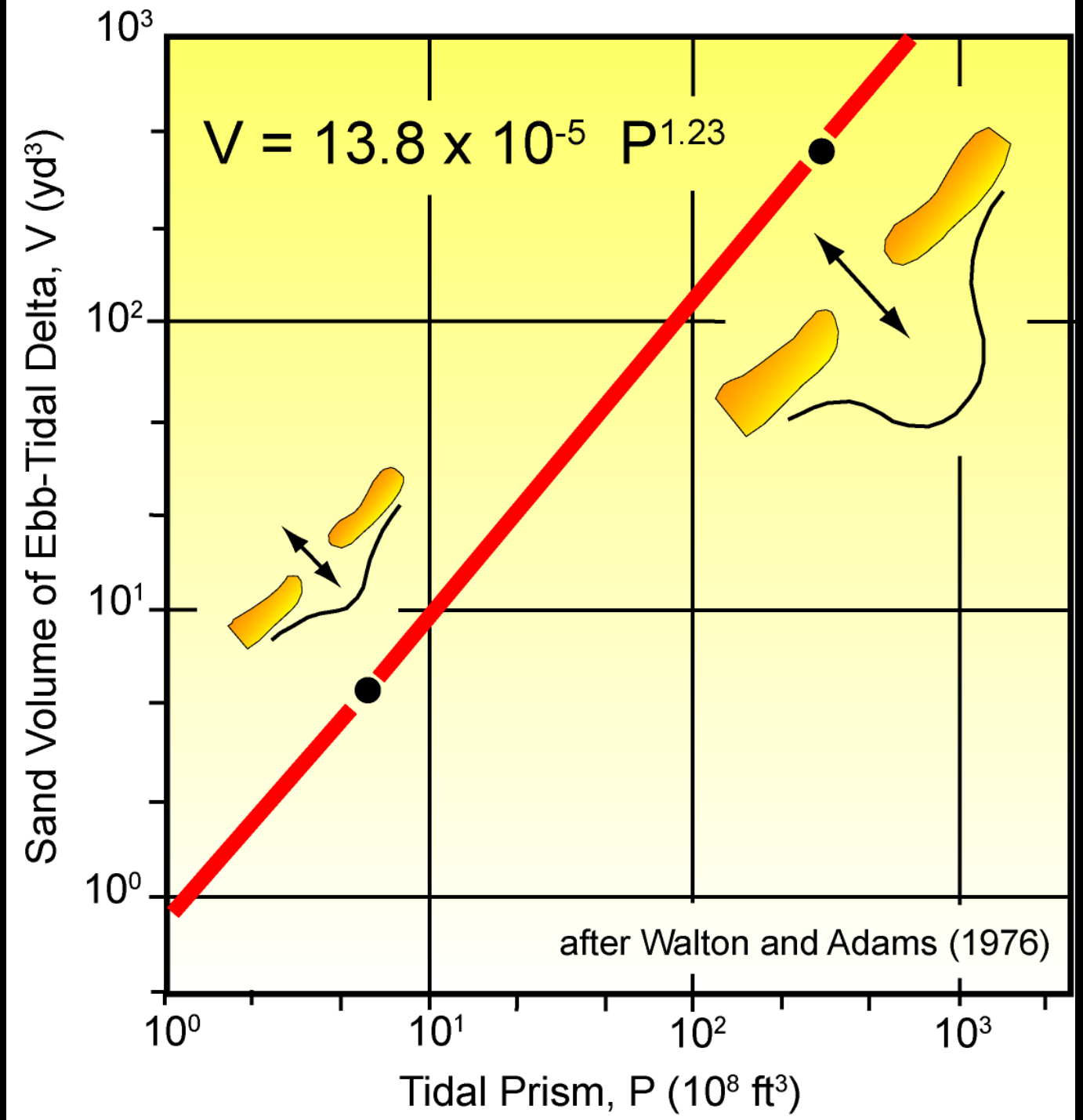

Present day system
Merrimack River
Parker River
Rowley River
Plum
Island
Plum
Island
Sound
Ipswich River


Conversion of Marsh to tidal flats


Drowning of tidal flats
Increased
Tidal exchange

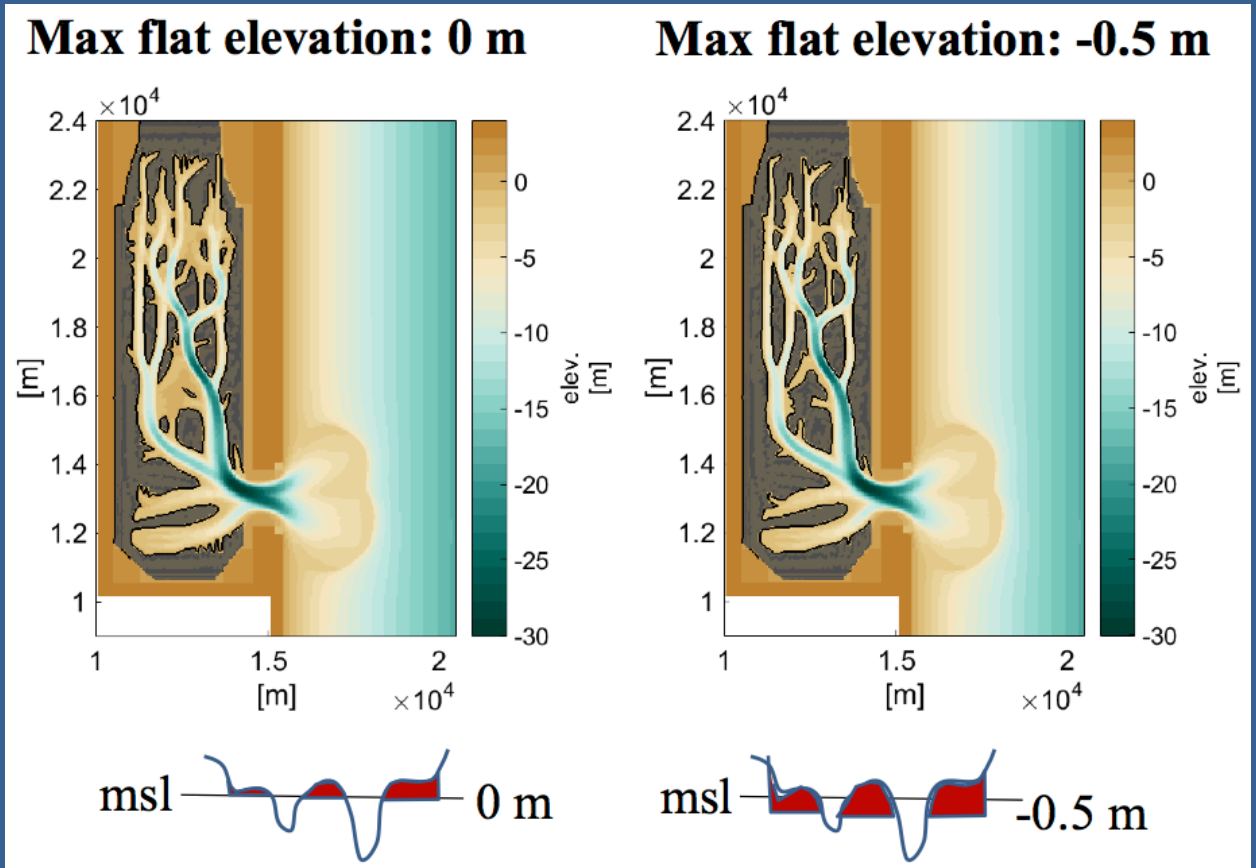

Greater Tidal Exchange (TP) → Morphological Changes & Transfer of Sand Reservoirs
Inlet X-sect
Ebb-tidal delta volume of sand


A = 4.69 x 10-4 P0.85
Total Prism (Spring or Diurnal, ft3 (P)
Minimum Cross-Sectional Area of Inlet
(ft2) below MSL (A)
10^11
10^10
10^9
10^8
10^7
10^2
10^3
10^4
10^5
10^6
1
2
1
2
modified from O'Brien (1931, 1965)


$V = 13.8 \times 10^{-5} \; P^{1.23}$
Sand Volume of Ebb-Tidal Delta, V (yd^3)
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Tidal Prism, P (10^8 ft^3)
after Walton and Adams (1976)

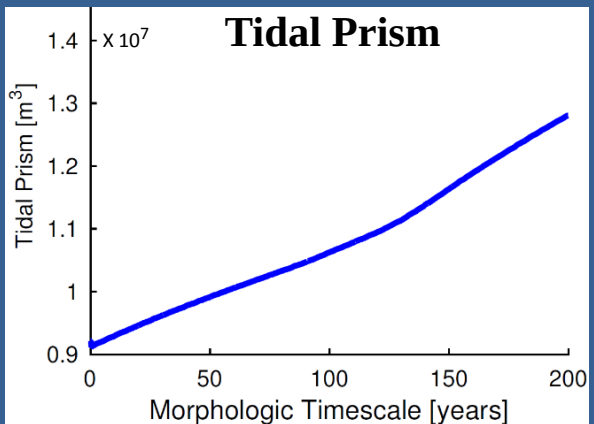

Enlarging
Inlet X-sect
Deposition of Sand
on the Ebb-tidal Delta

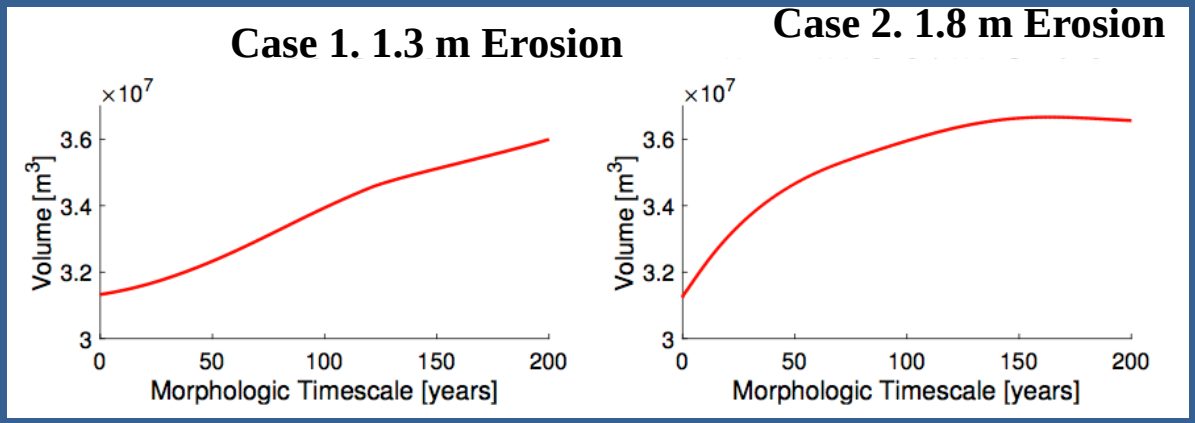
Marsh Collapse Experiments

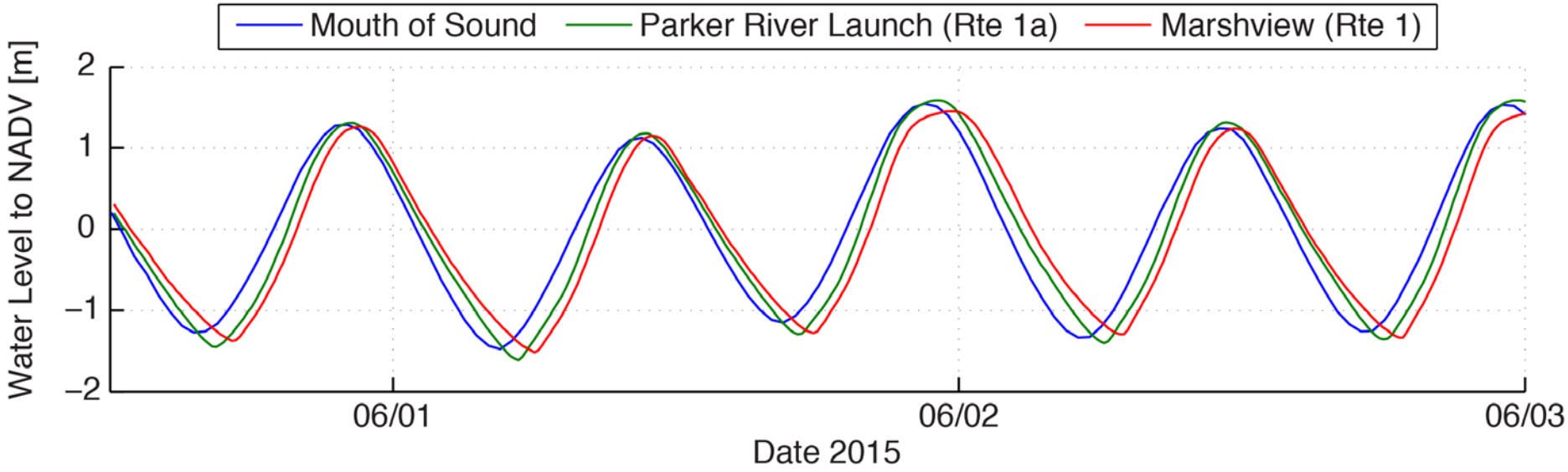


- Modeling: Delft3D
- Simulating Marsh Back-stripping
- Ebb-tidal growth

(Hanegan et al 2015)

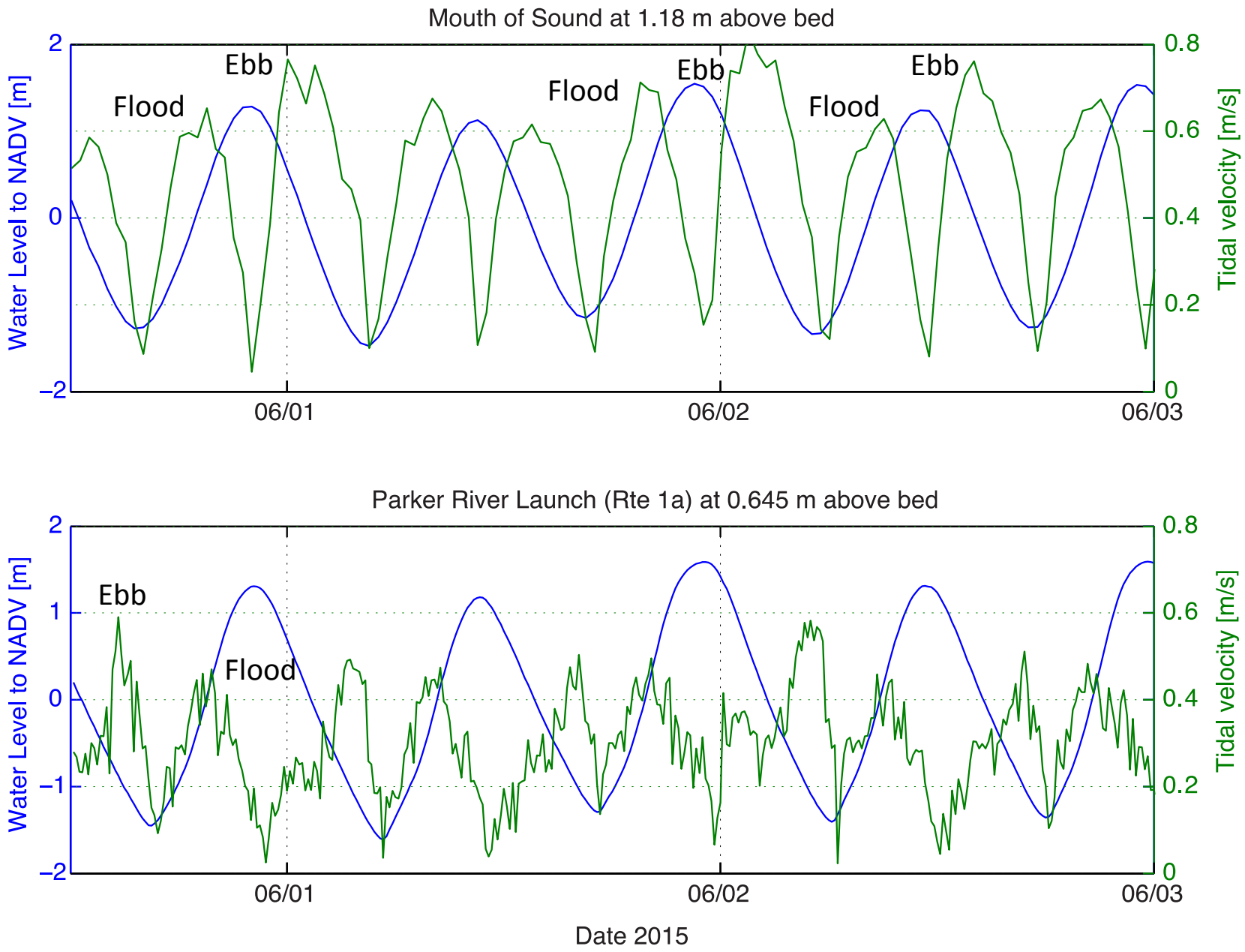





Mouth of Sound
Parker River Launch (Rte 1a)
Marshview (Rte 1)
Water Level to NADV [m]
2
1
0
−1
−2
06/01
06/02
06/03
Date 2015


Marshview
Parker River

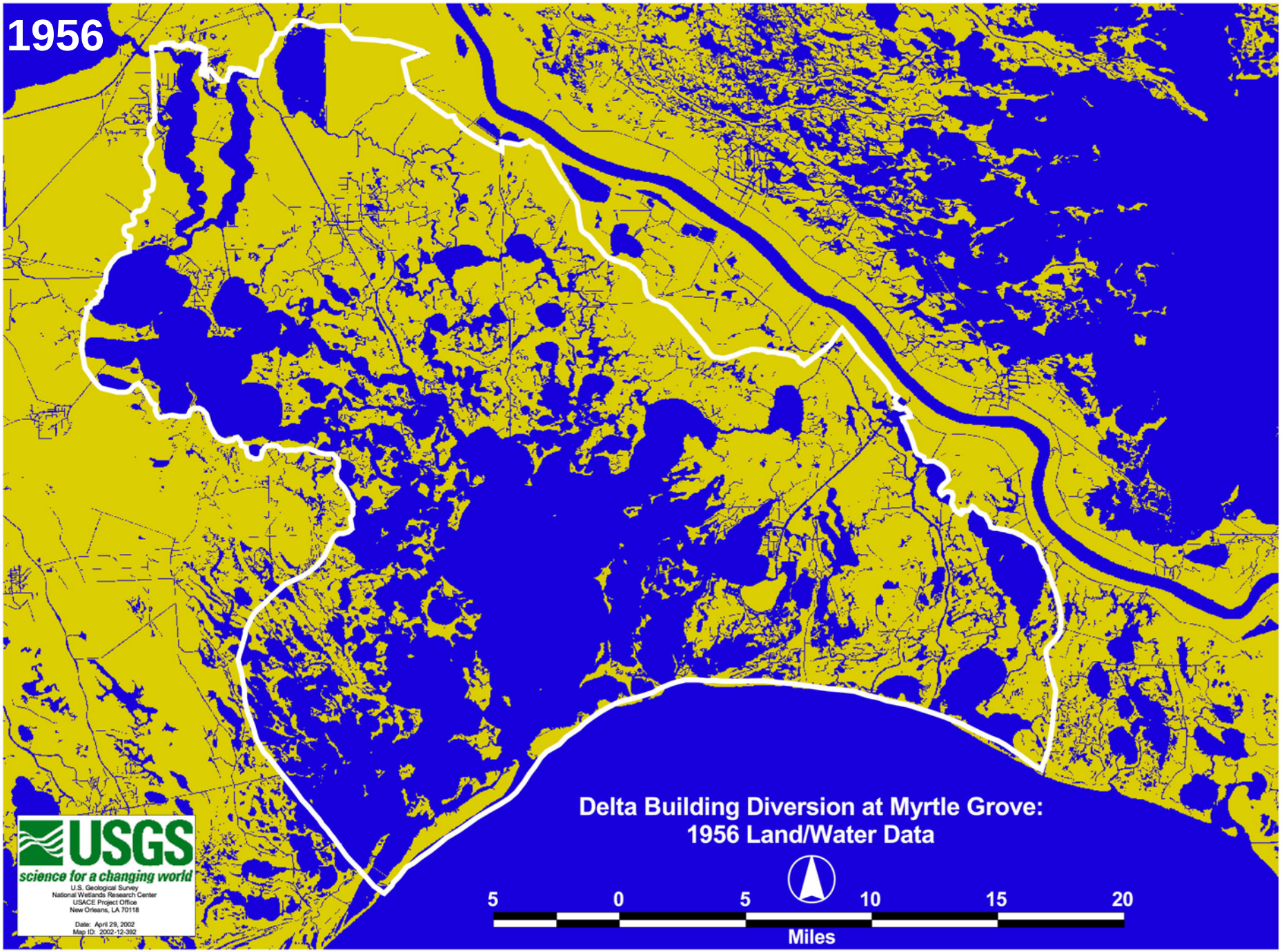

Mouth
of Sound

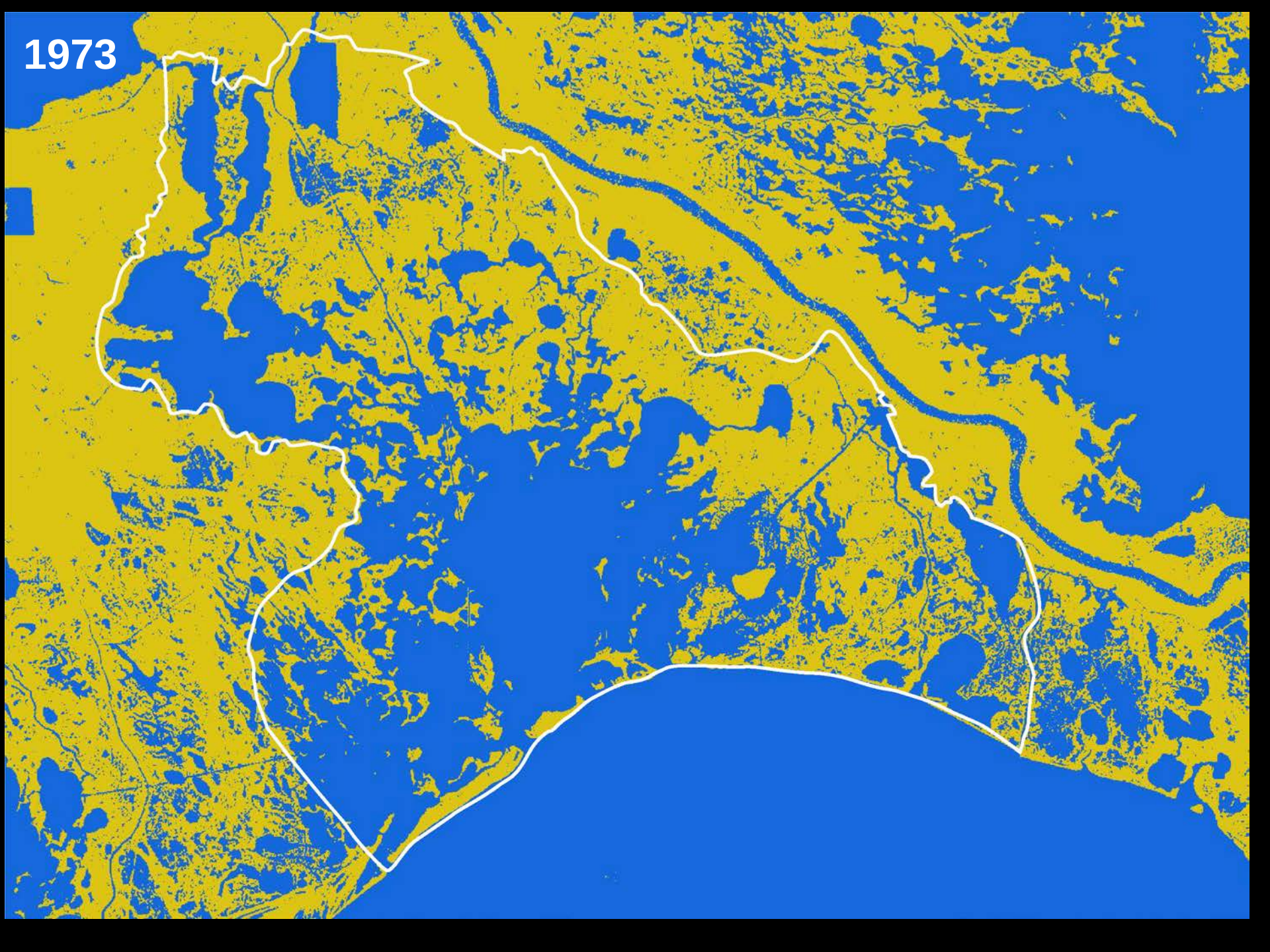

Mouth of Sound at 1.18 m above bed
Water Level to NADV [m]
Tidal velocity [m/s]
Flood
Ebb
Flood
Ebb
Flood
Ebb
2
0
−2
0.8
0.6
0.4
0.2
0
06/01
06/02
06/03
Parker River Launch (Rte 1a) at 0.645 m above bed
Water Level to NADV [m]
Tidal velocity [m/s]
Ebb
Flood
2
1
0
−1
−2
0.8
0.6
0.4
0.2
0
06/01
06/02
06/03
Date 2015

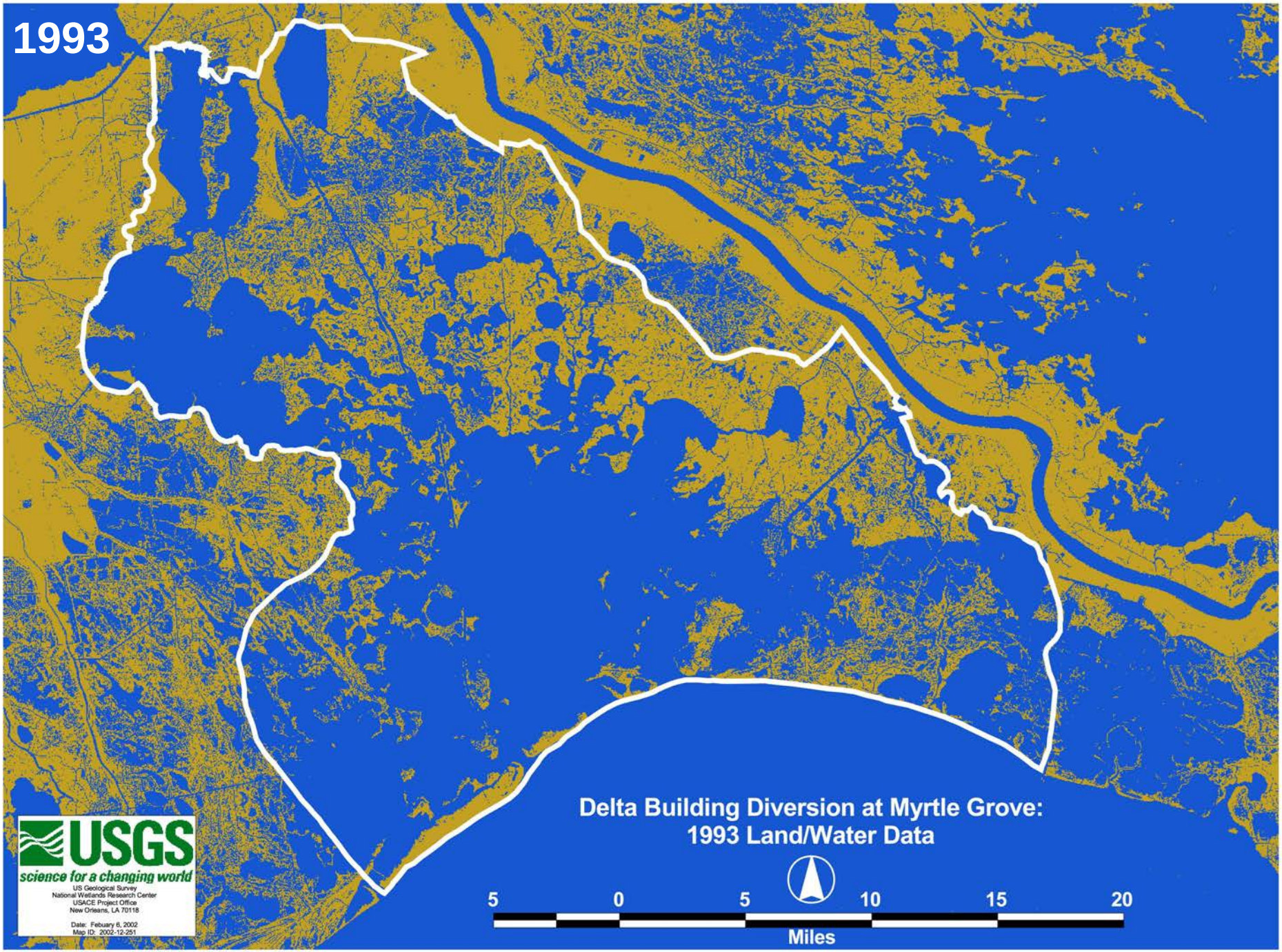
Sand deposition inside the basin

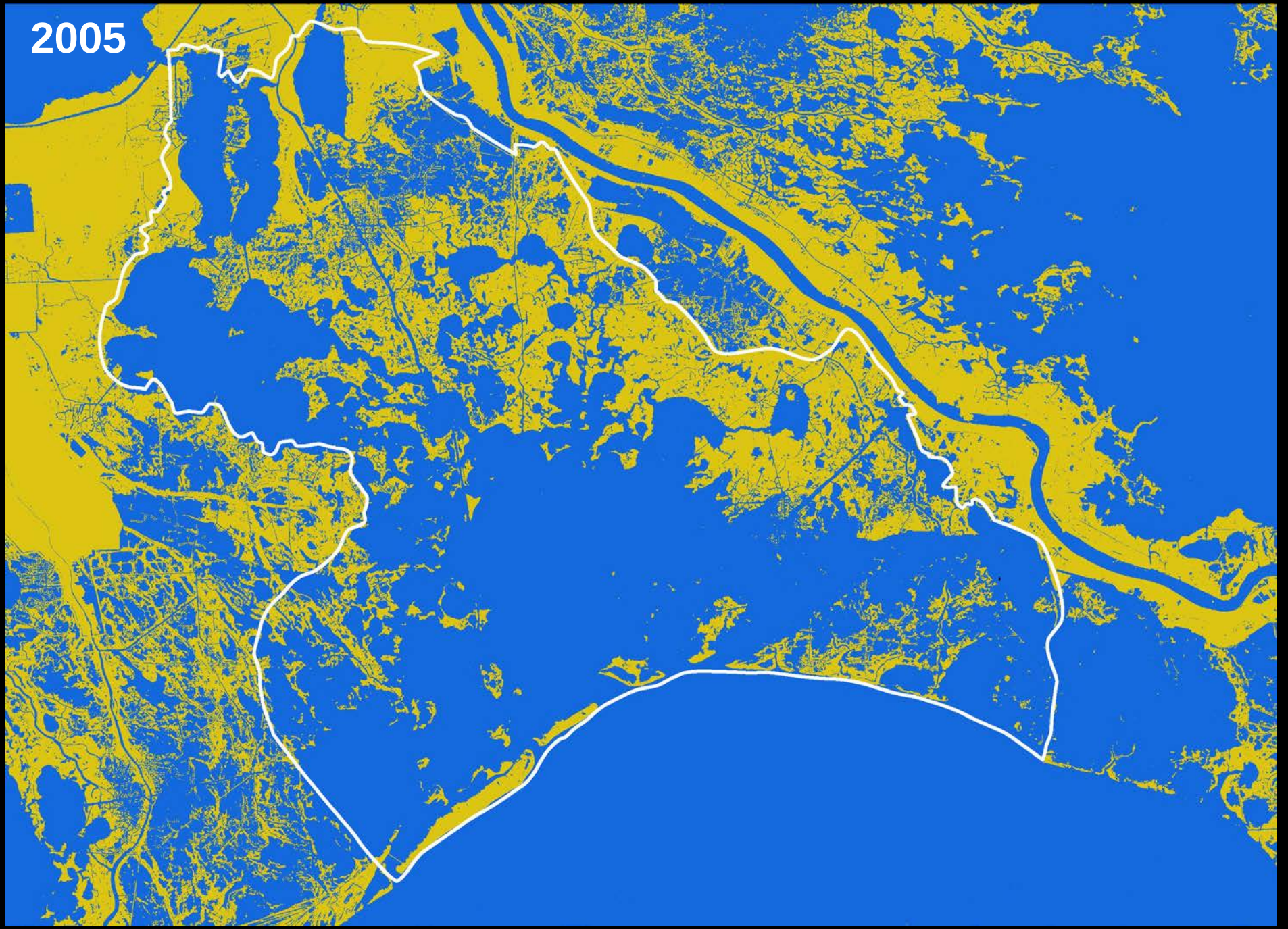

New Orleans
Barataria Bay
Birdfoot Delta

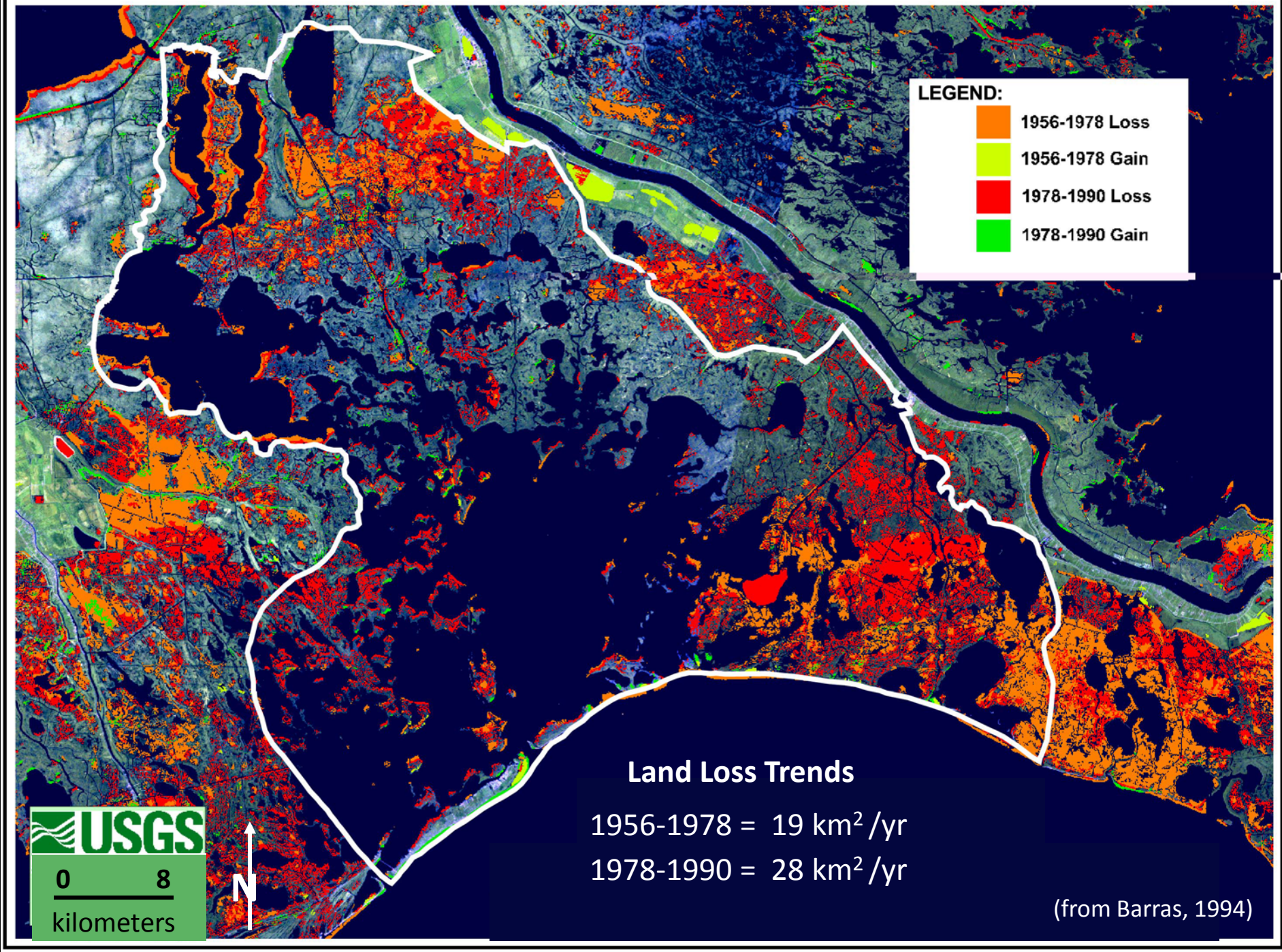

Barataria Bay
Mississippi River
Plaquemines Delta
LST
Lafourche Delta
LST

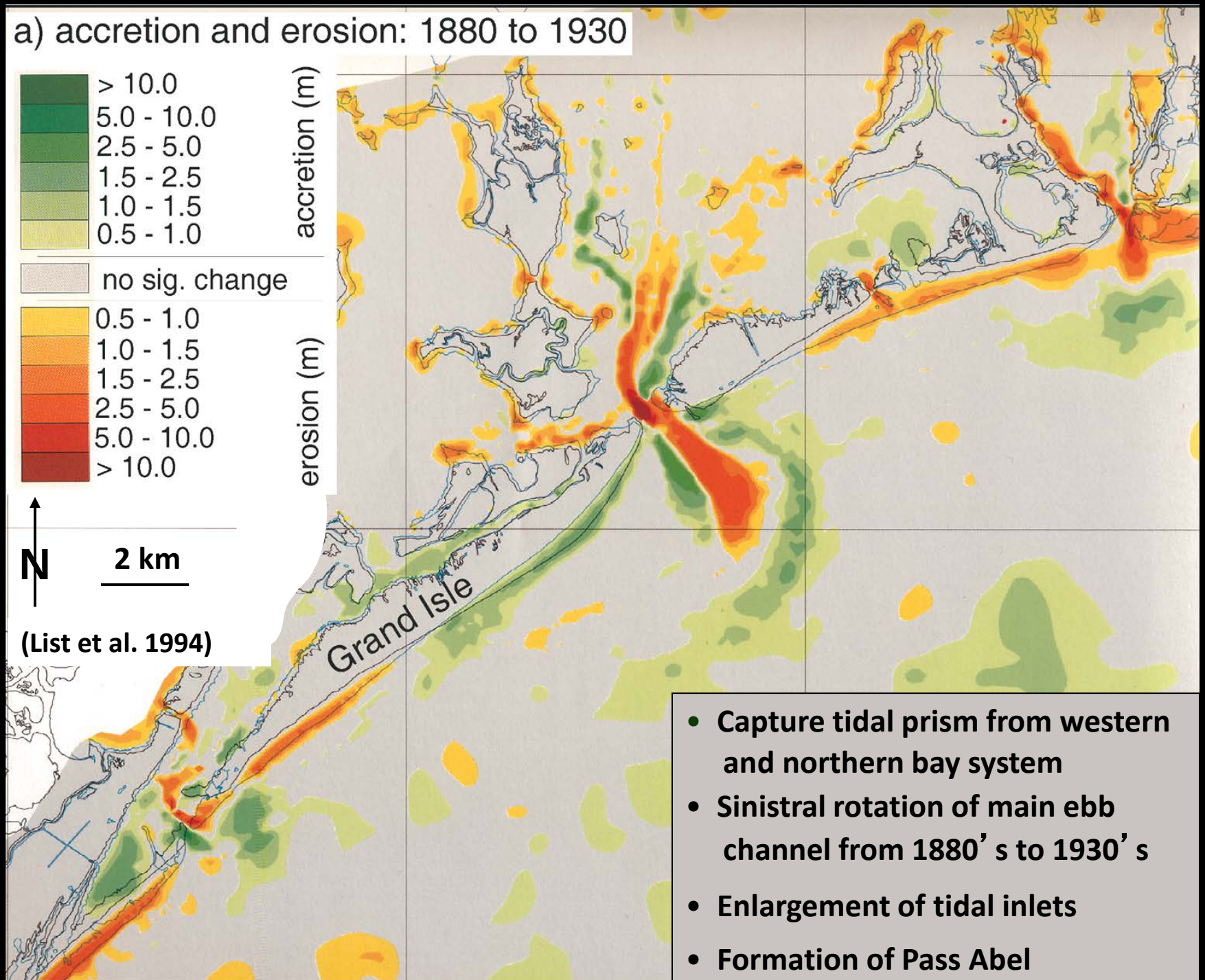

1956
Delta Building Diversion at Myrtle Grove:
1956 Land/Water Data
5 0 5 10 15 20
Miles
USGS
science for a changing world
U.S. Geological Survey
National Wetlands Research Center
USACE Project Office
New Orleans, LA 70118
Date: April 29, 2002
Map ID: 2002-12-392

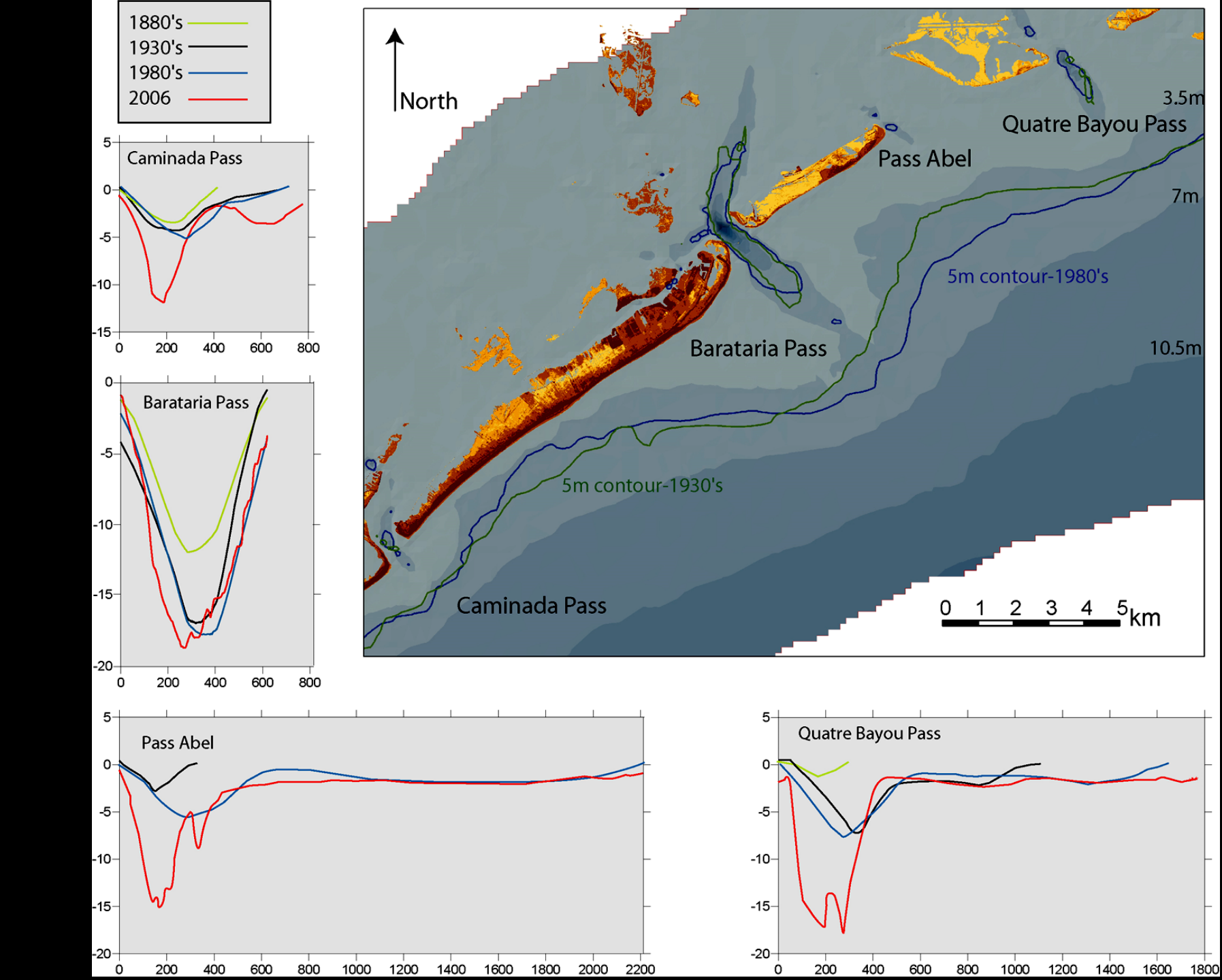

1973


1993
Delta Building Diversion at Myrtle Grove:
1993 Land/Water Data
5 0 5 10 15 20
Miles
USGS
science for a changing world
US Geological Survey
National Wetlands Research Center
USACE Project Office
New Orleans, LA 70118
Date: Febuary 6, 2002
Map ID: 2002-12-251


2005

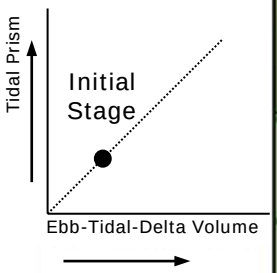

LEGEND:
1956-1978 Loss
1956-1978 Gain
1978-1990 Loss
1978-1990 Gain
Land Loss Trends
1956-1978 = 19 km² /yr
1978-1990 = 28 km² /yr
(from Barras, 1994)
USGS
0
8
kilometers
N

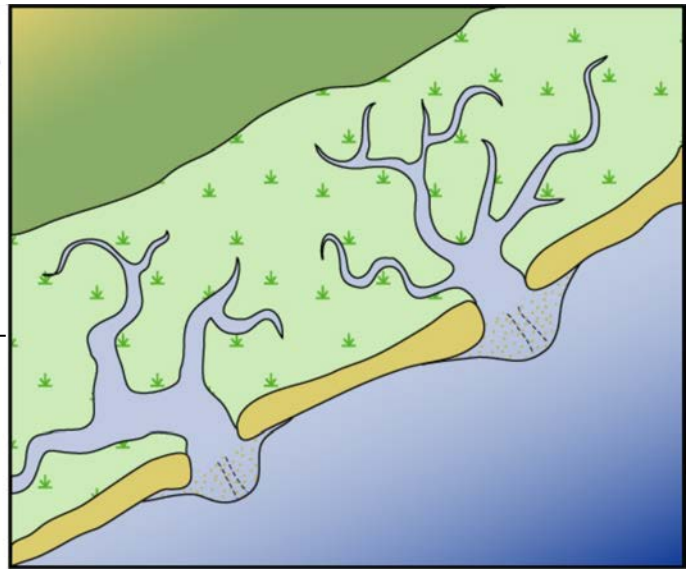

a) accretion and erosion: 1880 to 1930
> 10.0
5.0 - 10.0
2.5 - 5.0
1.5 - 2.5
1.0 - 1.5
0.5 - 1.0
accretion (m)
no sig. change
0.5 - 1.0
1.0 - 1.5
1.5 - 2.5
2.5 - 5.0
5.0 - 10.0
> 10.0
erosion (m)
N
2 km
(List et al. 1994)
Grand Isle
• Capture tidal prism from western and northern bay system
• Sinistral rotation of main ebb channel from 1880's to 1930's
• Enlargement of tidal inlets
• Formation of Pass Abel


1880's
1930's
1980's
2006
North
3.5m
Quatre Bayou Pass
Pass Abel
7m
5m contour-1980's
Barataria Pass
10.5m
5m contour-1930's
Caminada Pass
0 1 2 3 4 5 km
Caminada Pass
Barataria Pass
Pass Abel
Quatre Bayou Pass

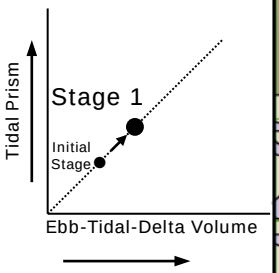
Conceptual Model of Barrier Island and Tidal Evolution in a Regime of Accelerated Sea-Level Rise

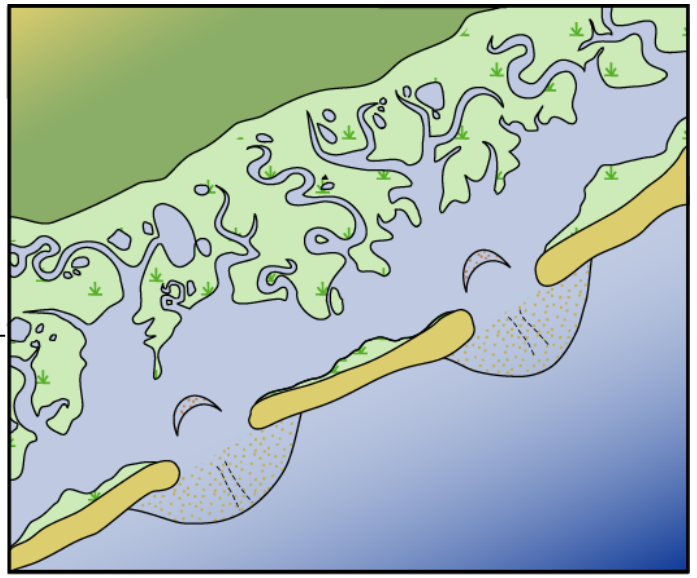
Initial Condition:
Stable Barrier



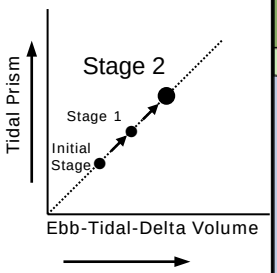


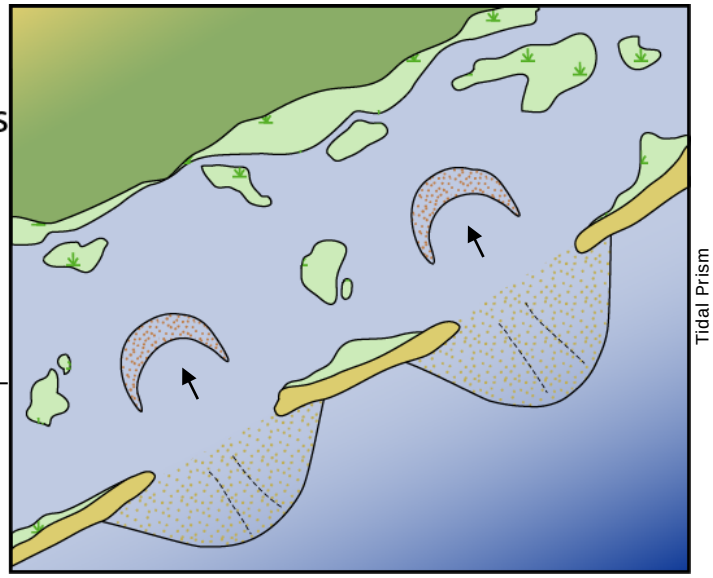
Stage 1:
Marsh Decline



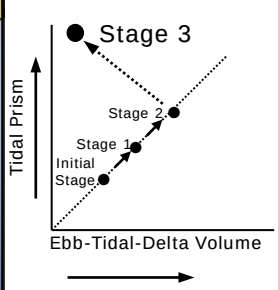


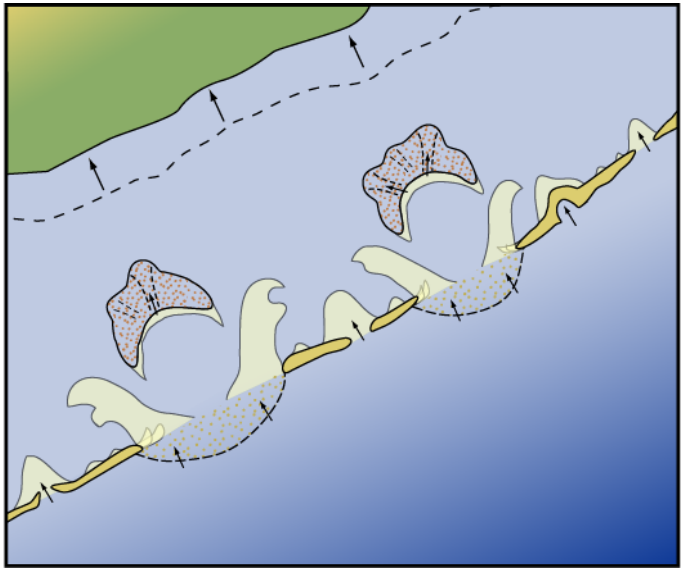
Stage 2:
Fringing Marsh
& Marsh Islands





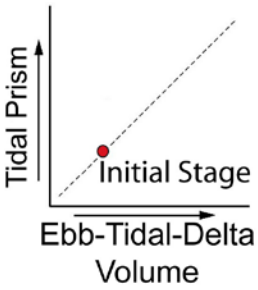
Stage 3:
Runaway
Transgression

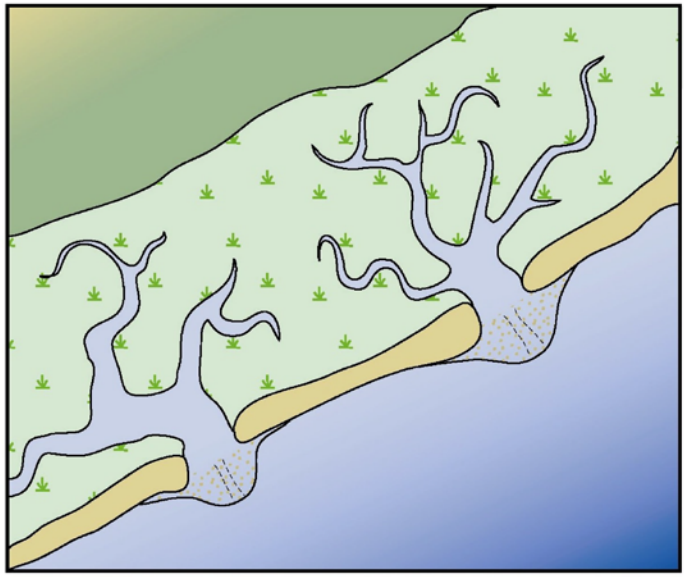




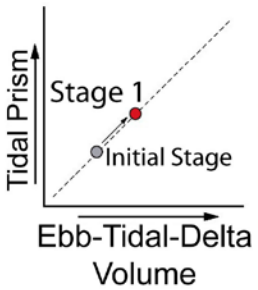
Back-stripping marsh (1 to 2m thick)
Doubles the Tidal Prism
Vastly Enlarging the E-T-D
Equivalent to 65% of Plum Island

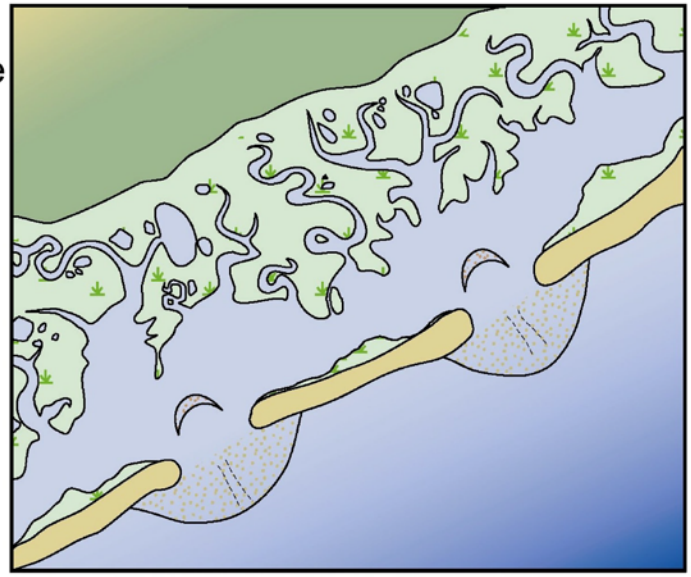
Initial Condition:
Stable Barrier



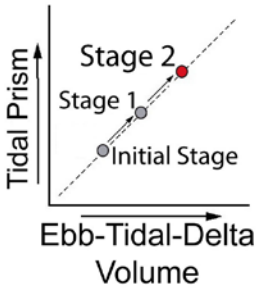


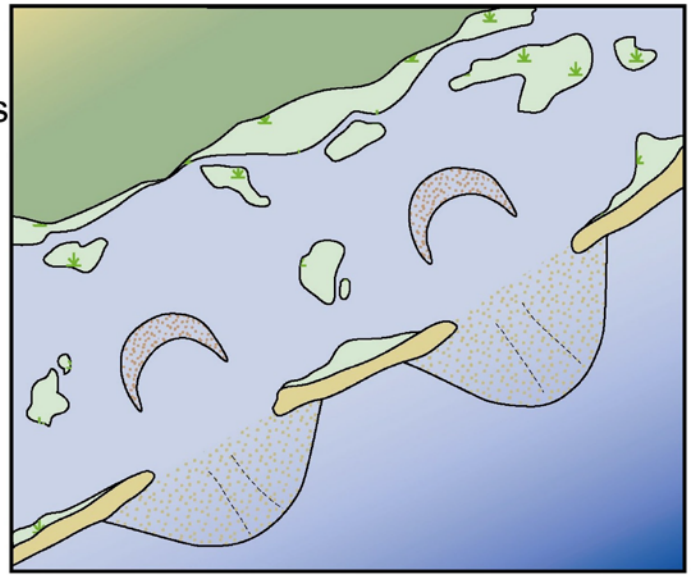
Stage 1:
Marsh Decline



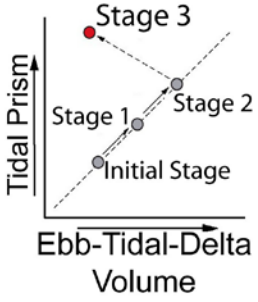


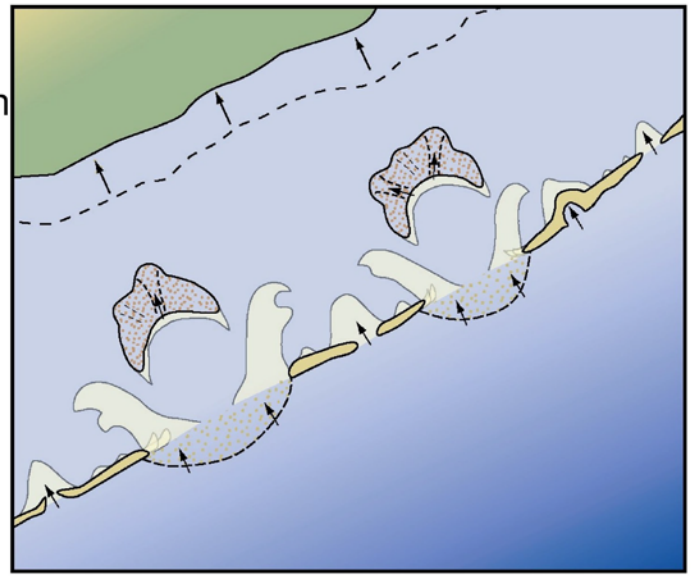
Stage 2:
Fringing Marsh
& Marsh Islands

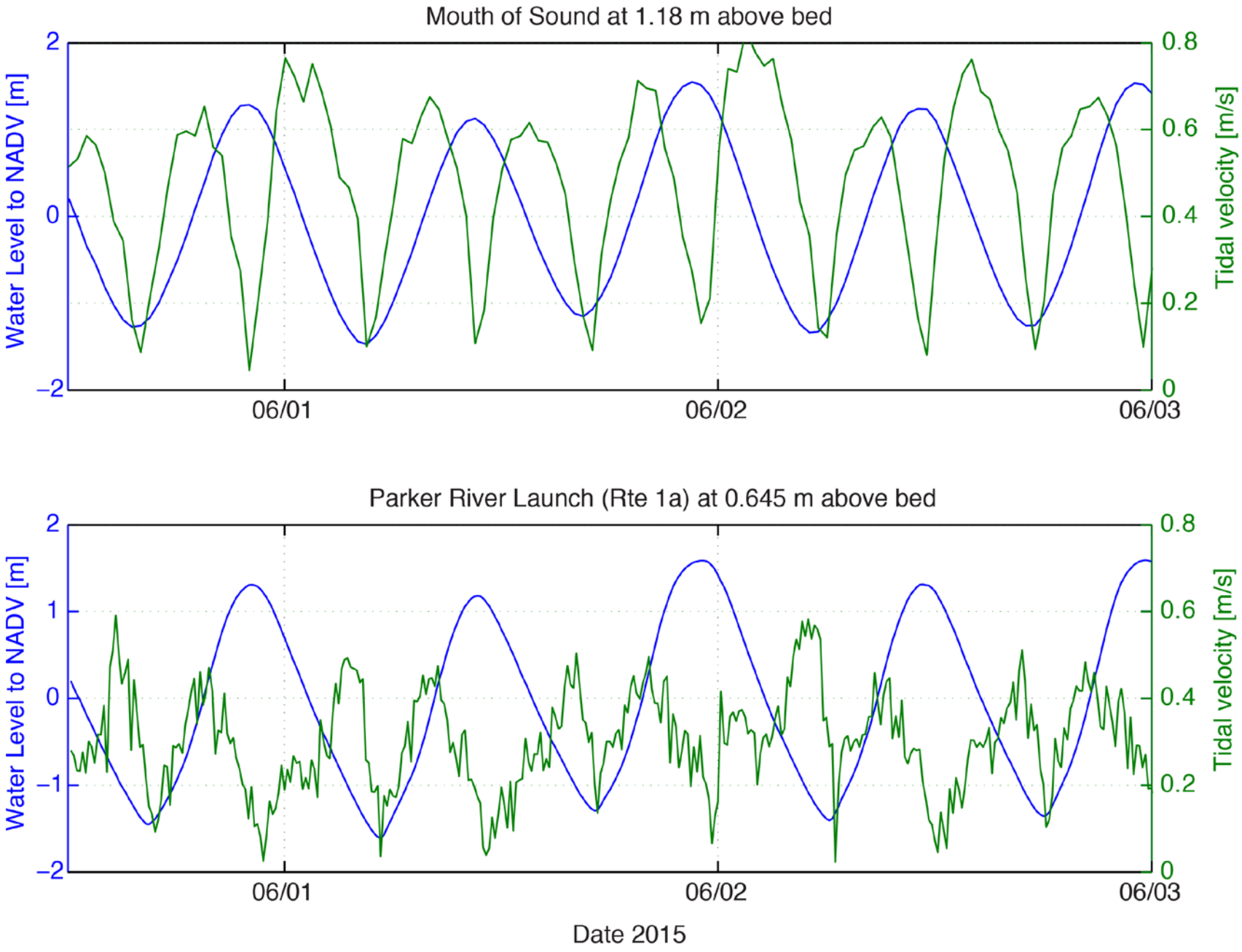




Stage 3:
Runaway
Transgression






Mouth of Sound at 1.18 m above bed
Water Level to NADV [m]
Tidal velocity [m/s]
2
0
−2
0.8
0.6
0.4
0.2
0
06/01
06/02
06/03
Parker River Launch (Rte 1a) at 0.645 m above bed
Water Level to NADV [m]
Tidal velocity [m/s]
2
1
0
−1
−2
0.8
0.6
0.4
0.2
0
06/01
06/02
06/03
Date 2015


Salisbury Sites
SAL-1
SAL-2
SAL-3


Newbury Site
NEW-1


Plum Island Sound
Sites
PI-6
PI-2
PI-5
PI-1
PI-4
PI-3

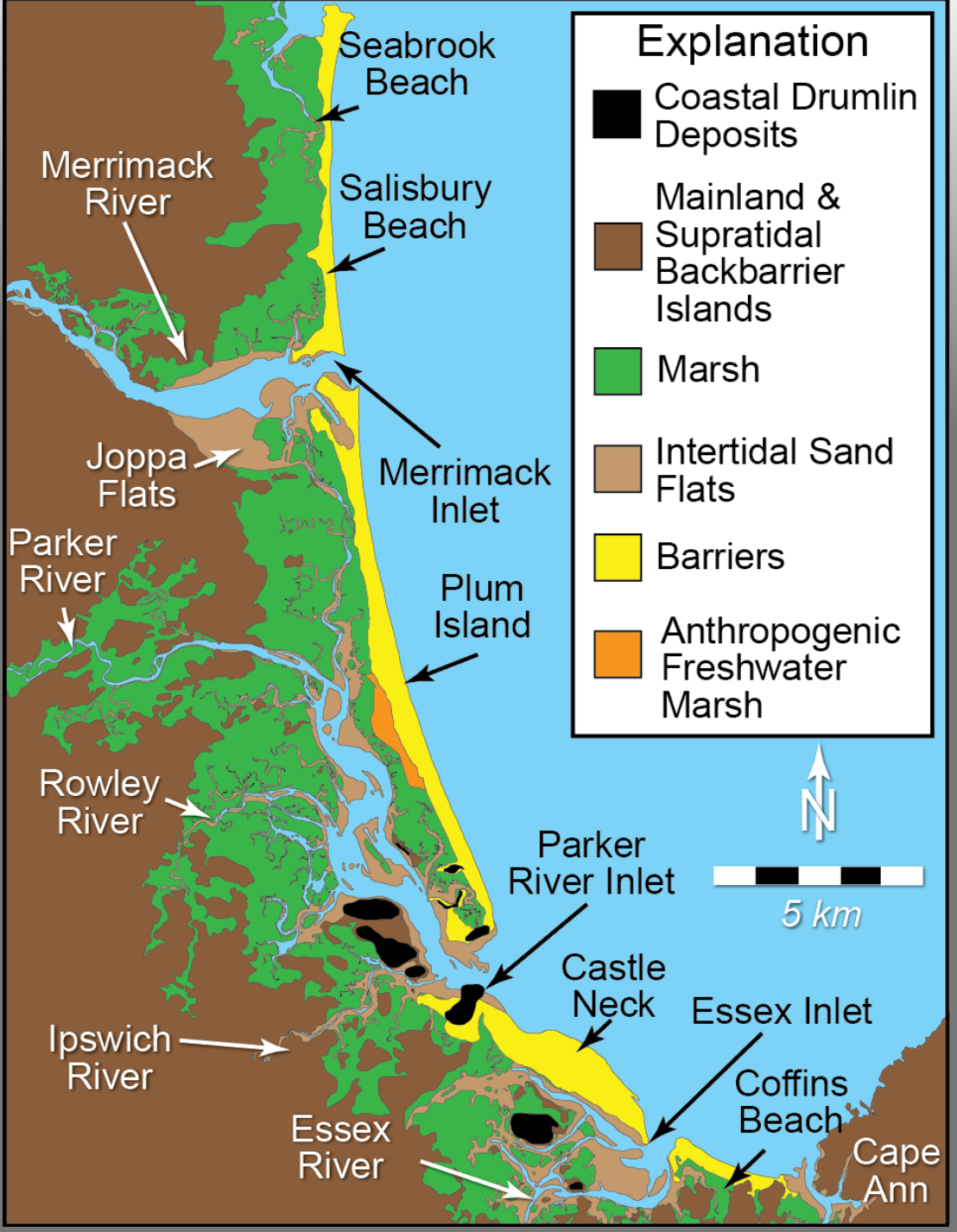

Essex Bay Sites
EB-3
EB-2
EB-1
EB-6
EB-5
EB-4


Salem Sound
SS-2
SS-1


Romney Sites
RM-1
RM-2


Rowley Sites
RW-1
RW-2
RW-3


08.24.2014



Beach and Barrier Island Response to Climate Change

- Frequency of storms will likely not change
- Warmer water may lead to larger magnitude storms
- Geomorphic changes primarily responding to SLR
- SLR leads to loss of sand offshore
- Sand will be lost to Ebb-tidal delta
- Plum Island contains 30 million m^3
- Changes to barrier system will occur slowly (although houses adjacent to the beach will be impacted)

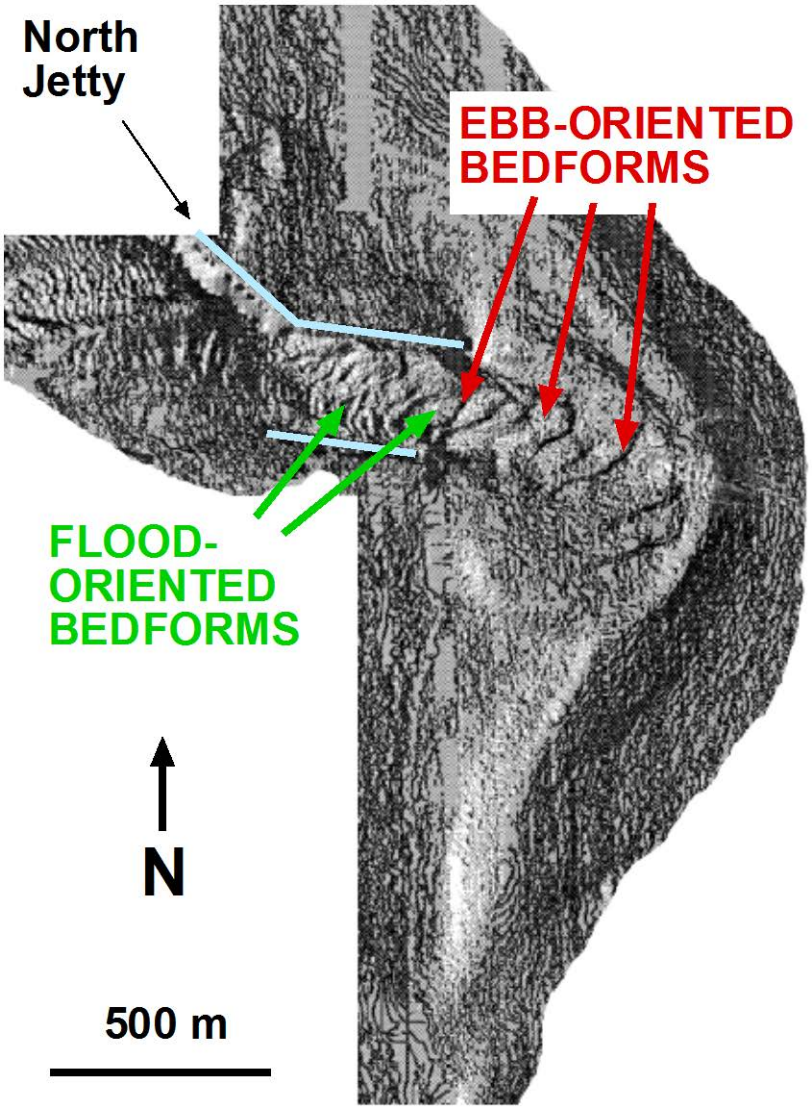
Transport Pathways

Lidar Survey shows configuration of the channel bottom

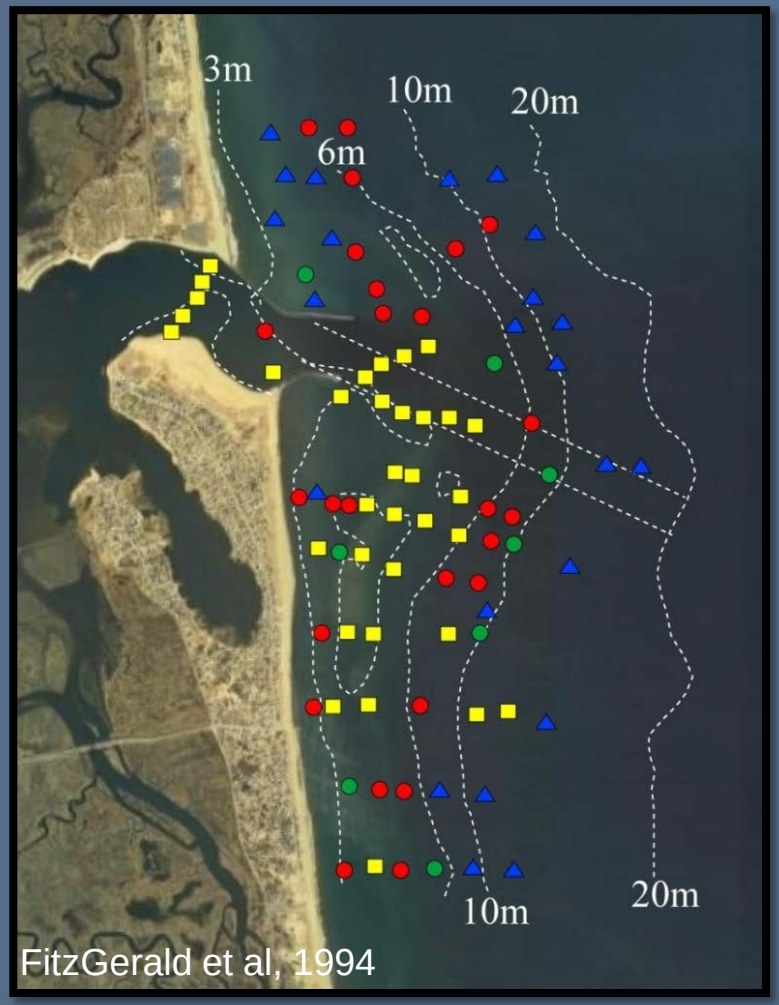
Ebb-oriented 1.5 m high, λ = 80 m migrating out the inlet channel

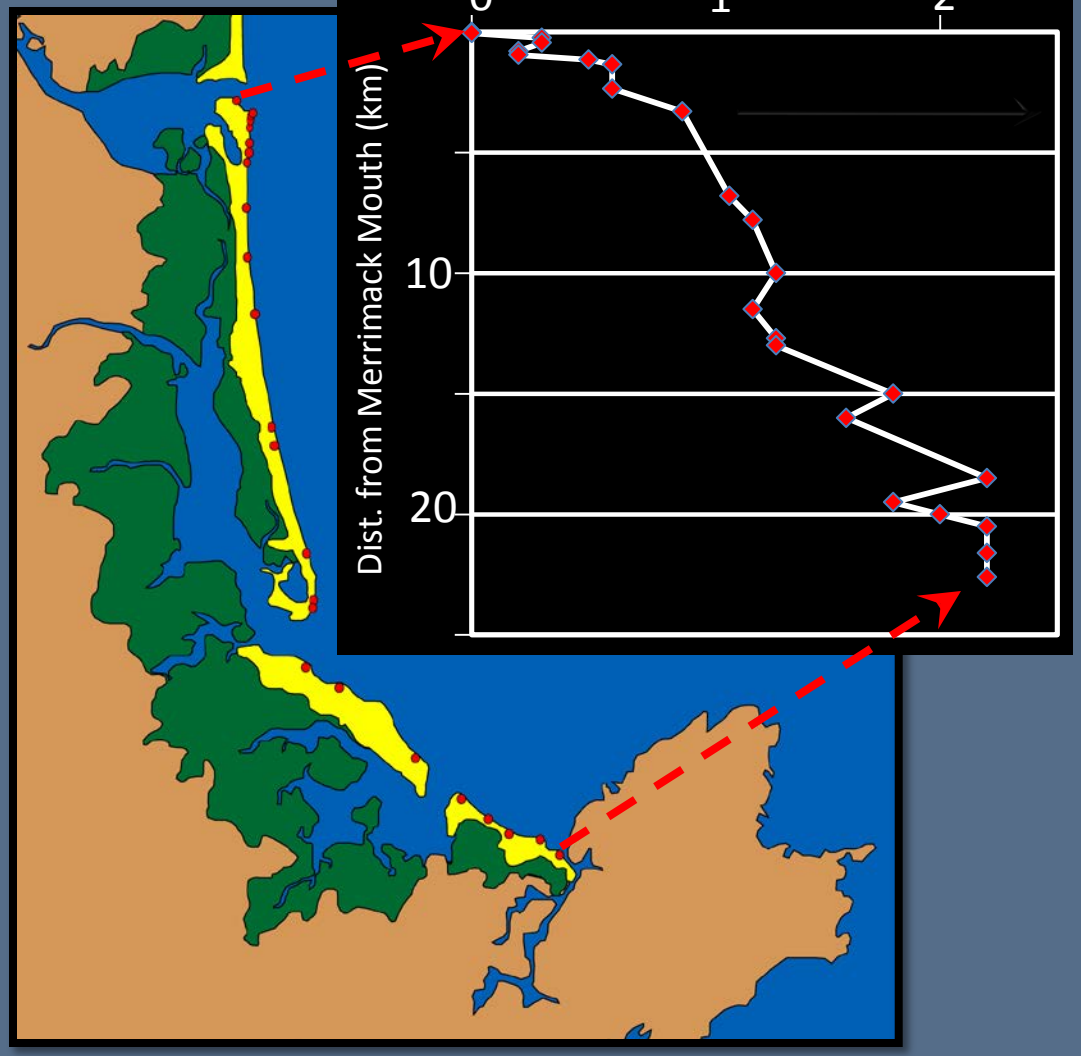
South side of channel exhibits flood oriented megaripples

Indicates inlet exporting sand and some recirculation of sand



Plum Island Formation: Riverine Source & Regressive Delta Deposits



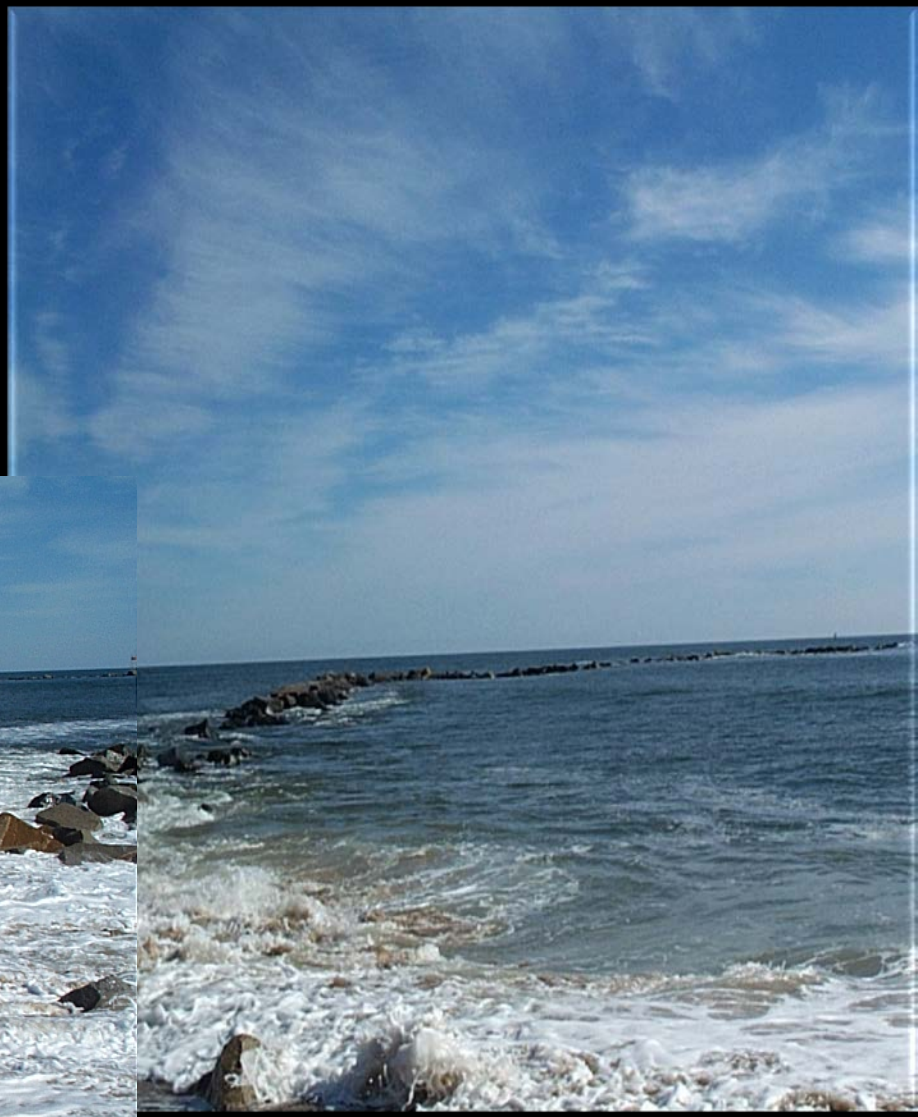


- Very Coarse Sand and Gravel (<0 ϕ)
- Coarse Sand (0-1ϕ)
- Medium Sand (1-2 ϕ)
- Fine and Very Fine Sand (>2 ϕ)


Jetties
Groins
Photo by Michael Morris

South Jetty

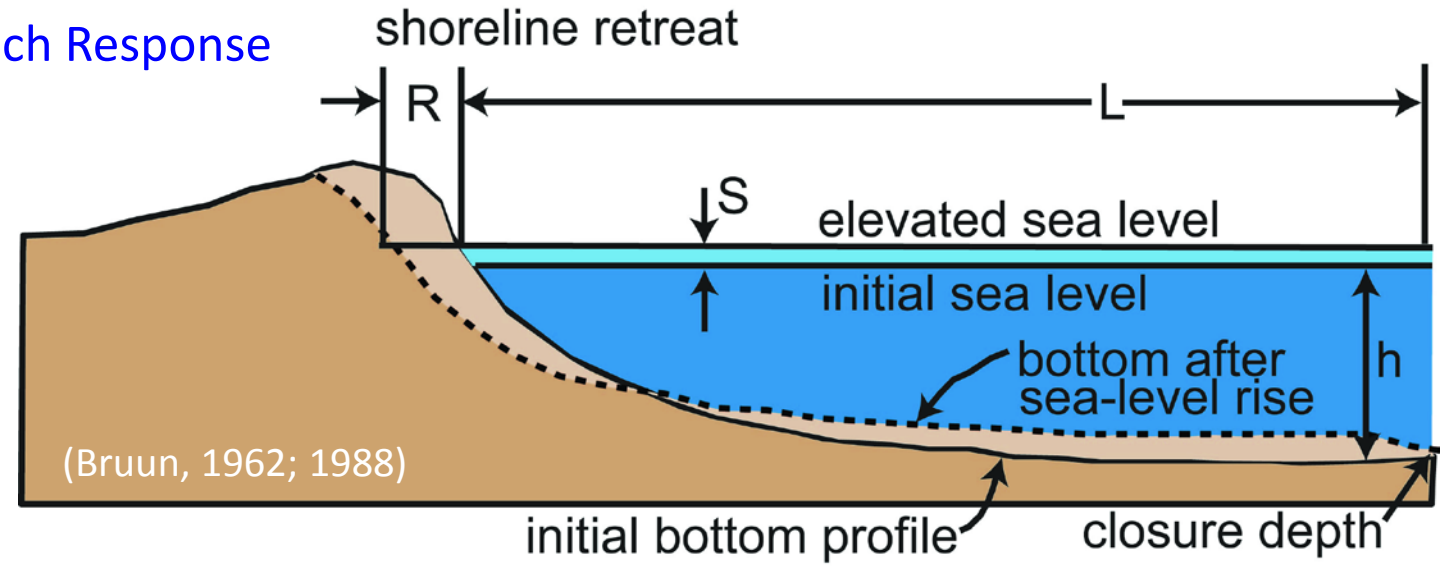
Transport over the jetty by large wave swell feeding sand into the inlet and to Reservation Terrace beach



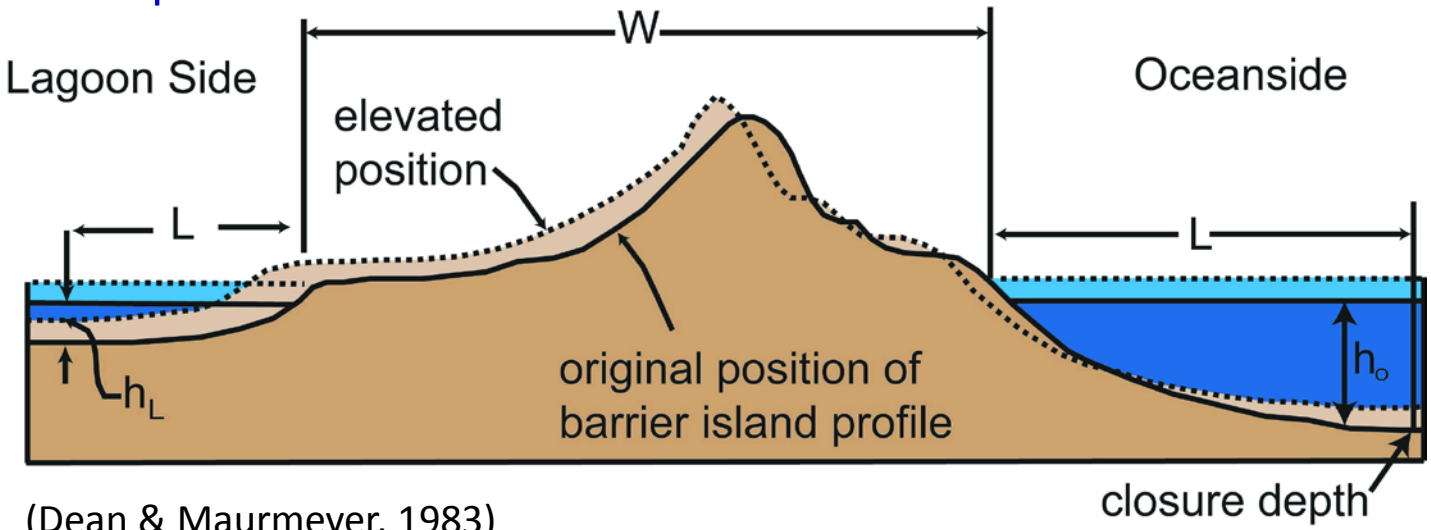
Photos from Michael Morris

Beach & Barrier Response to Sea Level Rise

1. Beach Response

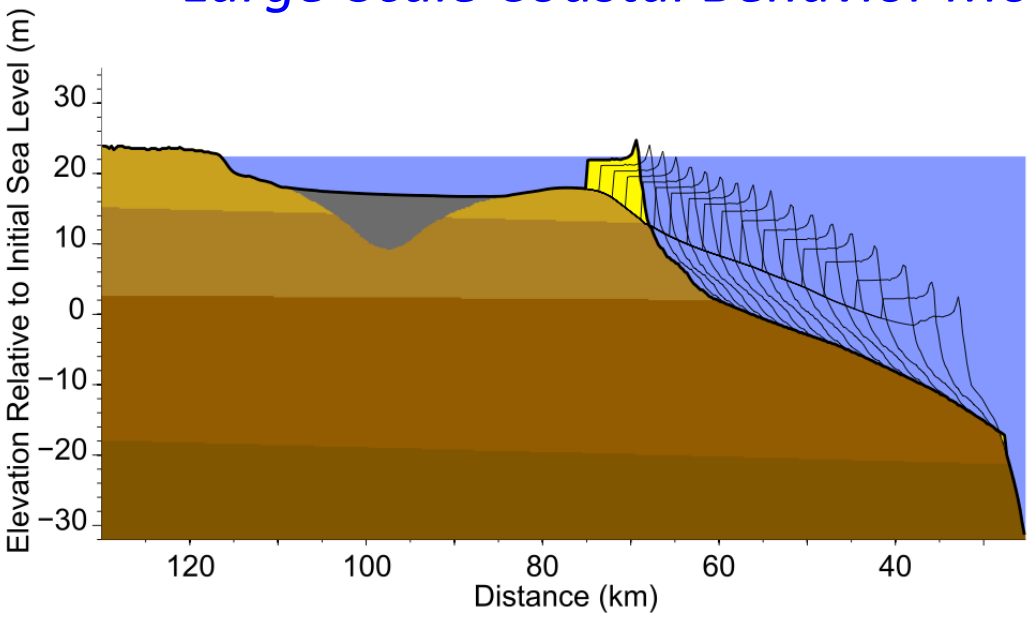


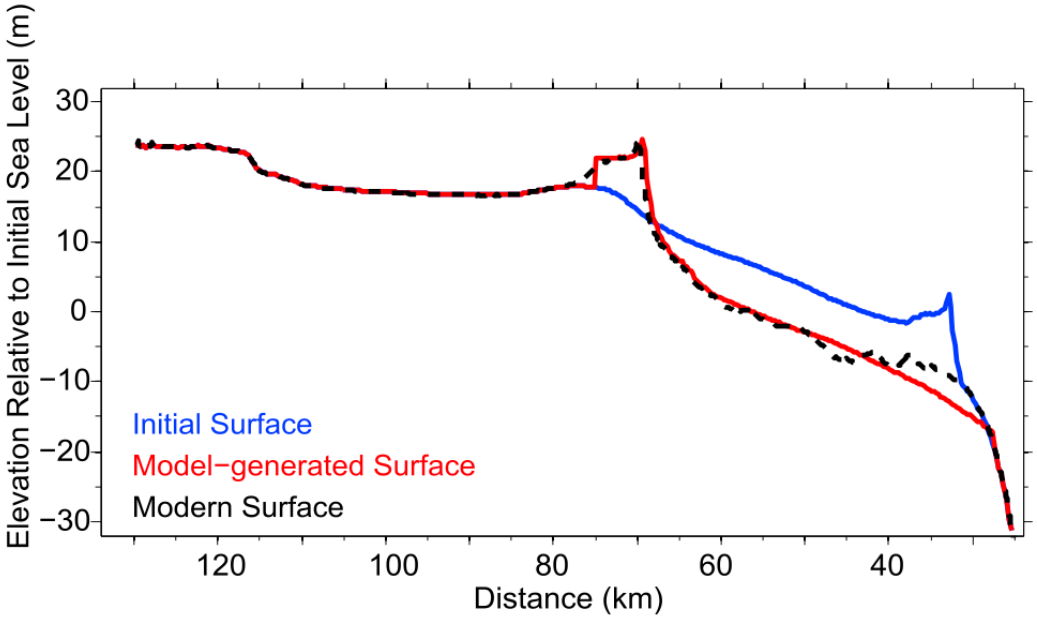
2. Barrier Response



(Dean & Maurmeyer, 1983)

Large-Scale Coastal Behavior Models





(Moore et al, 2010)

Initial Models:

- Governed by SLR scenario
- Geometric Cross-shore model
- Conservation of mass
- Equilibrium profile

GEOMBEST (Geomorphic Model of Barrier, Estuarine, and Shoreface Translations)

- Improved by adding composition of sea floor
- Erodible substrate
- Useful for inverse modeling

- *Plum Island* 150 -450 m wide
- *Castle Neck* 250 to ~1 km wide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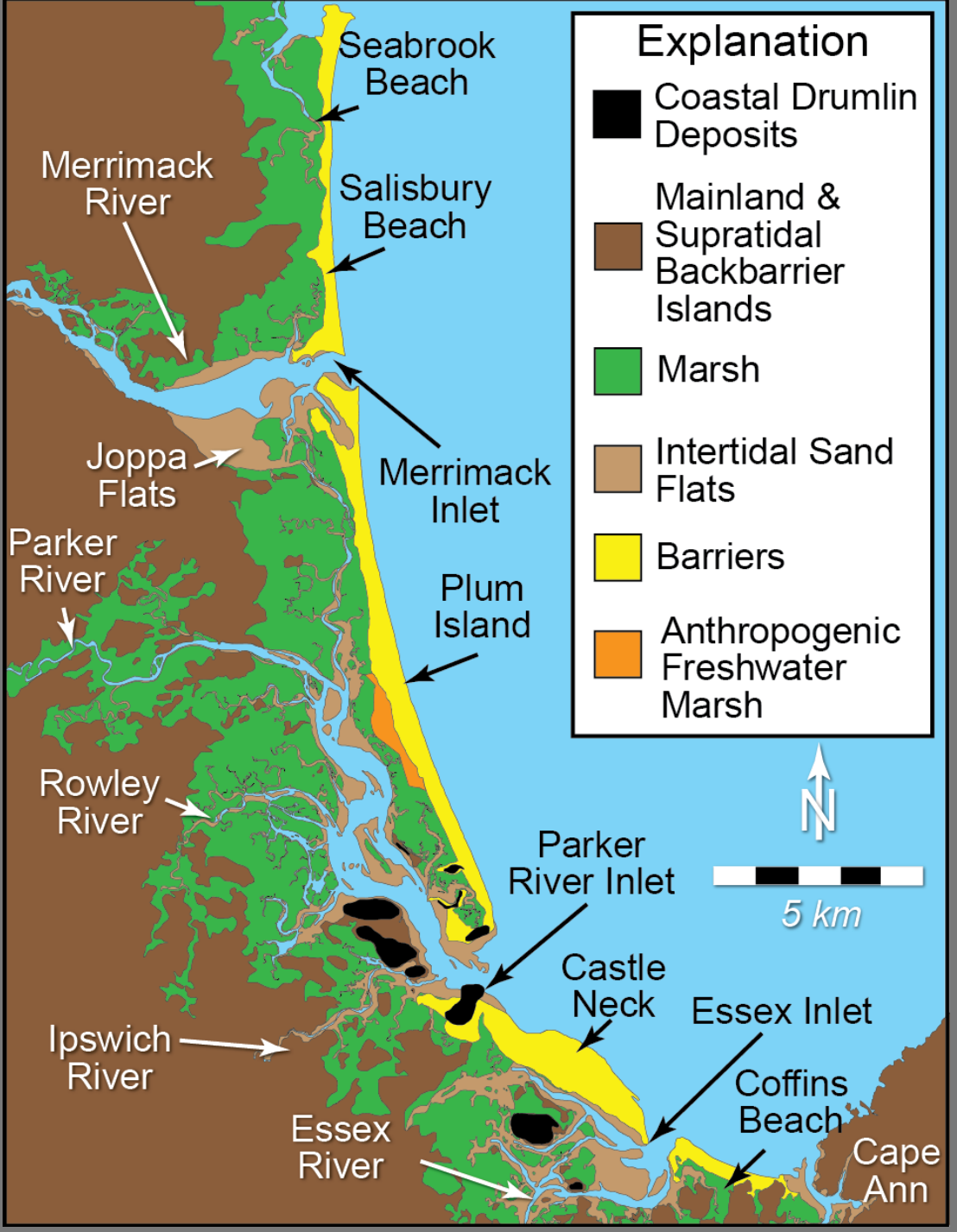

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