Numerically modeling the potential sediment management impacts of channel-adjacent BUDM

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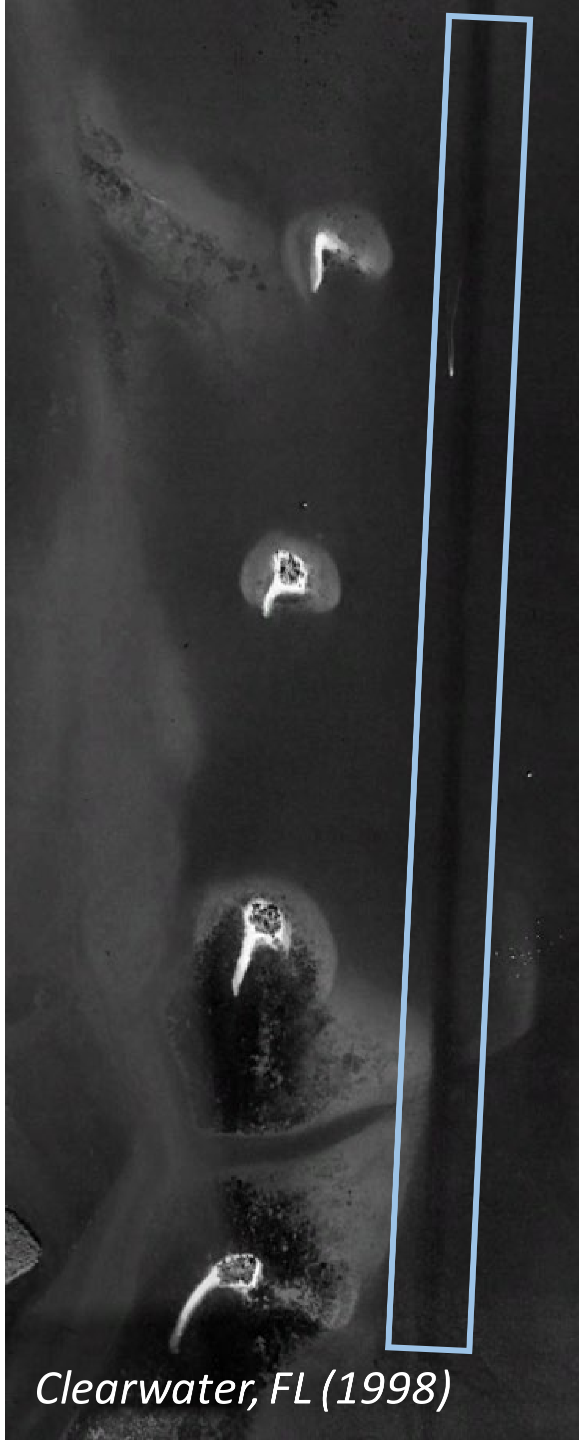
Motivation

Guidance on **lifecycle management of wetland nourishment** with dredged material **for coastal navigation**

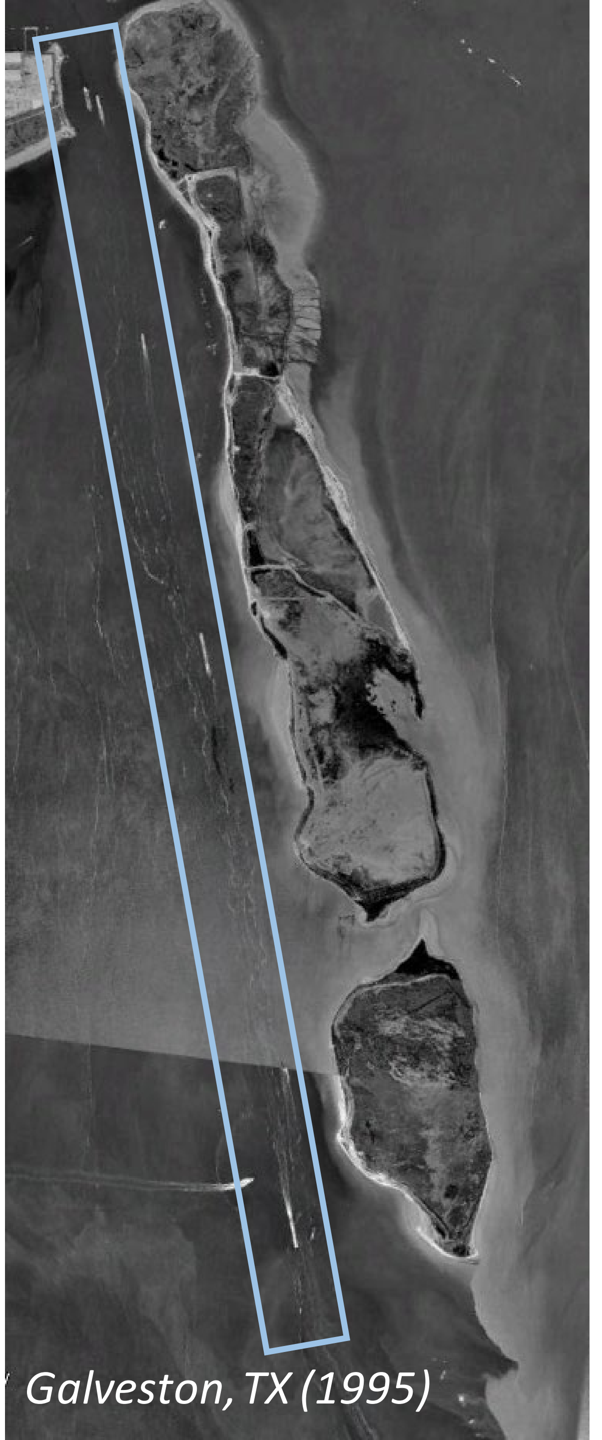
FY22 & FY23 focus: Channel-adjacent islands

SONs

- Sustainable dredged sediment management practices to support wetlands (FY20 1411)
- Nearshore placement for wetland nourishment (FY20 1322)
- *Multi-scale analyses of BUDM impacts on long-term navigation channel maintenance (FY24 1970)*

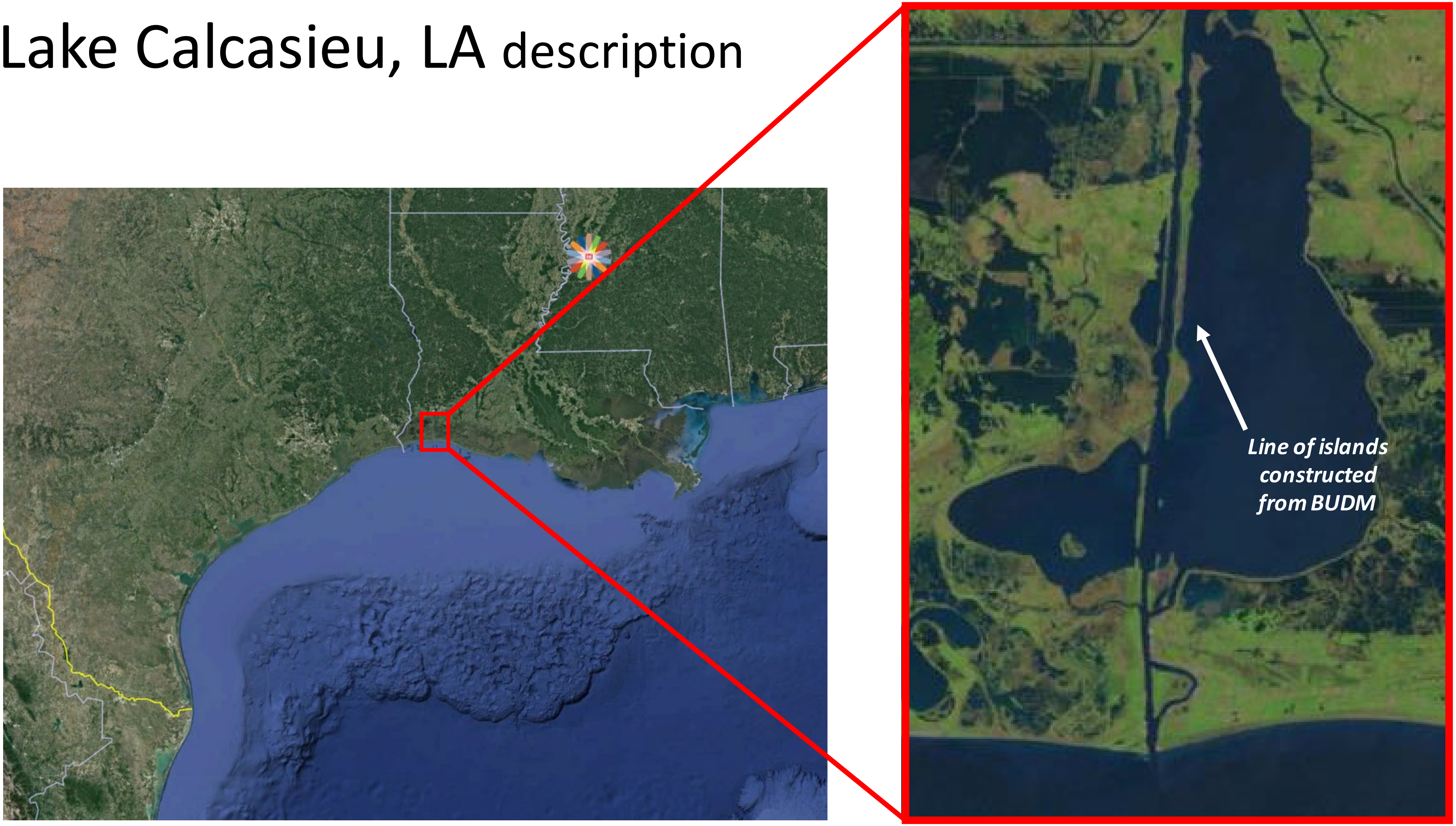


Clearwater, FL (1998)

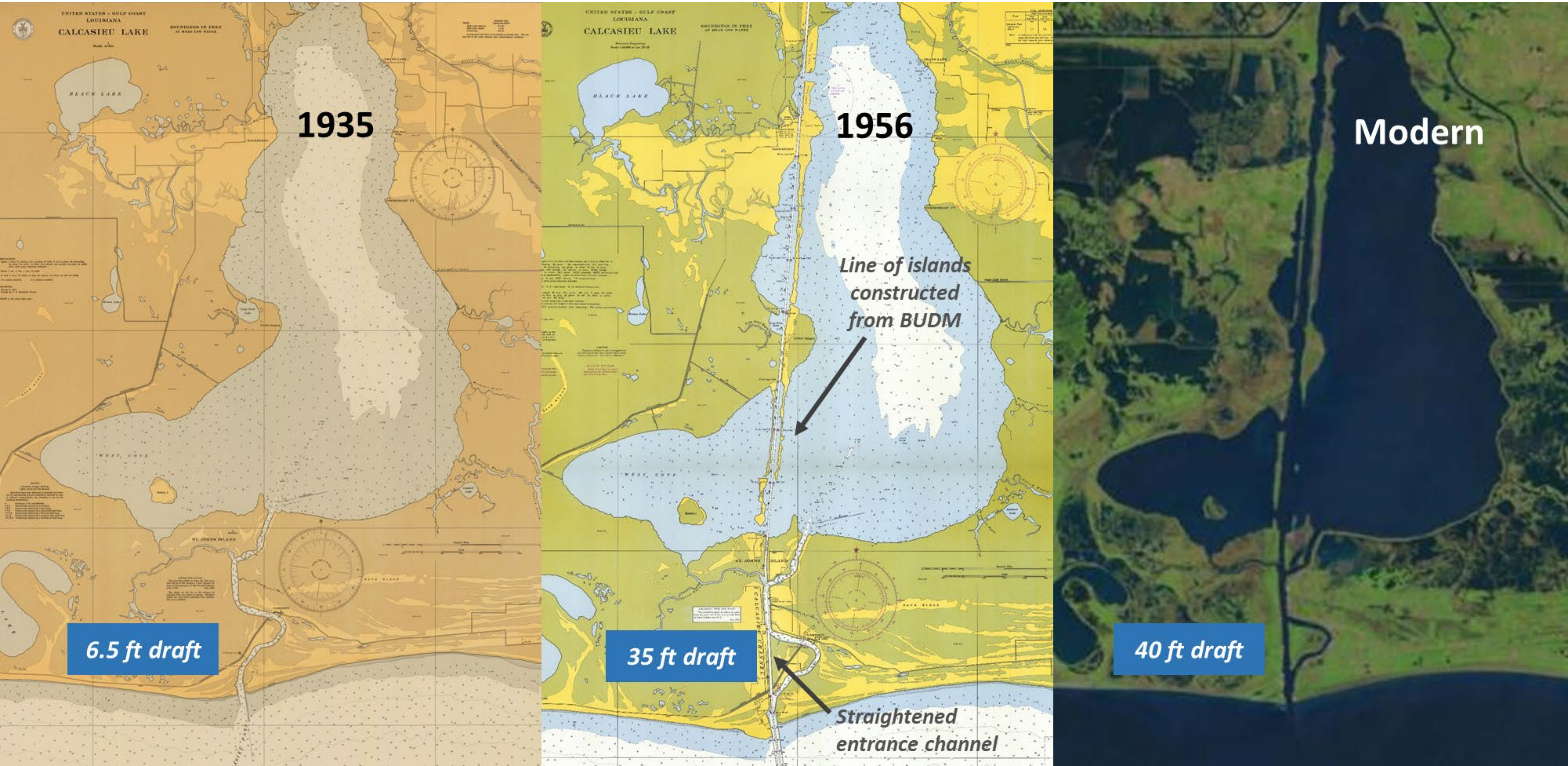


Galveston, TX (1995)

Lake Calcasieu, LA description



Lake Calcasieu, LA

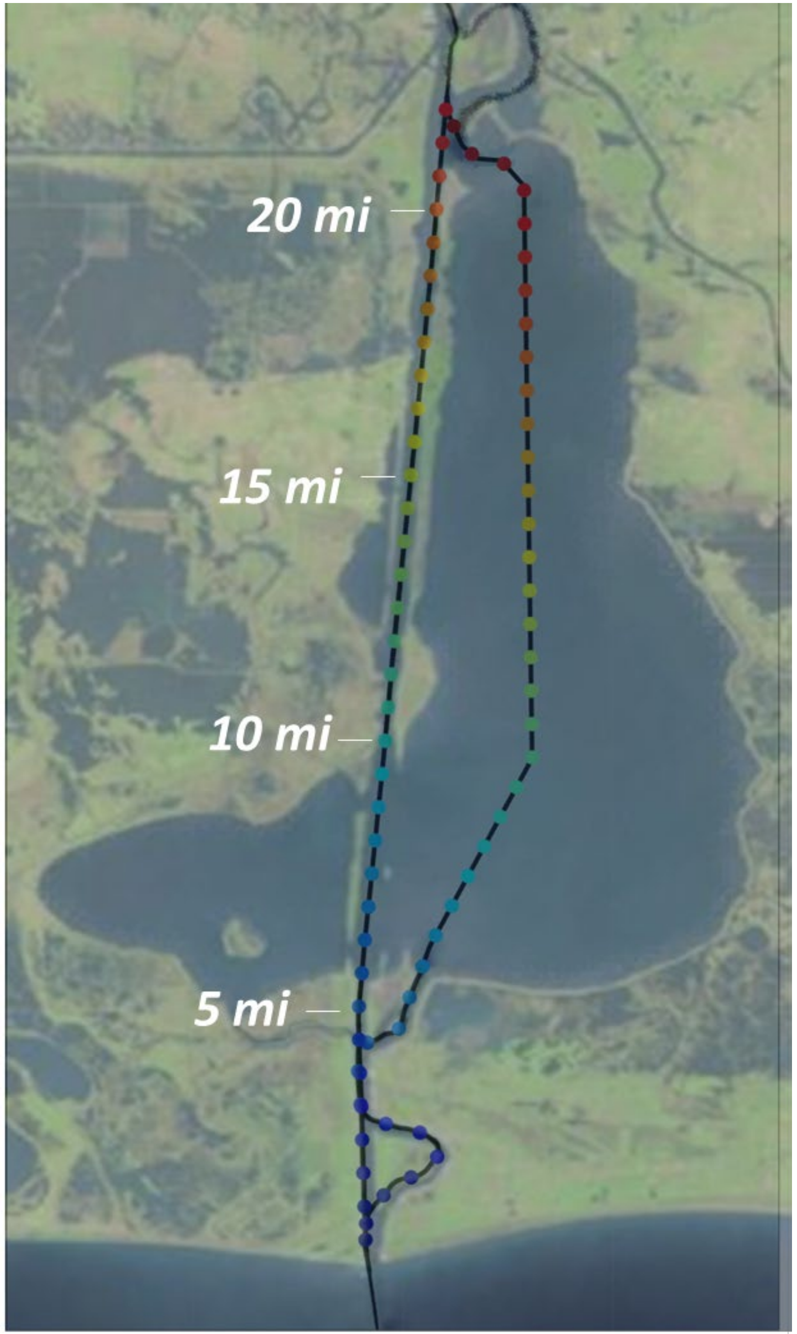


Previous work

Sediment Budget

- Predominantly marine from RM 0-5 and riverine from RM 5+ (Perkey et al., 2022; Brown and Luong, 2022)
- Missing contributions? (+40%)
    - Shoreline/bank erosion (Water Institute, 2019)
    - Interior wetland loss to well/canal dredging (Cadigan, et al., submitted to *JWPCOE*)

RM = river mile



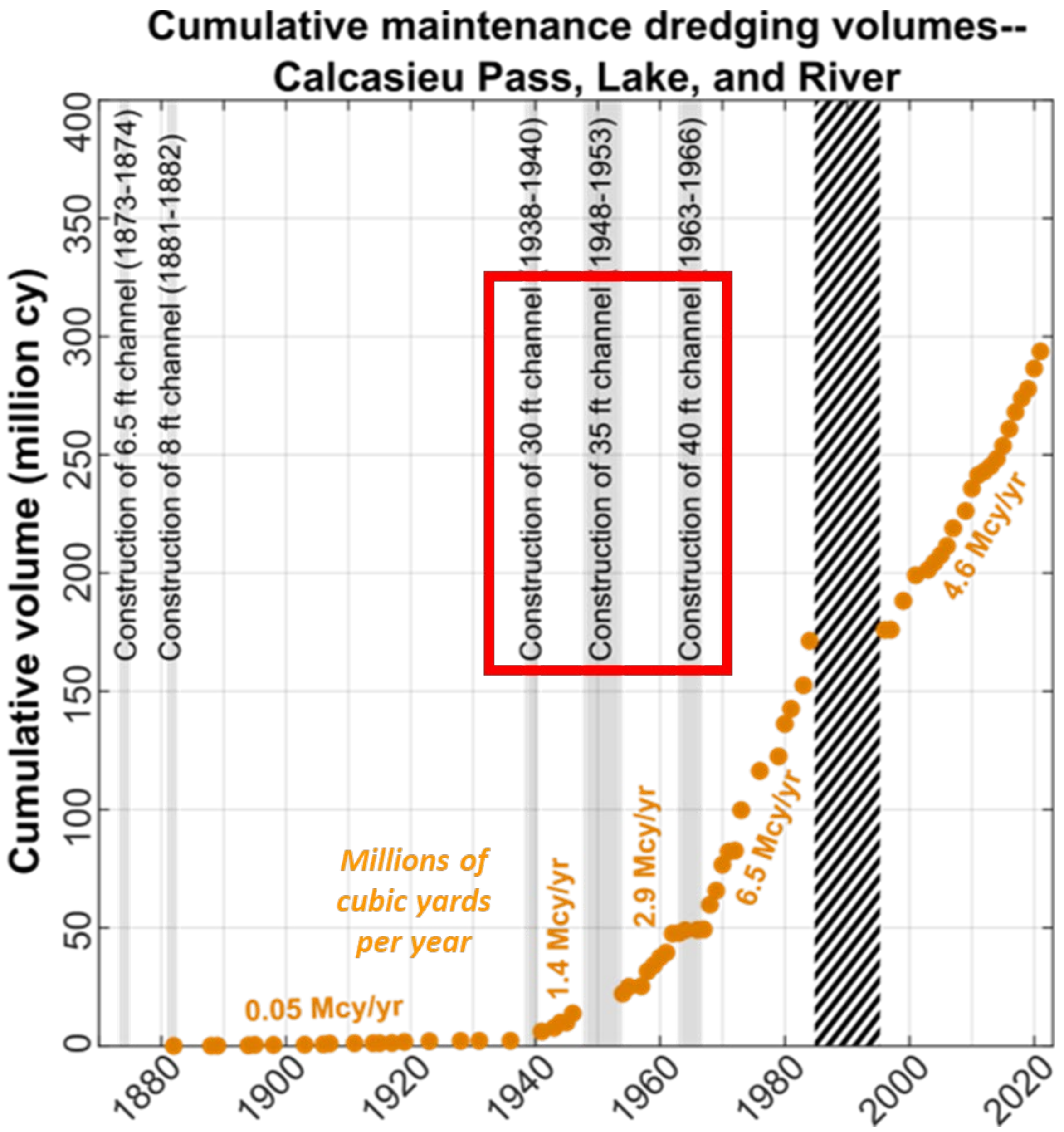
This work

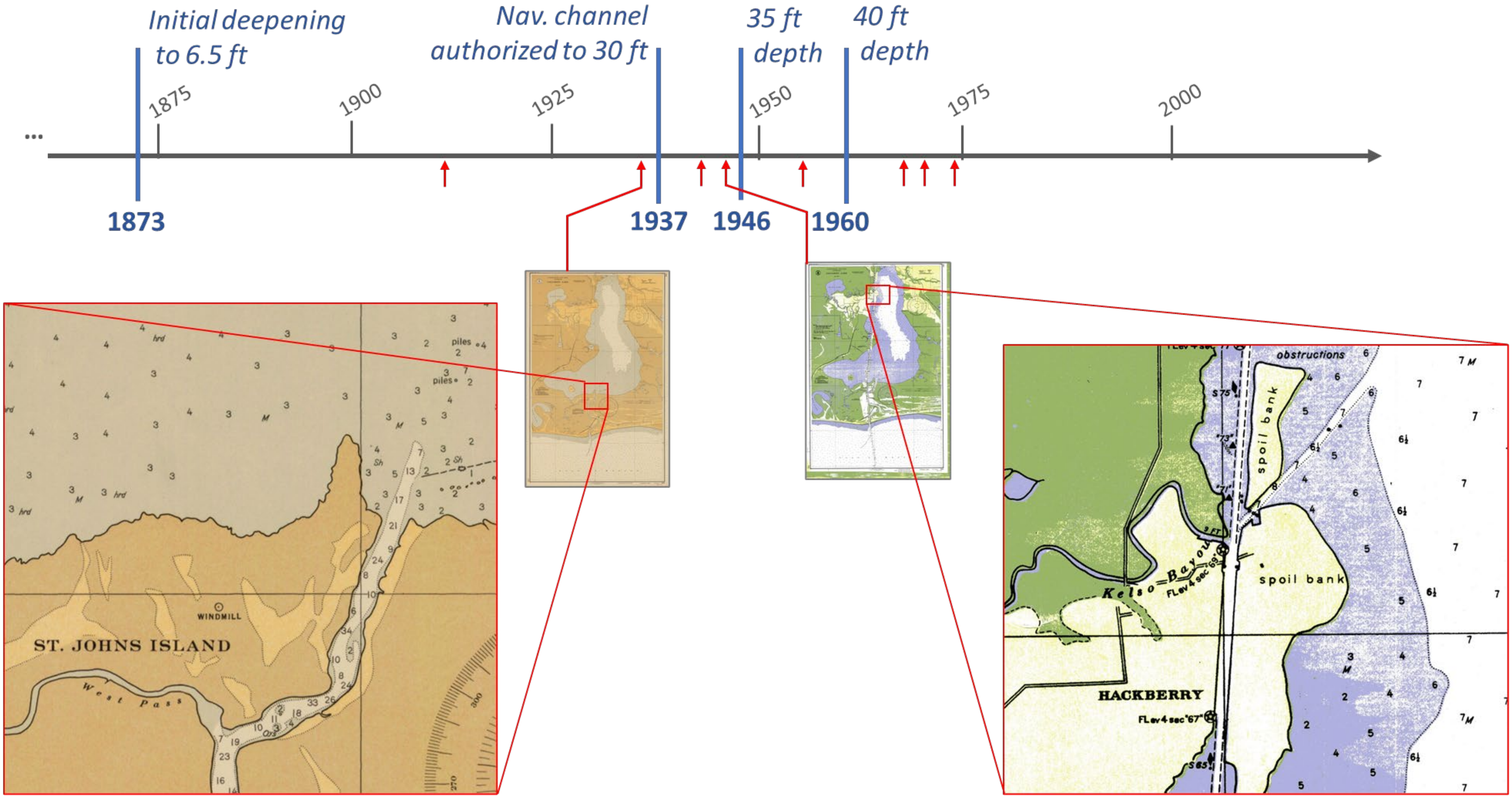
Sediment Pathways

How does topo/ bathymetric features modify sediment transport pathways?

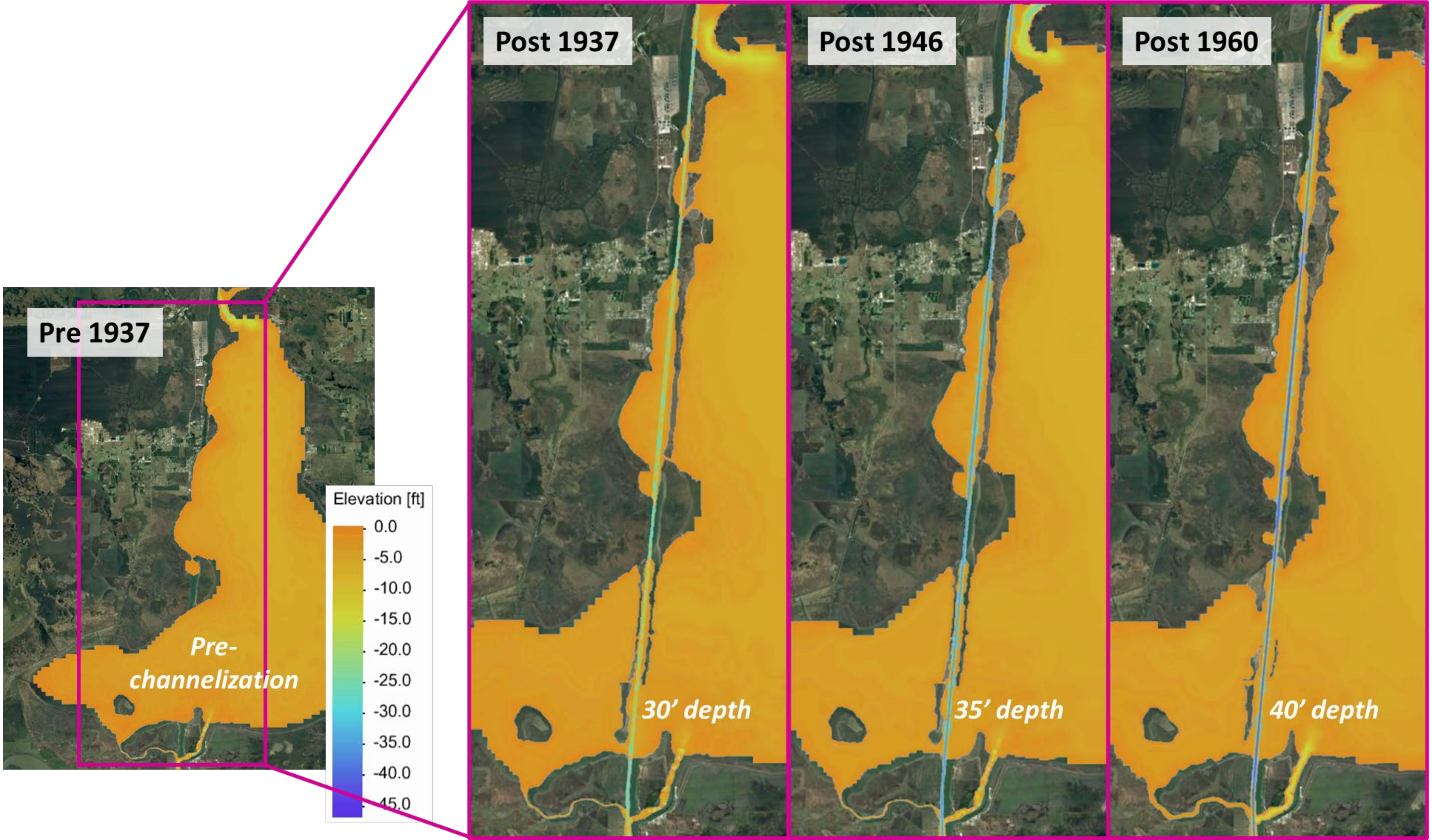
Dredging history

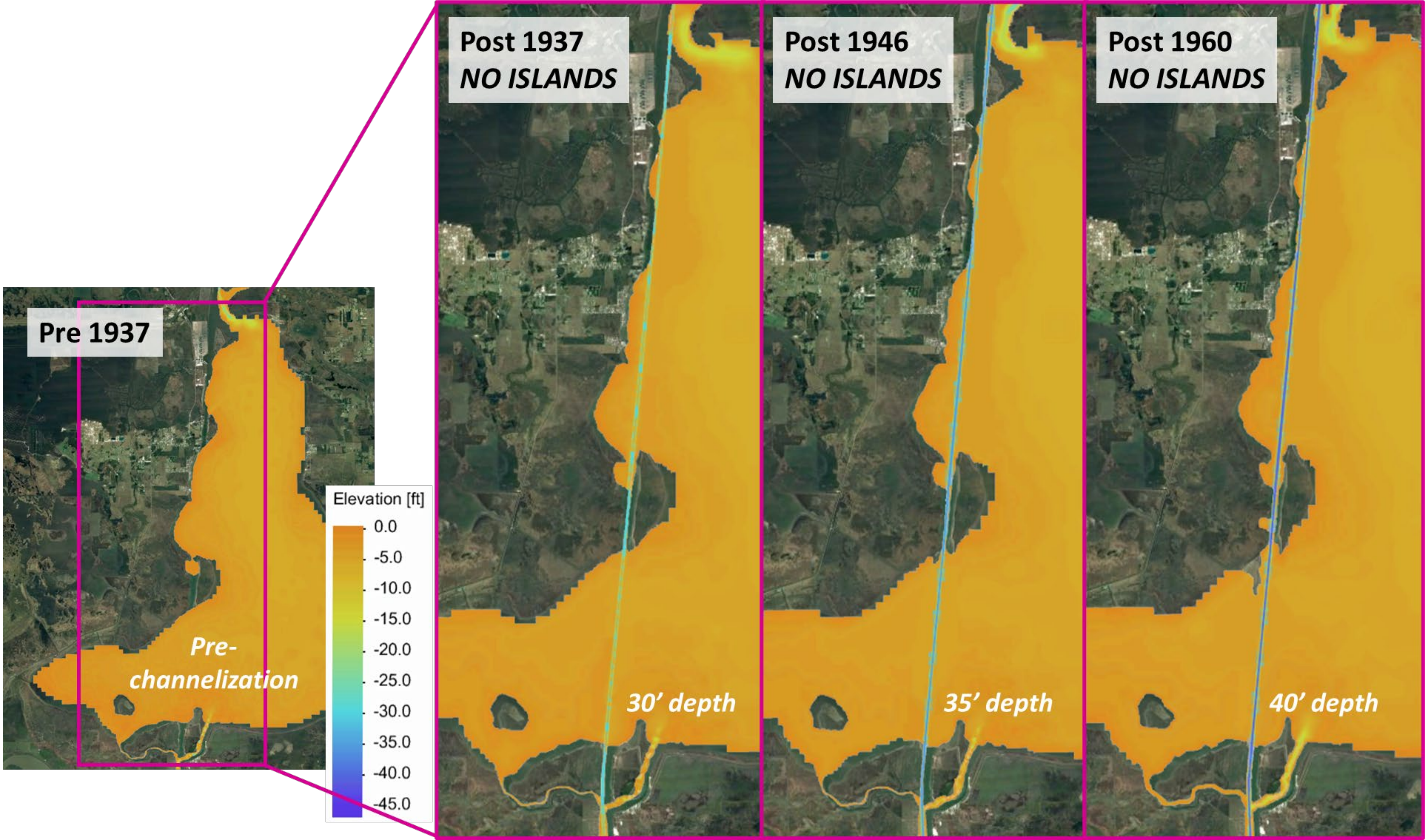
- Combined modern (1996-2021) reports with Annual Reports to the Chief of Engineers on Civil Works Activities (1874-1980)
- Focusing on maintenance dredging helps understand decadal scale shoaling rates





Initial deepening to 6.5 ft
Nav. channel authorized to 30 ft
35 ft depth
40 ft depth
...
1875
1900
1925
1950
1975
2000
1873
1937
1946
1960
ST. JOHNS ISLAND
WINDMILL
West Pass
obstructions
spoil bank
spoil bank
Kelso Bayou
HACKBERRY


Pre 1937
Pre-
channelization
Elevation [ft]
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
Post 1937
30' depth
Post 1946
35' depth
Post 1960
40' depth

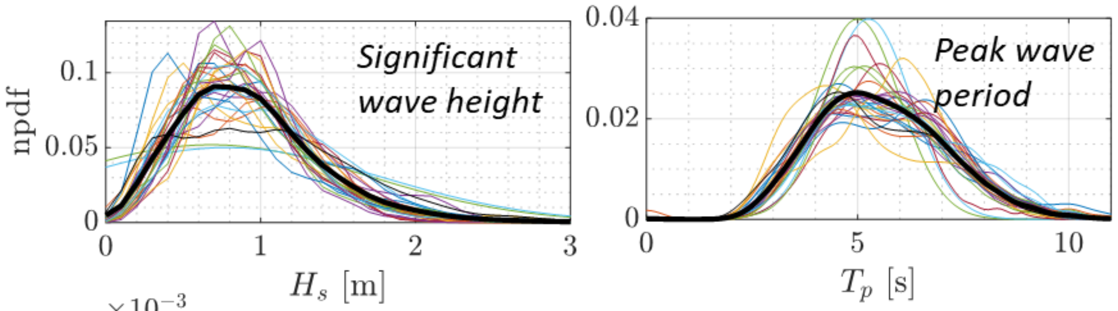

Pre 1937
Pre-
channelization
Elevation [ft]
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
Post 1937
NO ISLANDS
30' depth
Post 1946
NO ISLANDS
35' depth
Post 1960
NO ISLANDS
40' depth

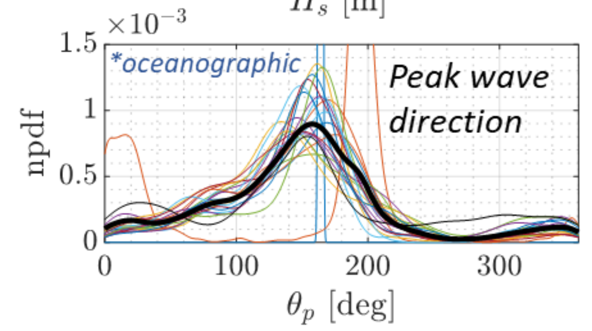
CMS-Flow + Wave

30-day period representative of Jan/March

- Time-varying: wind fields, tides
- Constant: offshore waves, streamflow

NDBC Stat. 42035 & 42091





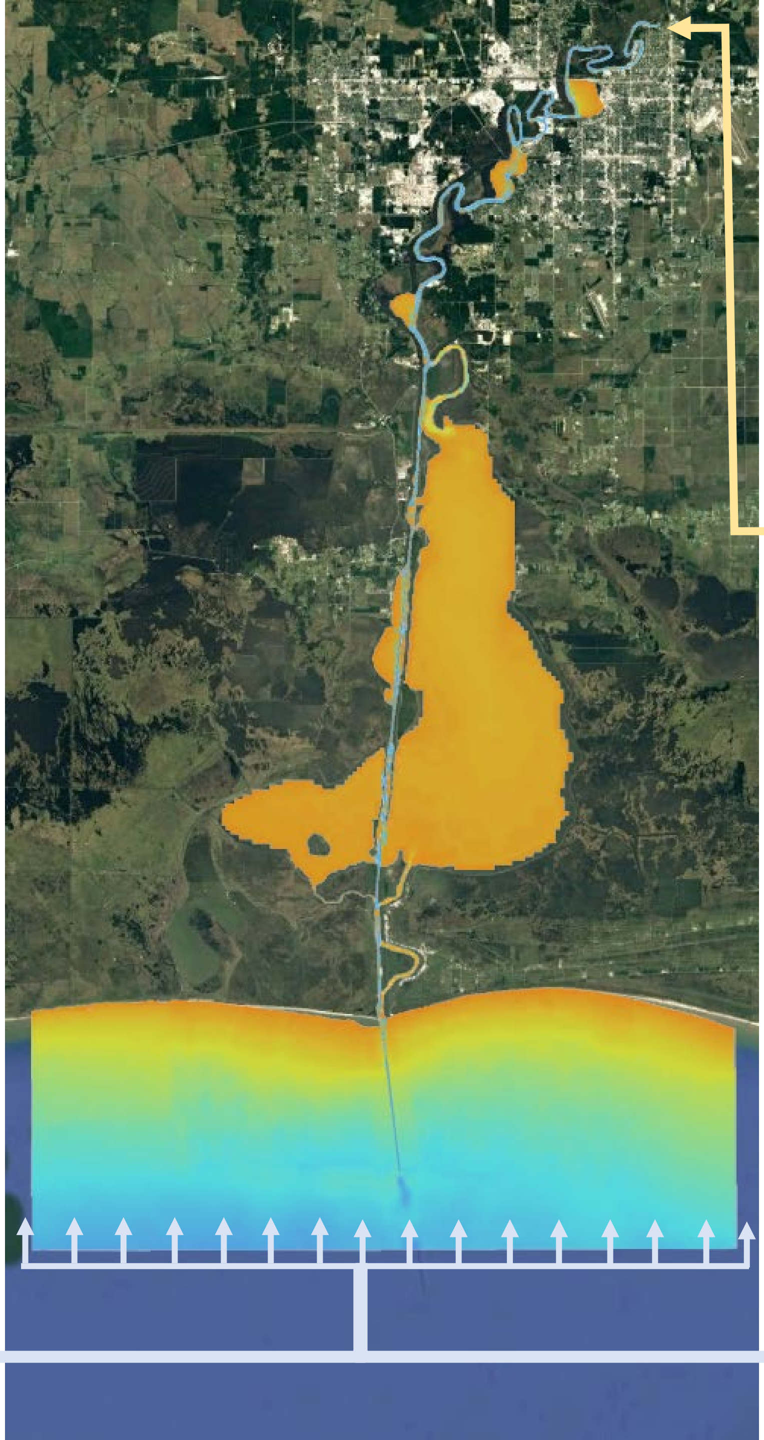
Wave BC - *JONSWAP*

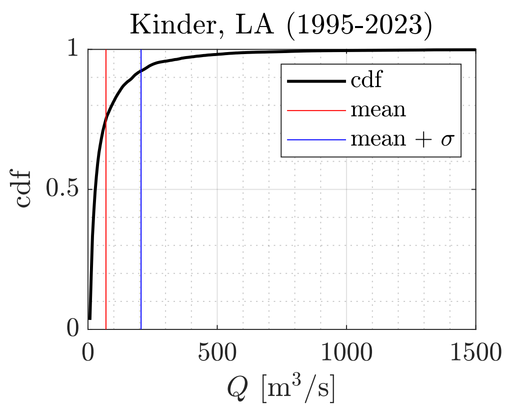
H_s = 0.8 m

T_p = 4.8 s

θ_p = 18.7° *shore normal

npdf = normalized probability distribution function





Riverine BC – USGS

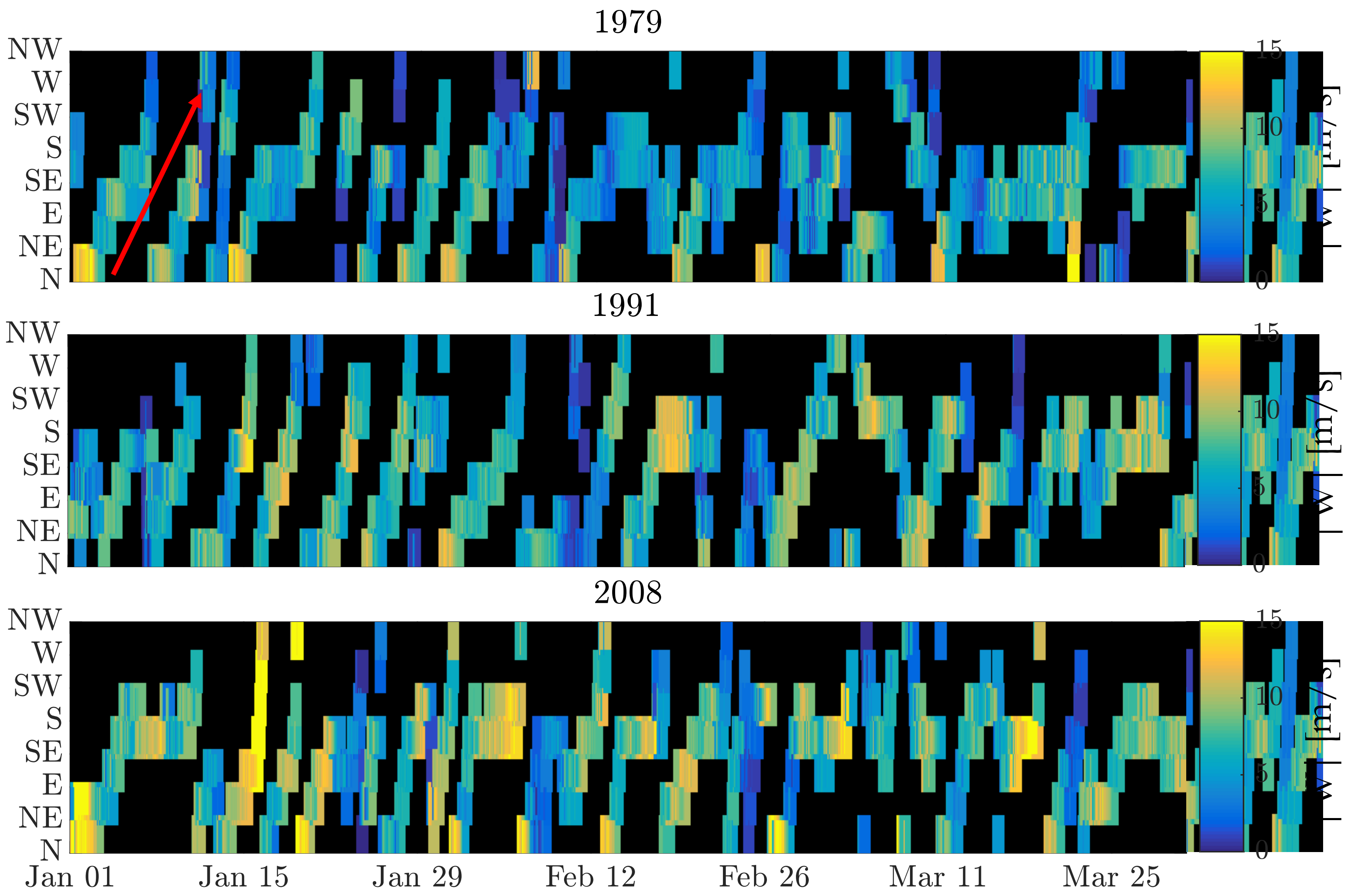
$\bar{Q}$ = 132 m³/s

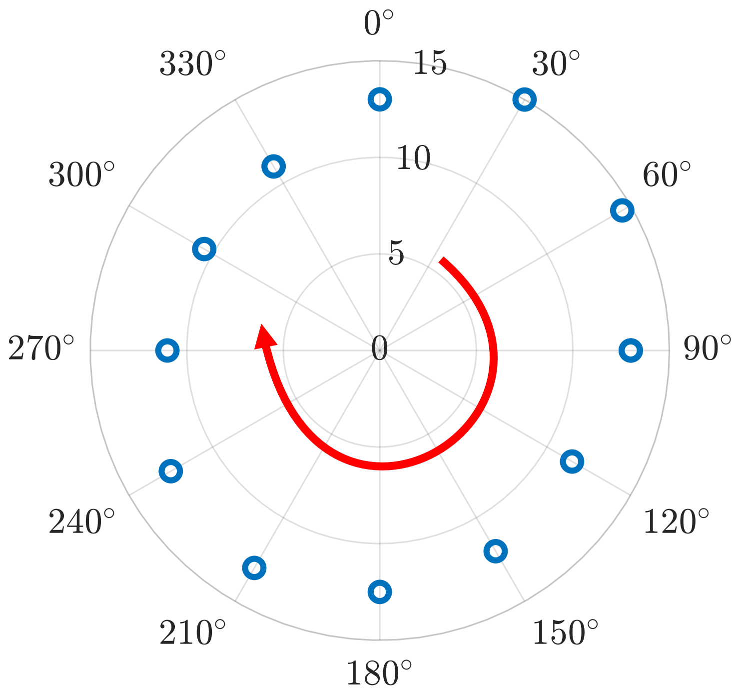
Tidal BC - OpenMesh2D*

	Amp [m]	Phs [°]
M2	0.160	247.1
S2	0.077	246.5
N2	0.040	243.7
K2	0.024	241.9
O1	0.185	16.6
P1	0.067	22.2
K1	0.020	21.0
Q1	0.042	5.23

Q = volumetric flow rate

CMS-Flow + Wave continued

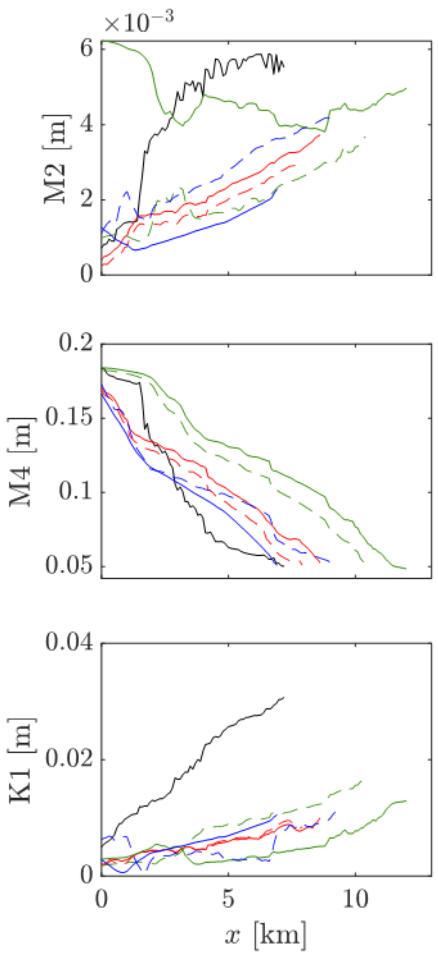




Rotation freq. 1/10 days

Wind speed |W| represents 5% exceedance value, per direction

Results – tidal dynamics



30’ 35’ 40’

Channelization (post 1937) results in:

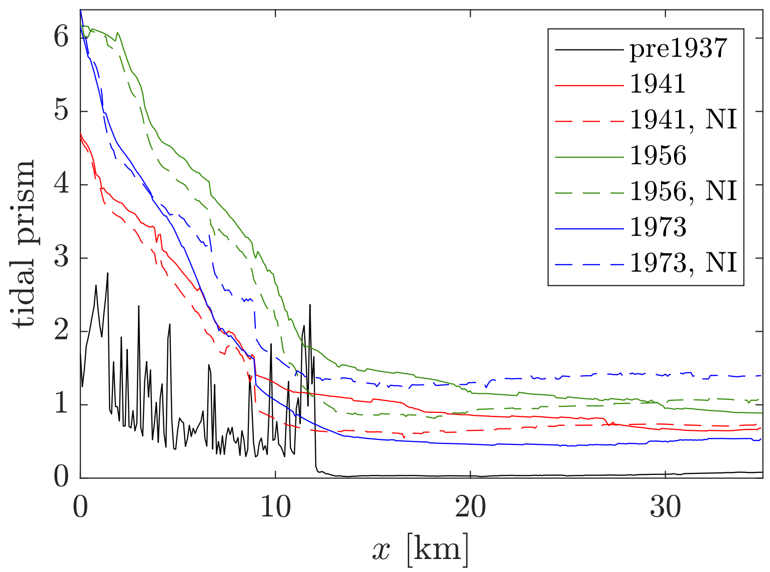
- *Decrease* in dominant tidal amplitudes (M2, K1)
- *Increase* in nonlinear overtide (M4) amplitude at Rkm 3+

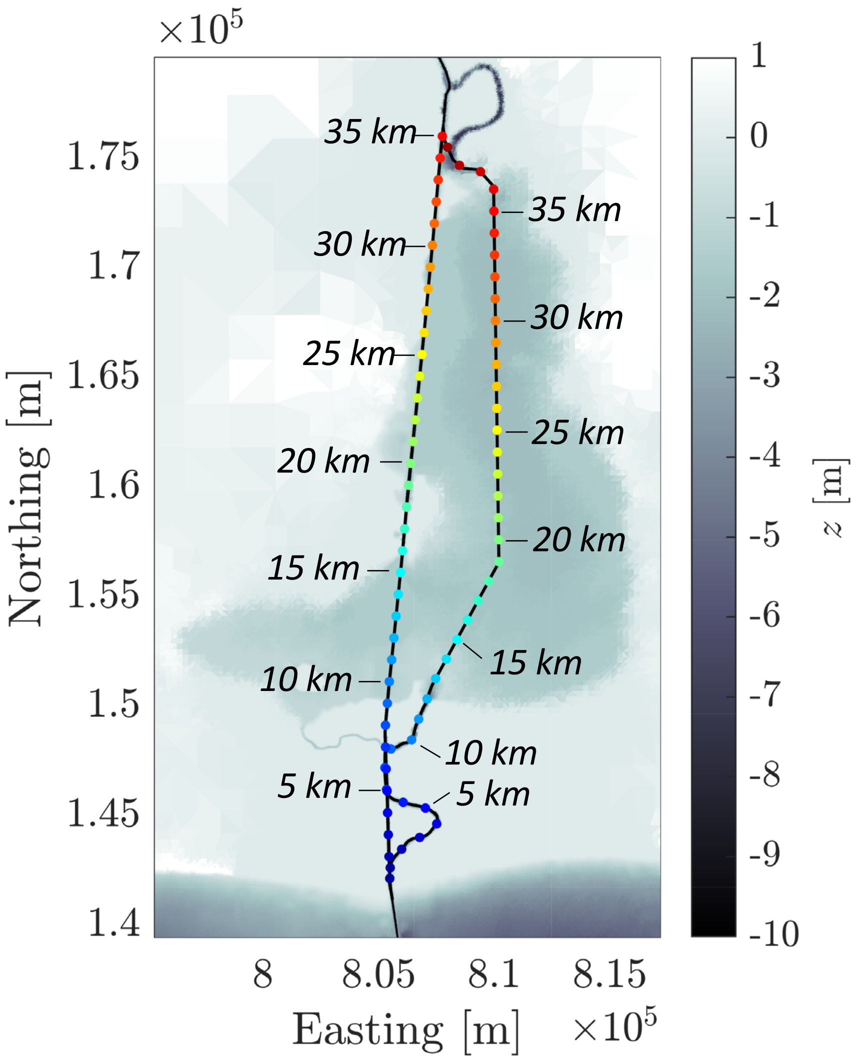
Channelization increases tidal prism

Islands tend to:

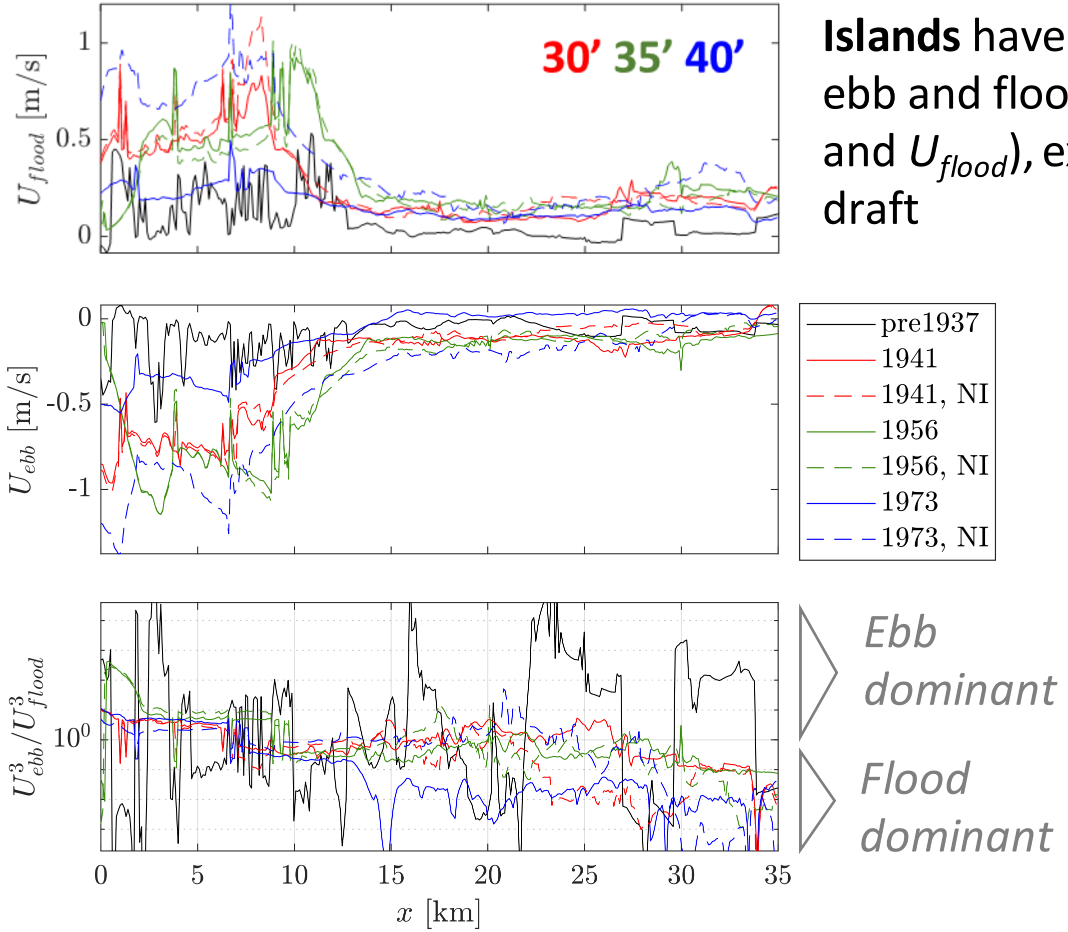
- Increase M4 amplitude
- Increase and/or decrease dominant constituent amplitude

Islands increase tidal prism up to given RM, then decrease prism (especially for 40’ draft)

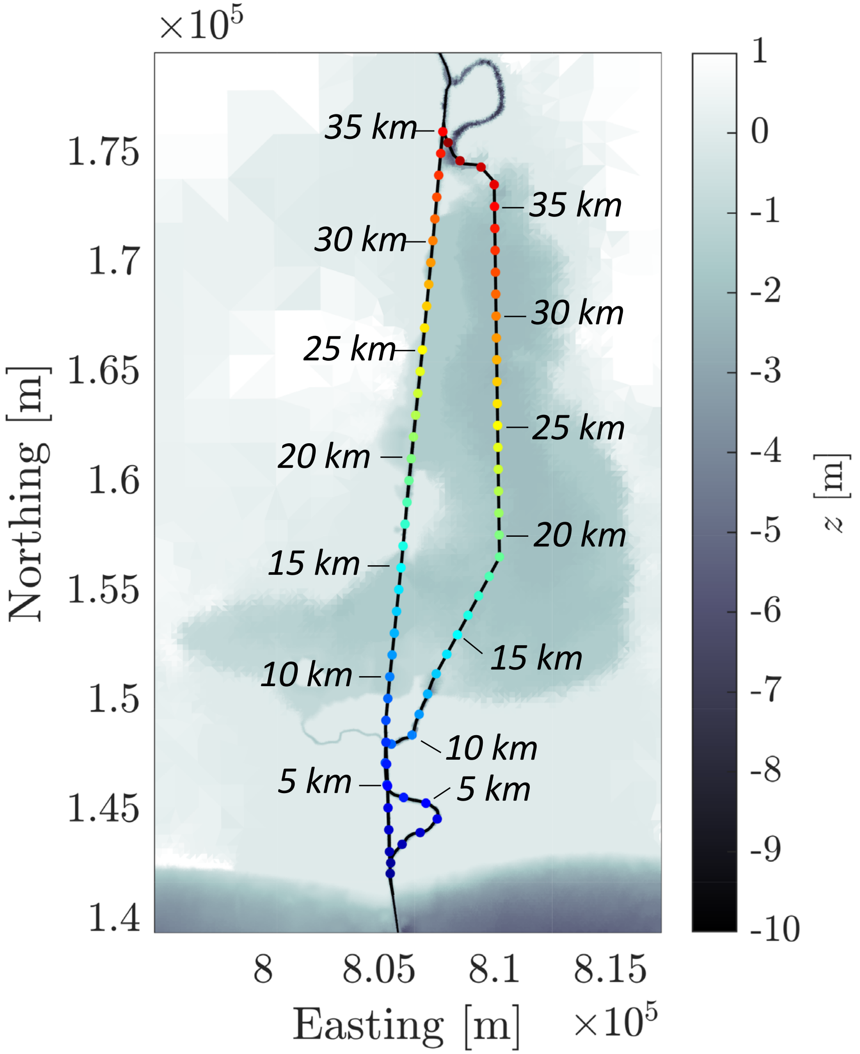




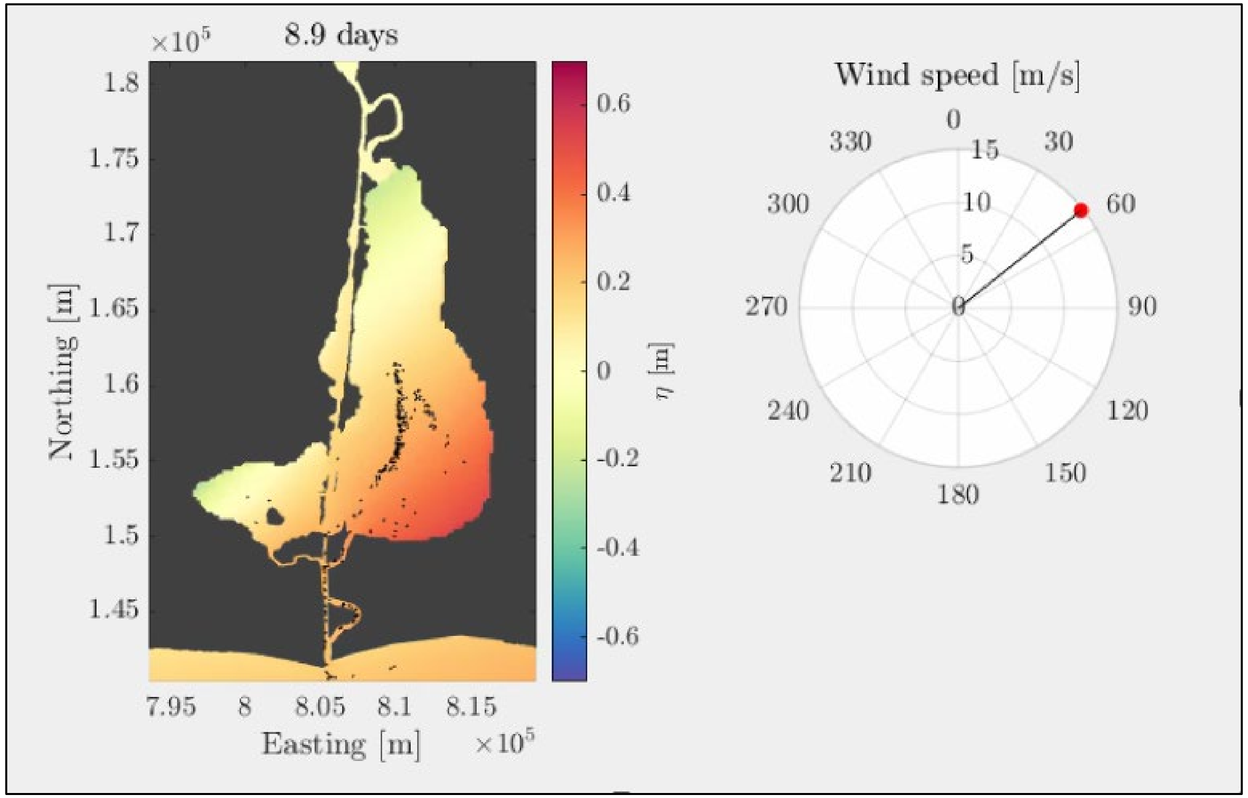
Results – tidal dynamics continued



Islands have small impact on ebb and flood velocities (U_{ebb} and U_{flood}), except in case of 40’ draft

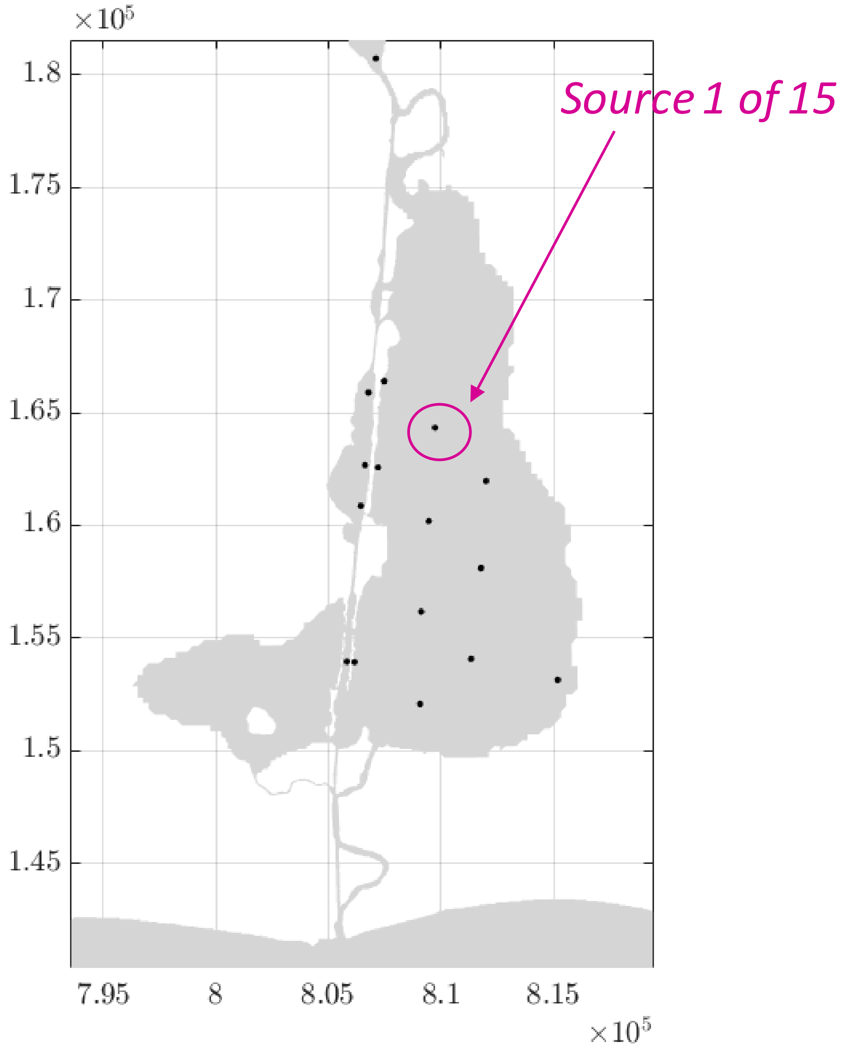


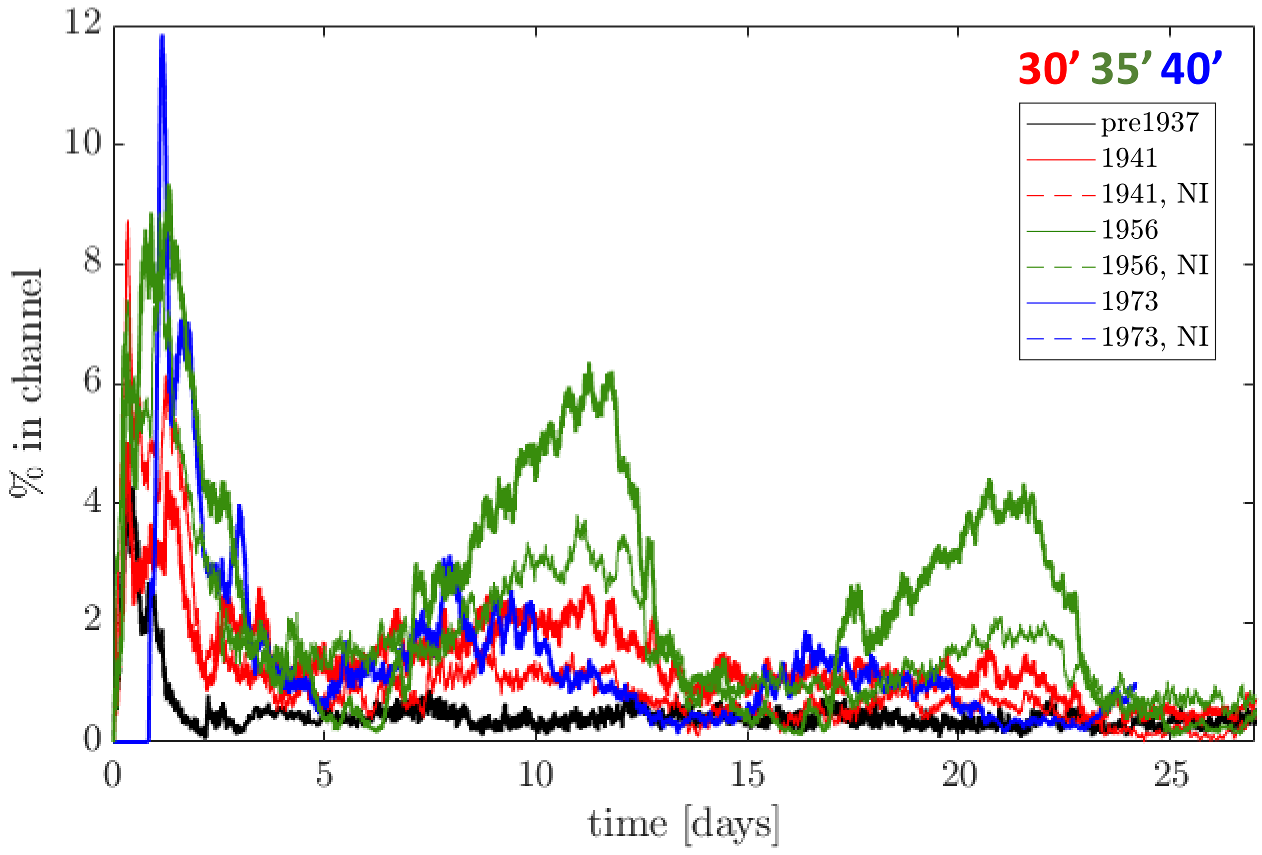
Results - sample PTM



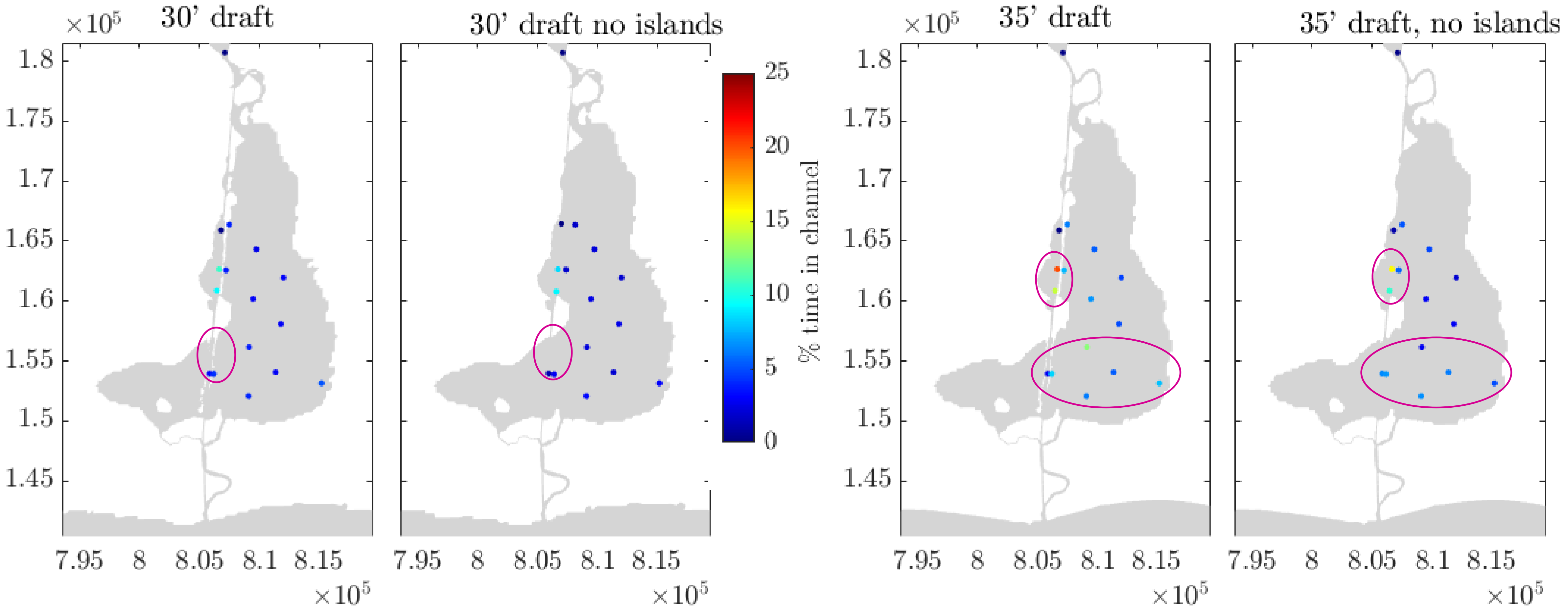
- Modeled water surface elevation η and current velocities *U*, *V* used to drive particle tracking model (PTM)
- Here, particles are treated as ***neutrally buoyant*** (using post-1960 topo/bathy)

Results – PTM (neutrally buoyant)



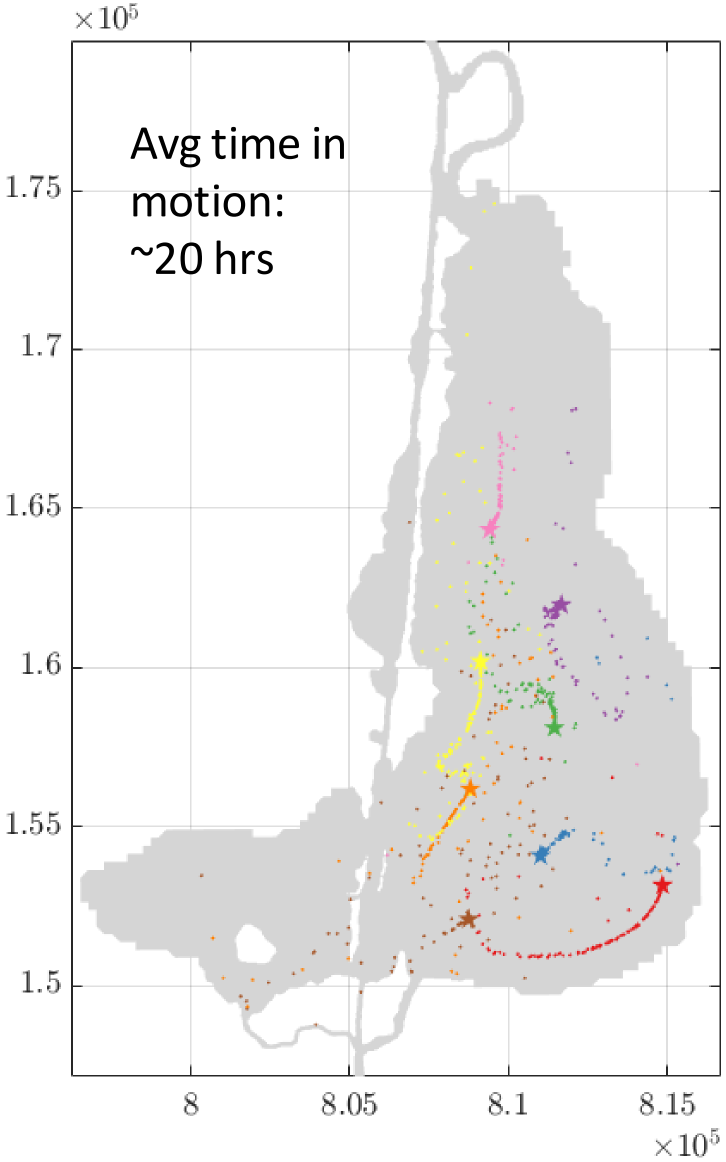


Results – PTM (neutrally buoyant) continued



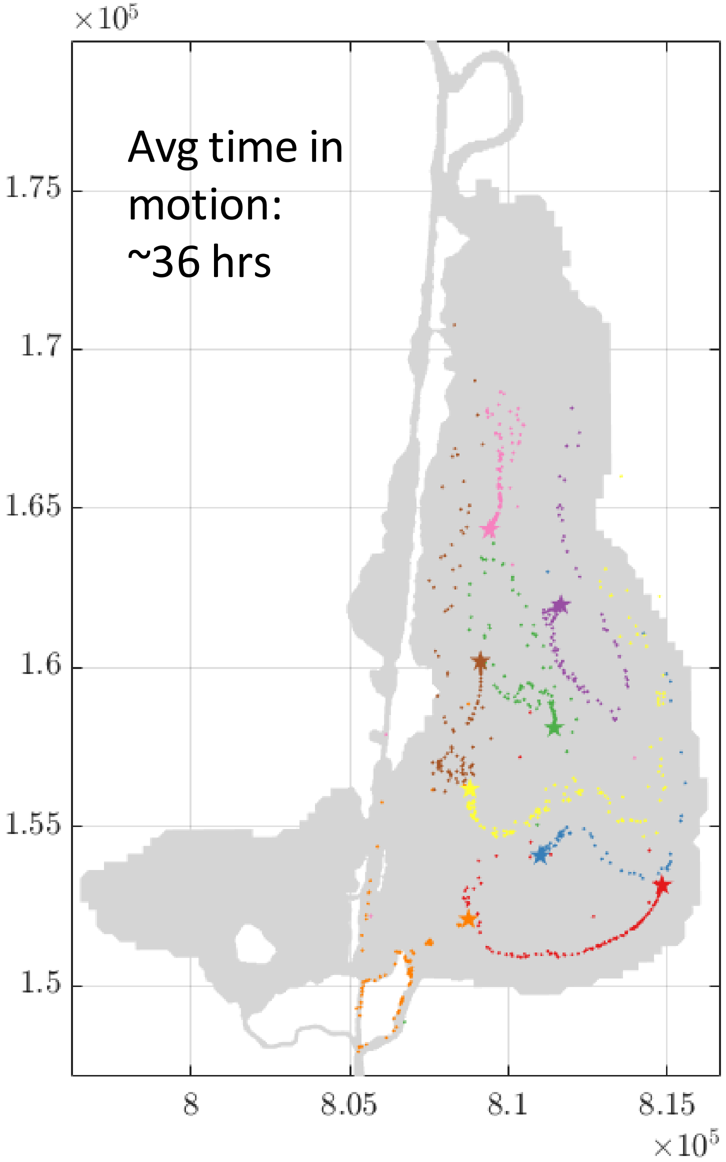
With draft of 30’, islands may confine more material in the channel, but ***difference is very slight***

Results – PTM (settling enabled)



< Settling rates from Brown and Luong (2022)

Settling rates > computed within PTM



Summary

Performed 30-day numerical simulations of representative winter-type (no tropical storms or cyclones) hydrodynamic and wind conditions

- CMS modeling indicates changes basin/channel geometry alone can alter tidal statistics (i.e., tidal prism)
- PTM modeling indicates that islands of Lake Calcasieu retain sediment that makes it way towards the channel. Possible sources include:
  - Suspension by ship wake (hypothesized by Brown and Luong, 2022)
  - Erosion of islands themselves (The Water Institute, 2019)
  - Erosion of shoreline and/or interior wetlands (Cadigan et al., submitted to *JWPCOE*)

Next steps

- Dependence of (weighted) particle on wind direction
- Identify potential hotspots of (re)suspension, relative to island geometry
- Identify pathway “hotspots” relative to gaps between islands