Southeast Florida Sediment Morphodynamics study (SEFMOD)

A 'System-understanding' Approach to manage navigation & coastal storm risk critical missions.

Lake Worth Inlet Metocean and Sand Tracer Study, Lake Worth, FL.

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US Army Corps of Engineers ®

RSM RCX

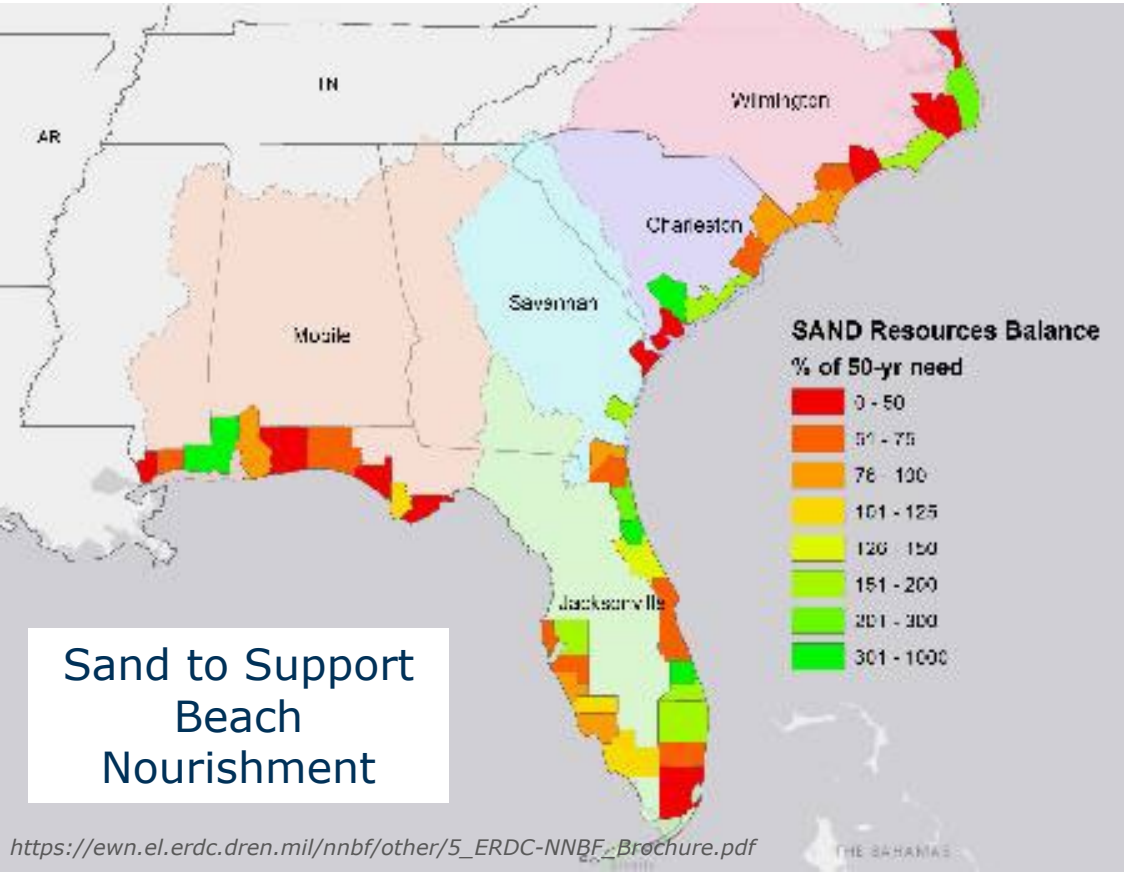
"The views, opinions and findings contained in this report are those of the authors(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other official documentation."

ENVIRONMENTAL TRACING

WATER PROOF

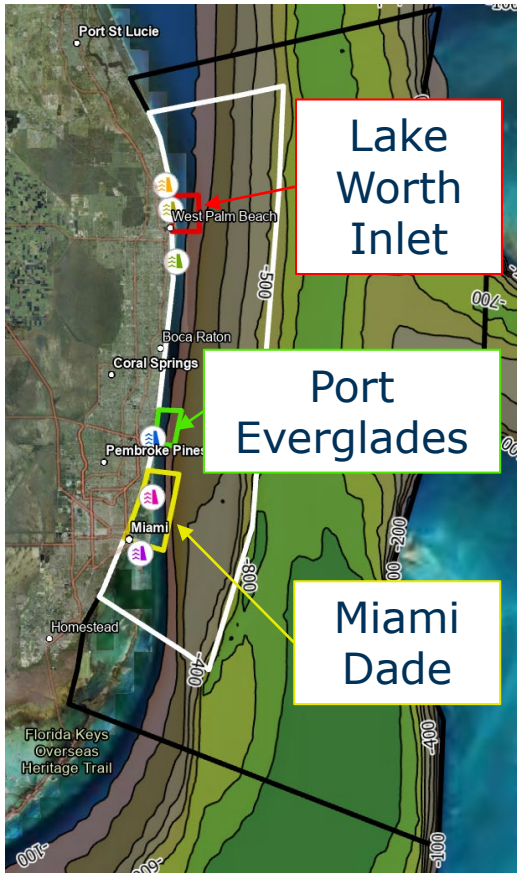
Southeast Florida Sediment Morphodynamics Project Overview

- Multi-year, multi-project hydrodynamic and sediment transport monitoring and modelling project: 80 miles
- Scientific approach to better understand the natural system = improved operational efficiencies & cost-savings



Sand to Support Beach Nourishment

https://ewn.el.erdc.dren.mil/nnbf/other/5_ERDC-NNBF_Brochure.pdf



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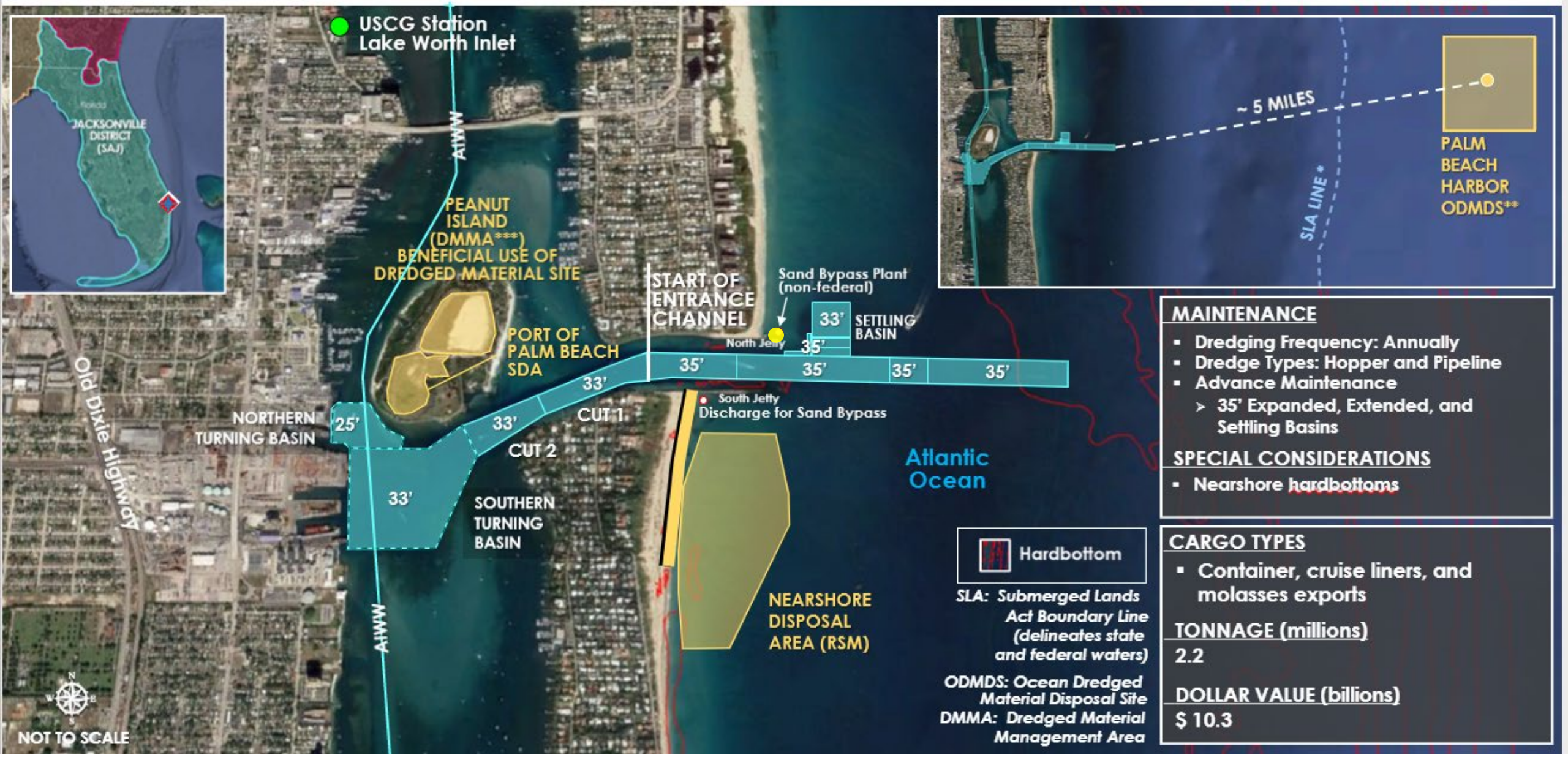
U.S. ARMY CORPS OF ENGINEERS | JACKSONVILLE DISTRICT

PALM BEACH HARBOR

Local Sponsor: Port of Palm Beach District

Placement Areas | Turning Basins | # Depths | Military: Coast Guard

0421



MAINTENANCE

- Dredging Frequency: Annually
- Dredge Types: Hopper and Pipeline
- Advance Maintenance
  - 35' Expanded, Extended, and Settling Basins

SPECIAL CONSIDERATIONS

- Nearshore hardbottoms

Hardbottom

SLA: Submerged Lands Act Boundary Line (delineates state and federal waters)

ODMDS: Ocean Dredged Material Disposal Site

DMMA: Dredged Material Management Area

CARGO TYPES

- Container, cruise liners, and molasses exports

TONNAGE (millions)

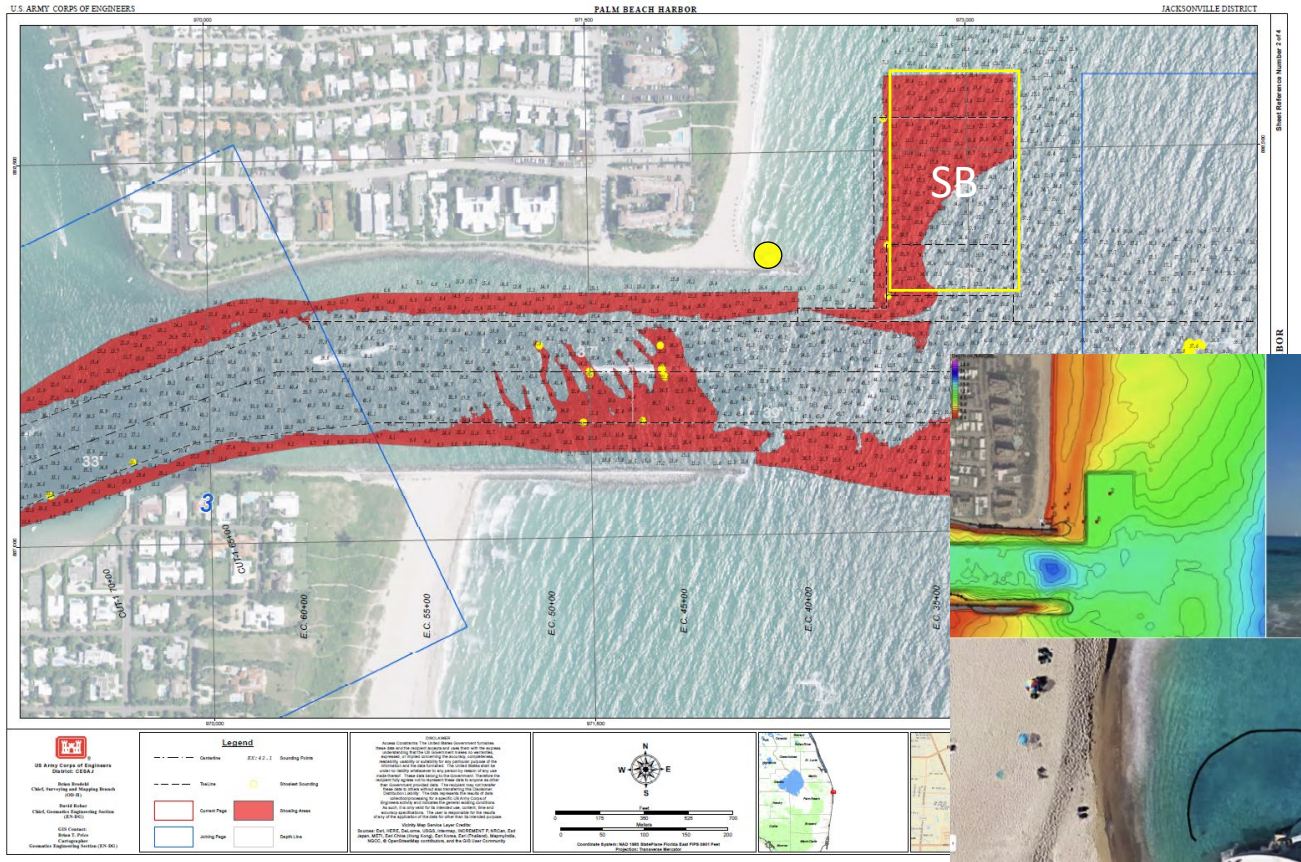
2.2

DOLLAR VALUE (billions)

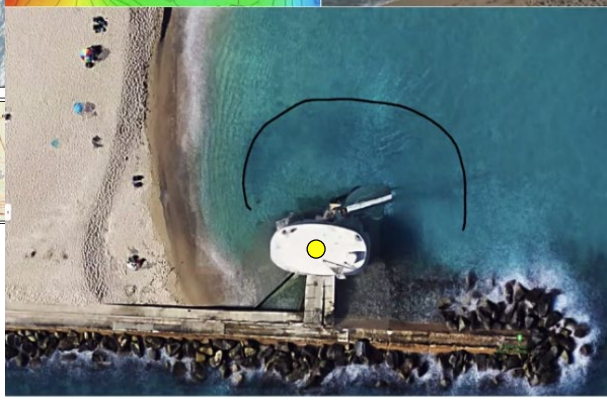
$ 10.3

Palm Beach Harbor, Lake Worth Inlet
The Problems & Goals

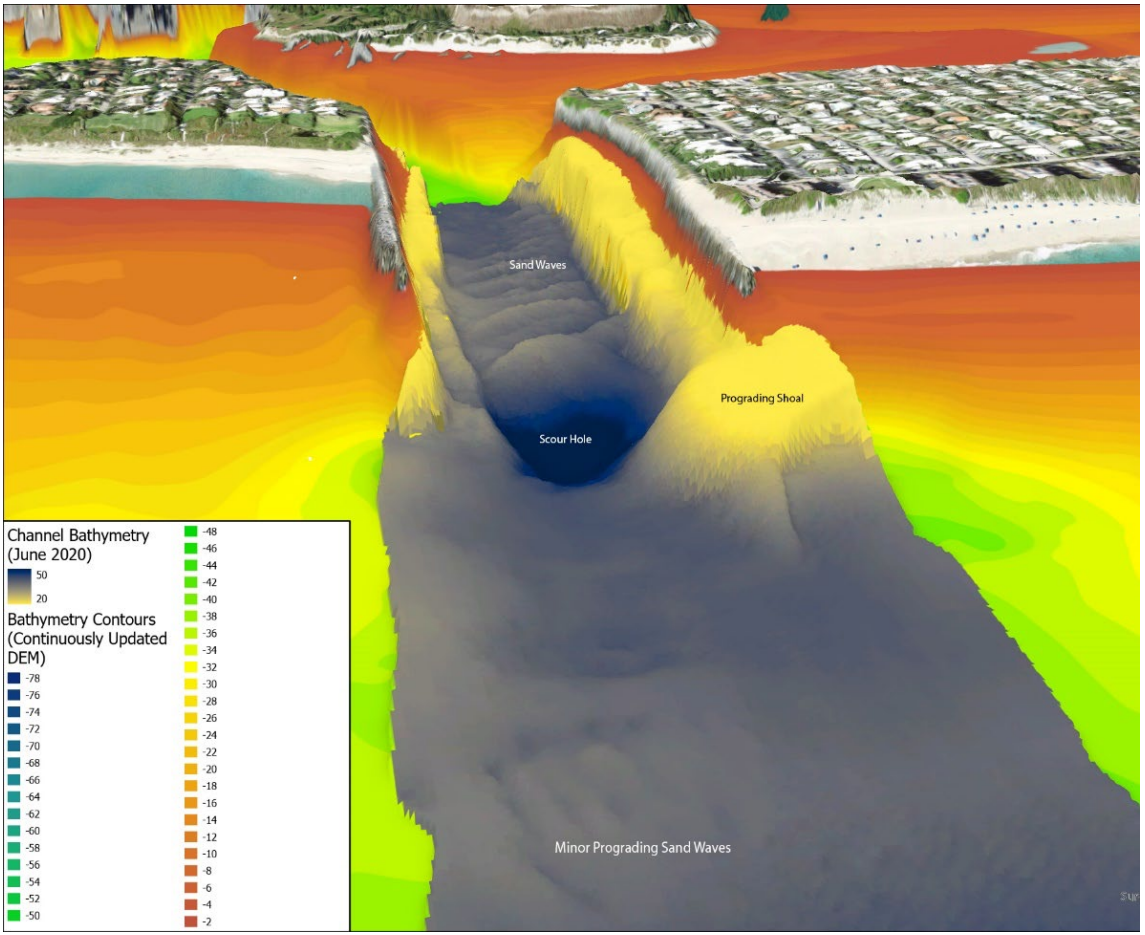
- **Problem:**
  - Chronic shoaling into channel (finger shoals); impacting navigation.
  - High frequency of dredging to remove shoaling, sometimes emergency type dredging events.
- **Goal:**
  - Understand and model ambient sediment transport
  - Determine ways to minimize shoaling and reduce O&M Federal navigation costs at the harbor.

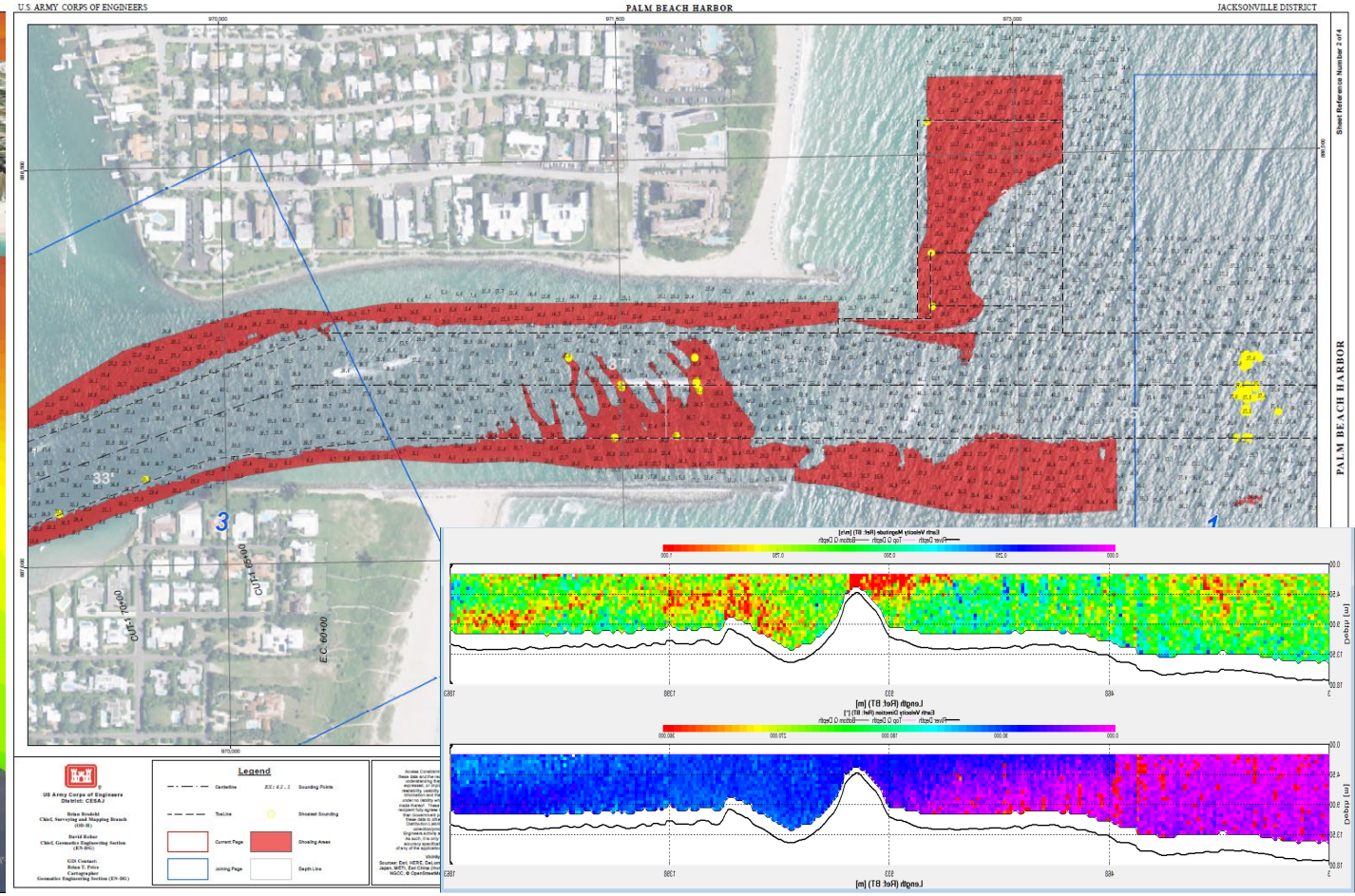


Bathymetry survey data difference plot: May '14 to Apr. '17.



- **Post Hurricane Dorian:** ADCP Neap tide survey highlighted prograding bar shoal.
  - Loss of up to 28’ (~8.5m) of navigable depth & narrowing of Entrance Channel.
  - Scour hole >45’ MLLW.
  - Sand waves/finger shoals >1m in central inlet channel.
  - ADCP Spring tide survey 1 week later, shoal eroded & finger shoals grown >1.3m.





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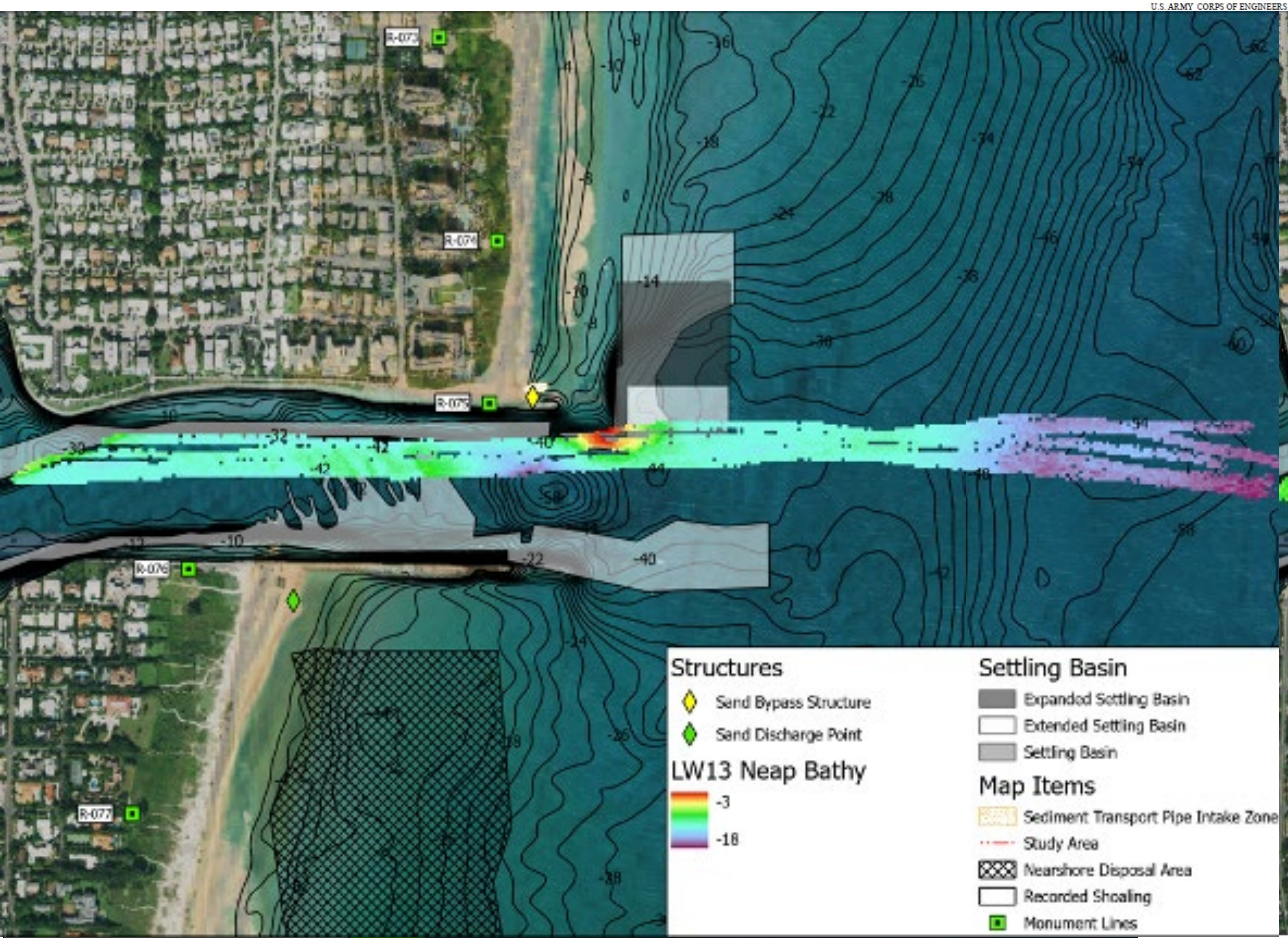
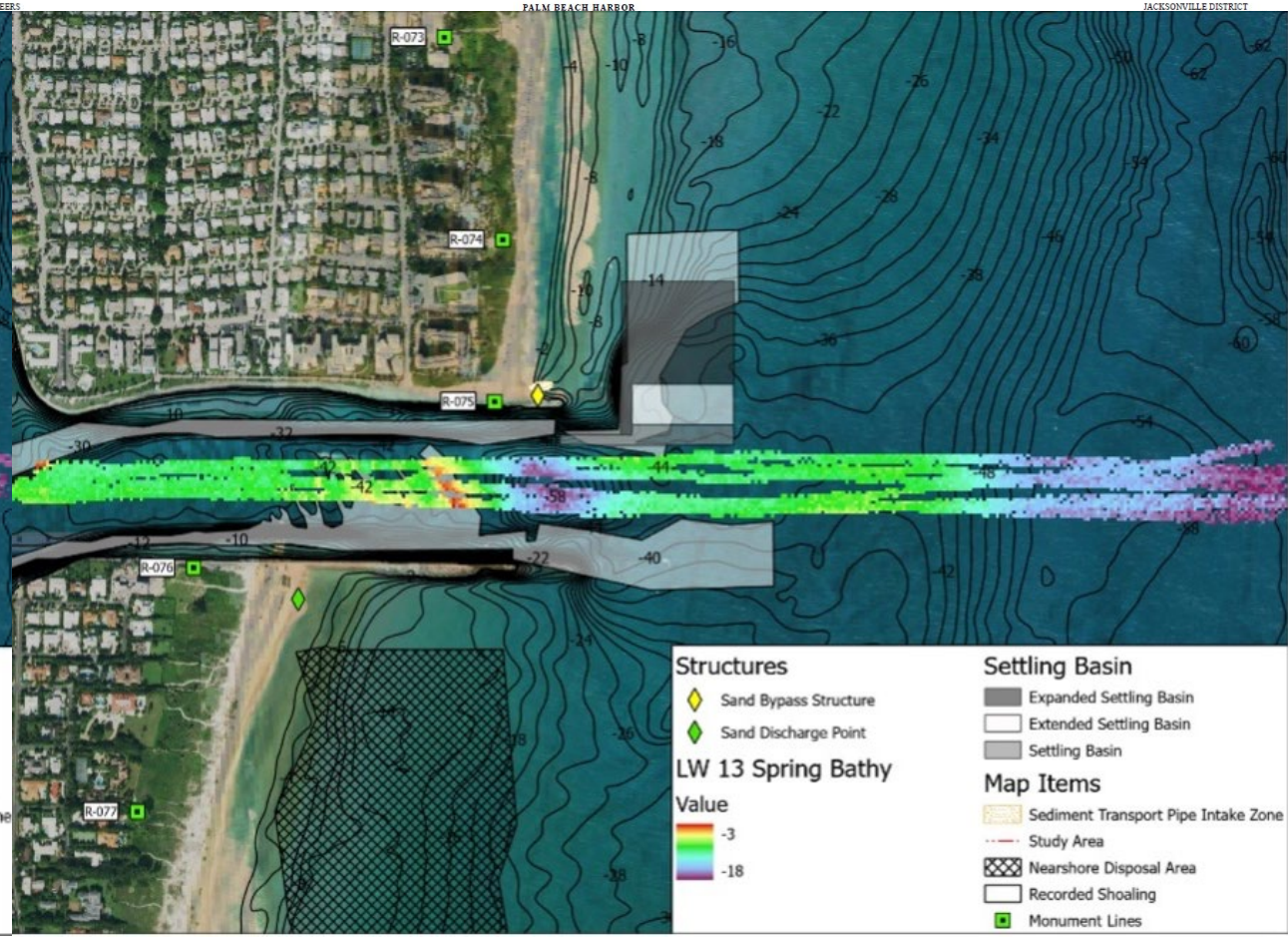


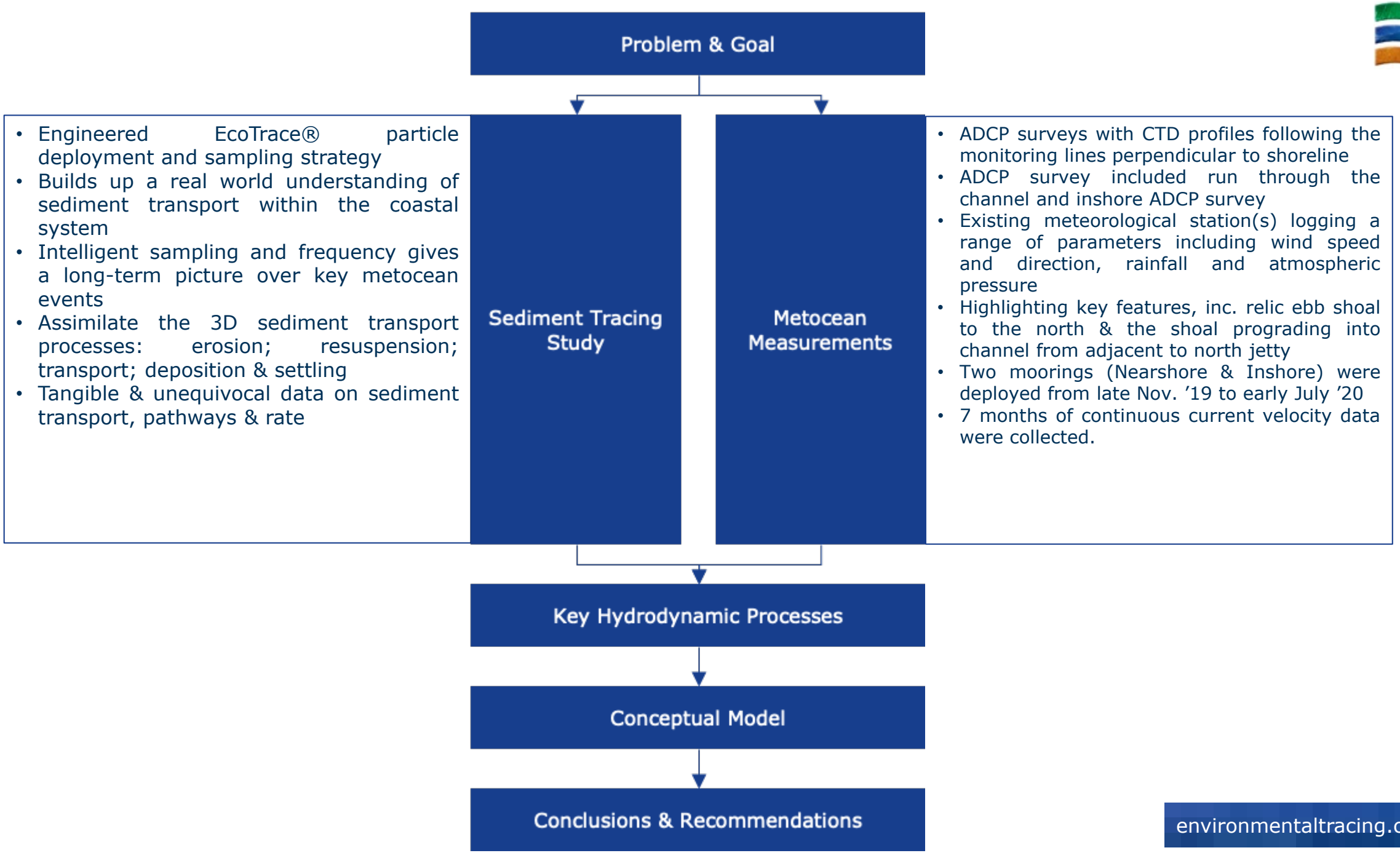


Introduction to ET's Experience

- >30 years experience:
  - oceanographic survey
  - sediment transport
  - Pollutant & hydro dynamics
  - sediment morphodynamic conceptual models
- >100 silt & sand transport studies worldwide
- Key Clients:
  - 15 US states & 13 USACE
  - SAD: FL, SC, AL, GA
  - Global: UK, EU, Australia
- RSM, Barrier island evolution, Coastal inlet assessment, Beach erosion & nourishment, Sand bypass systems, Beneficial use, Habitat restoration, 'Working with Nature' & 'living shoreline', Dredge optimization & Sedimentation rates…
- Prime: Environmental Tracing (LLC)
- Modelling: WaterProof and Prof. Leo van Rijn, NL

ENVIRONMENTAL TRACING

WATER PROOF

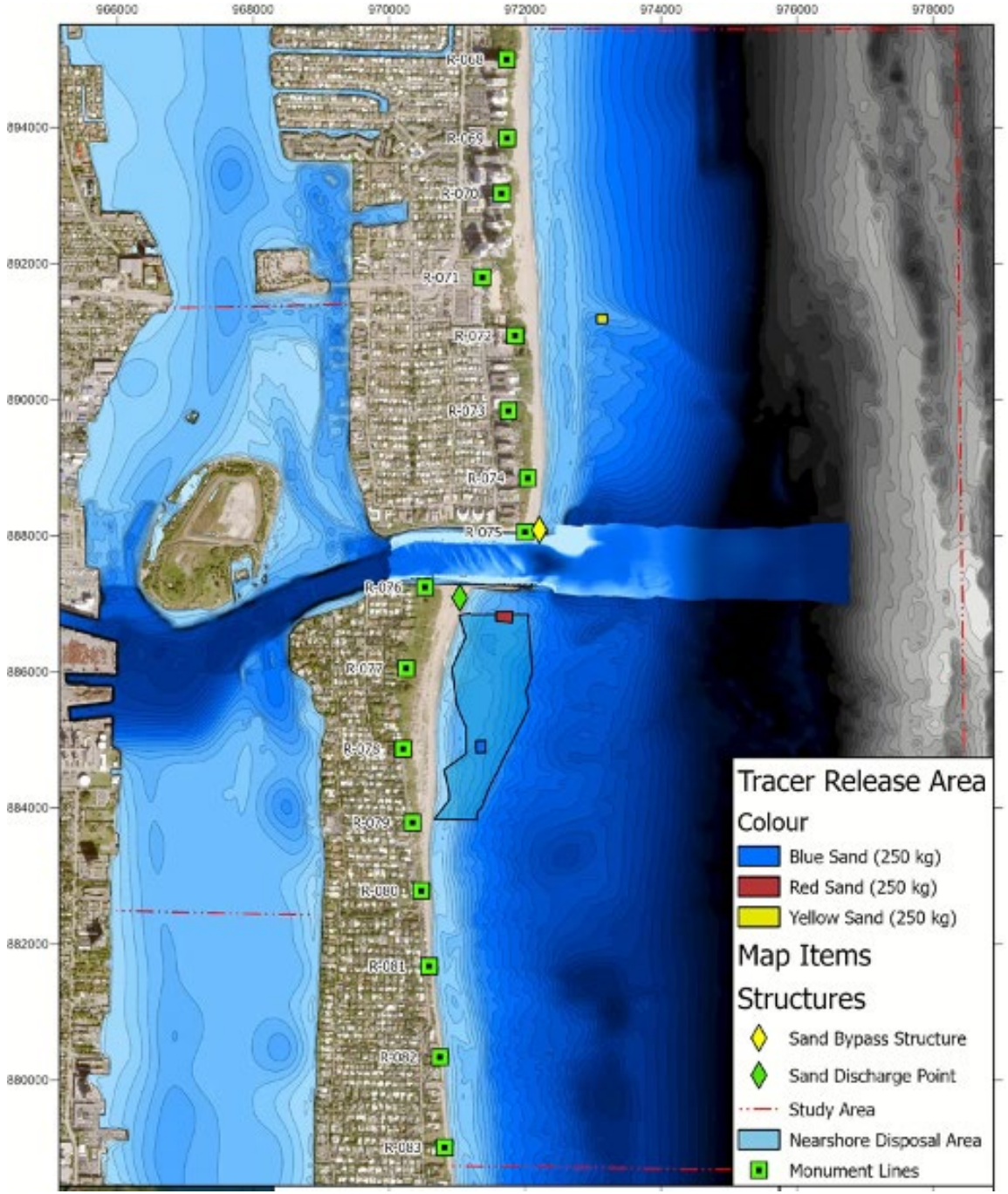


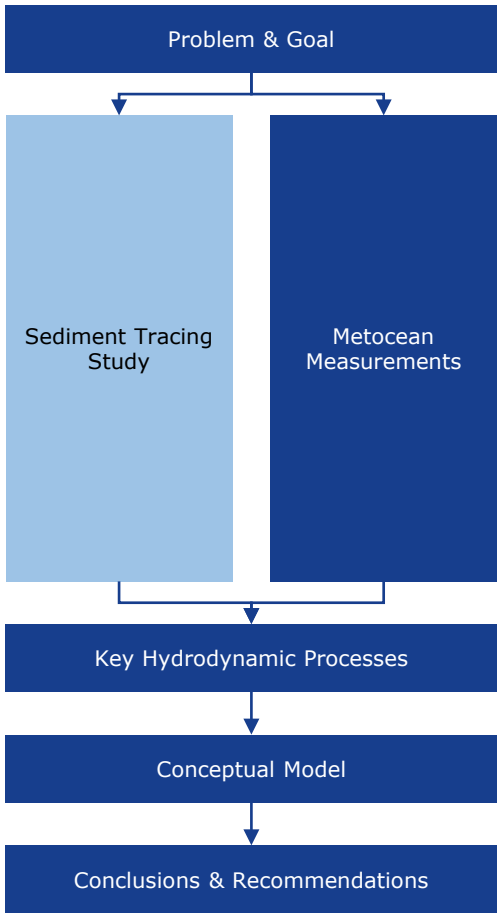
- Engineered EcoTrace® particle deployment and sampling strategy
- Builds up a real world understanding of sediment transport within the coastal system
- Intelligent sampling and frequency gives a long-term picture over key metocean events
- Assimilate the 3D sediment transport processes: erosion; resuspension; transport; deposition & settling
- Tangible & unequivocal data on sediment transport, pathways & rate

- ADCP surveys with CTD profiles following the monitoring lines perpendicular to shoreline
- ADCP survey included run through the channel and inshore ADCP survey
- Existing meteorological station(s) logging a range of parameters including wind speed and direction, rainfall and atmospheric pressure
- Highlighting key features, inc. relic ebb shoal to the north & the shoal prograding into channel from adjacent to north jetty
- Two moorings (Nearshore & Inshore) were deployed from late Nov. ’19 to early July ’20
- 7 months of continuous current velocity data were collected.

- 3 x environmentally benign fluorescent sand tracers
- Same size & density so eroded, transported & settle with sediment
- All released at ~12’ water depth within 24 hours
- All experienced & transported in the same metocean conditions and hydrodynamic processes

- **Overall:** Identify potential sediment source/s for material shoaling on north side of the entrance channel and finger shoals (sand waves) in the inlet channel.

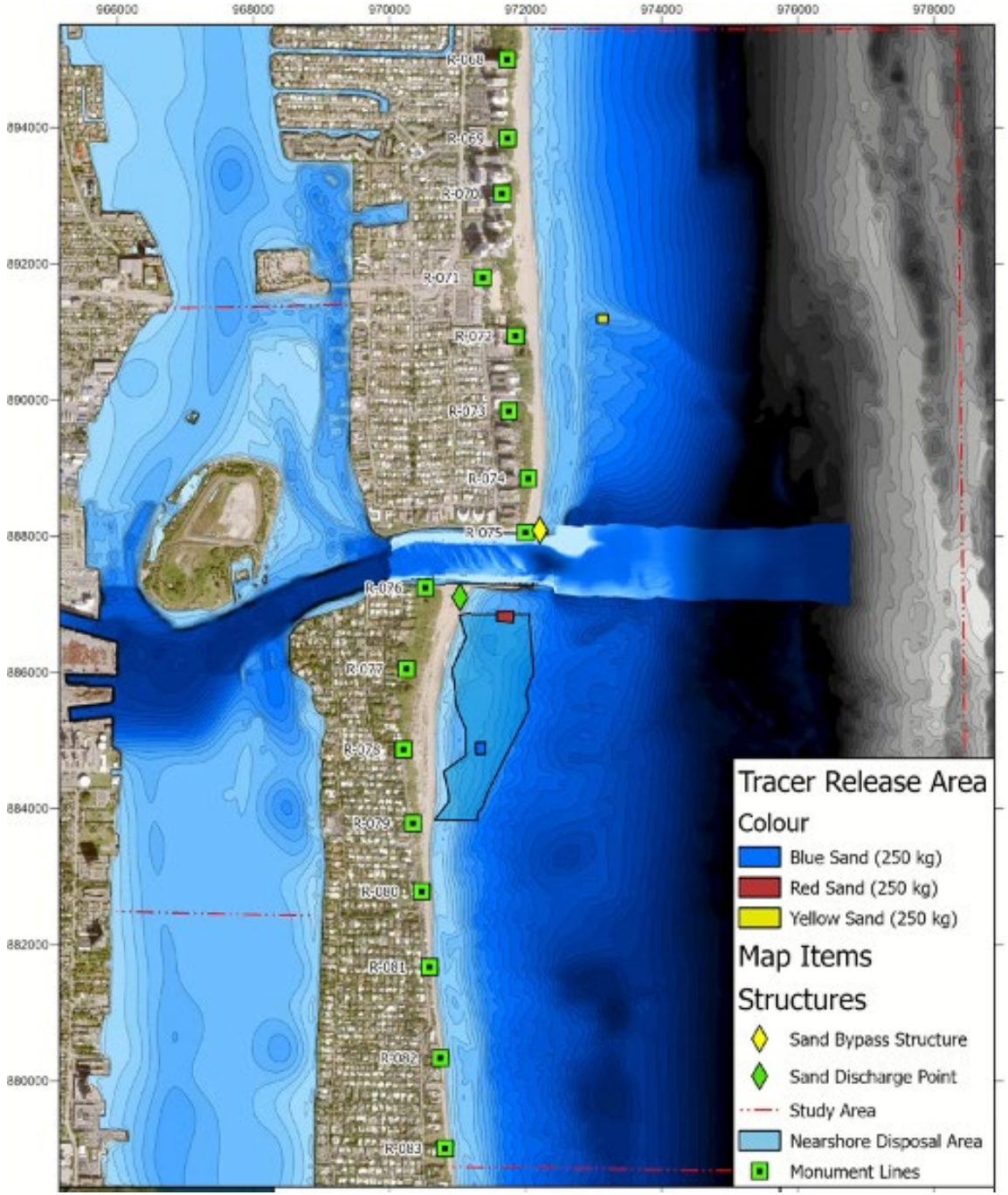


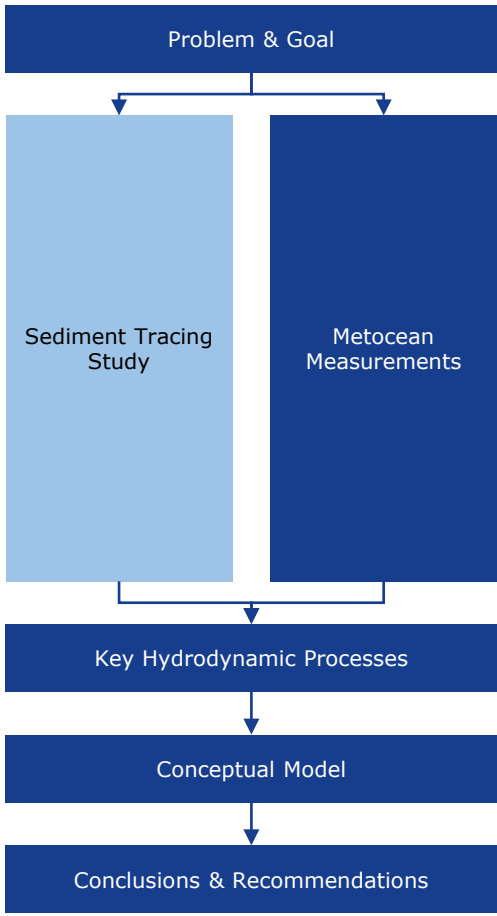


- **Yellow:** N of inlet (on relic ebb shoal)
- Characterize littoral drift from north down the coast & determine any transport across inlet

- **Red:** S of south jetty adjacent to SBP outlet
- Identify if sand discharged by SBP is returning to the inlet/channel or remains & nourishes the beach

- **Blue:** S of Nearshore Disposal Area
- Determine the fate of O&M dredge sand from channel, if it i) remains & protects and nourishes the adjacent beach, ii) is transported north back to the inlet or iii) south with littoral drift





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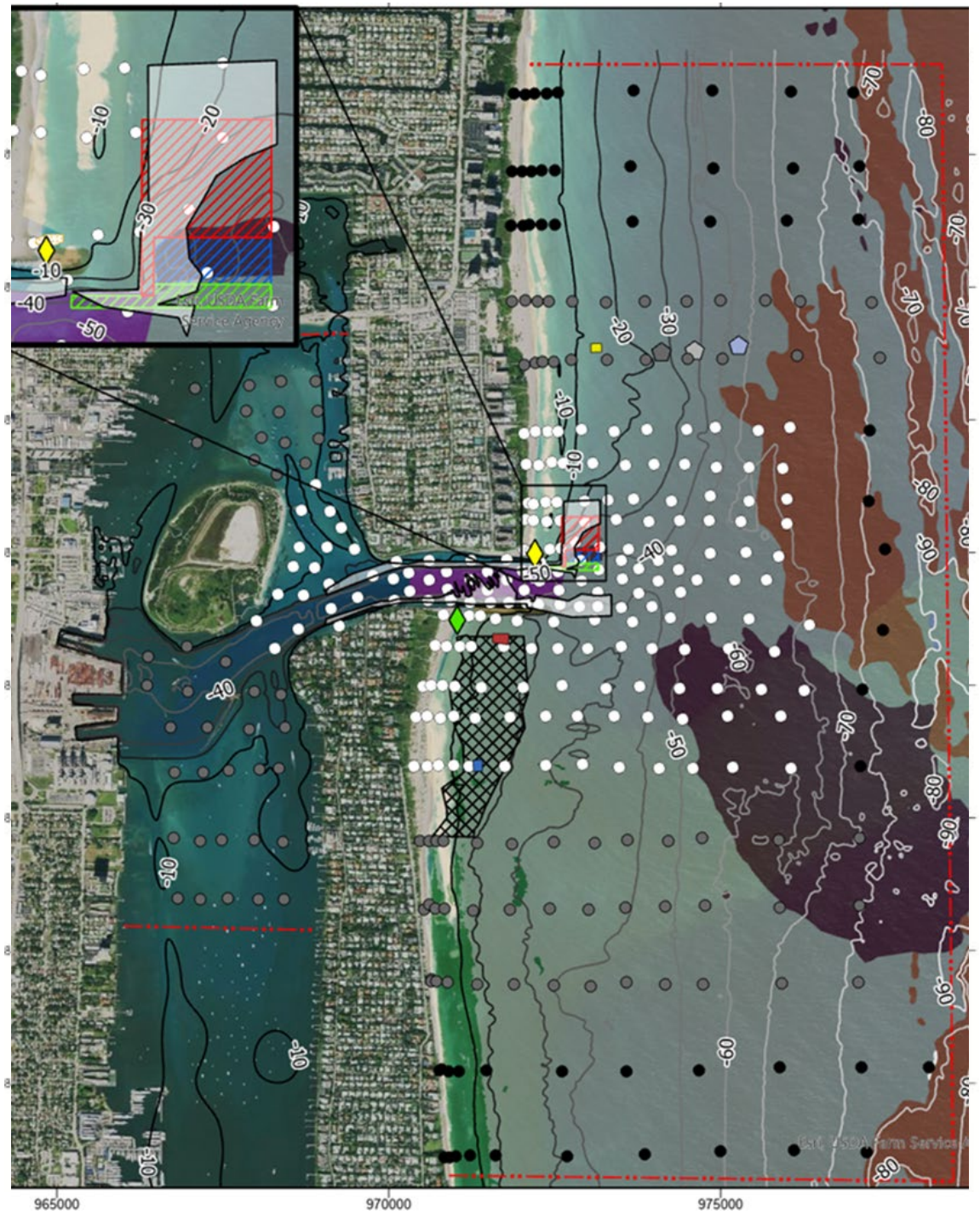
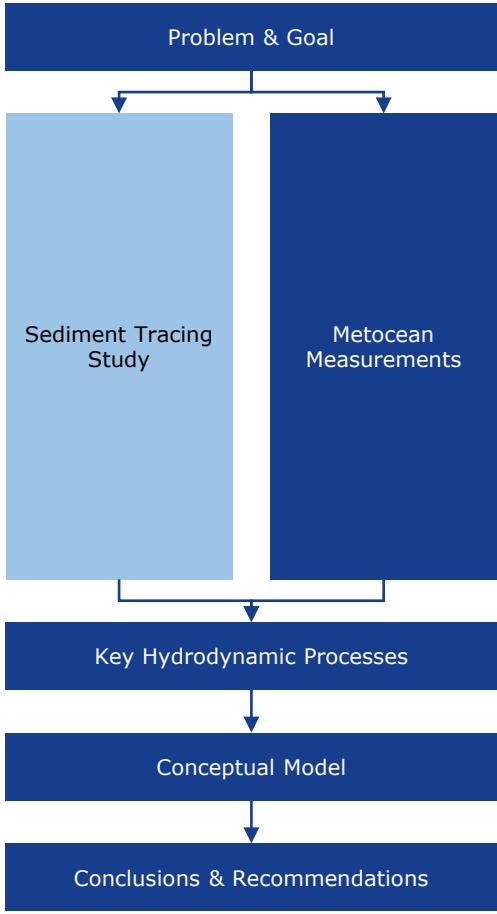
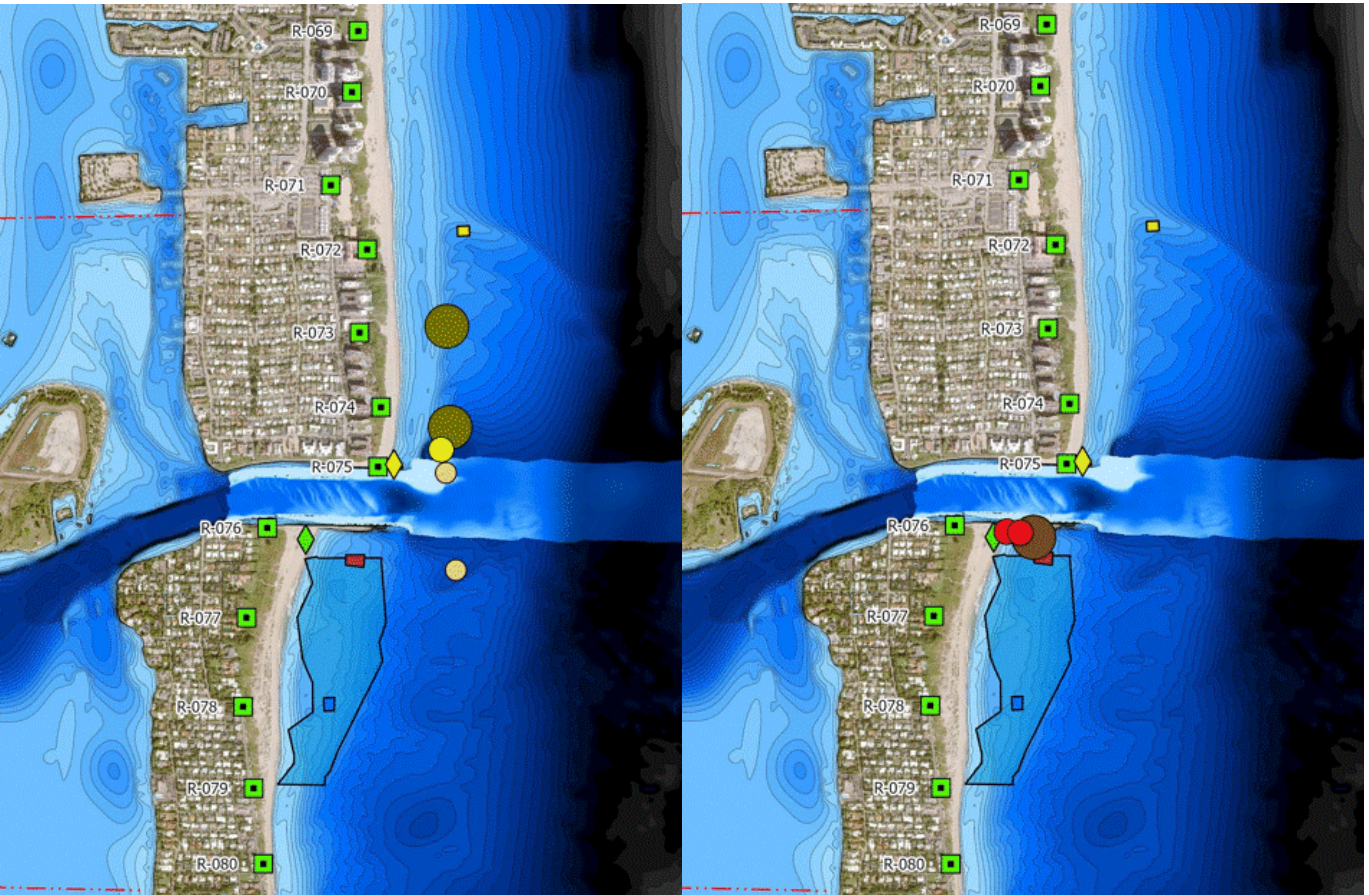
- **4 sampling rounds:** 2, 5, 9 and 32 weeks after release
- Beach and seabed samples (grab & ROV around hard-bottom resources)
- **>1200** total samples analysed
- PSD analysis of 325 Round 2 samples

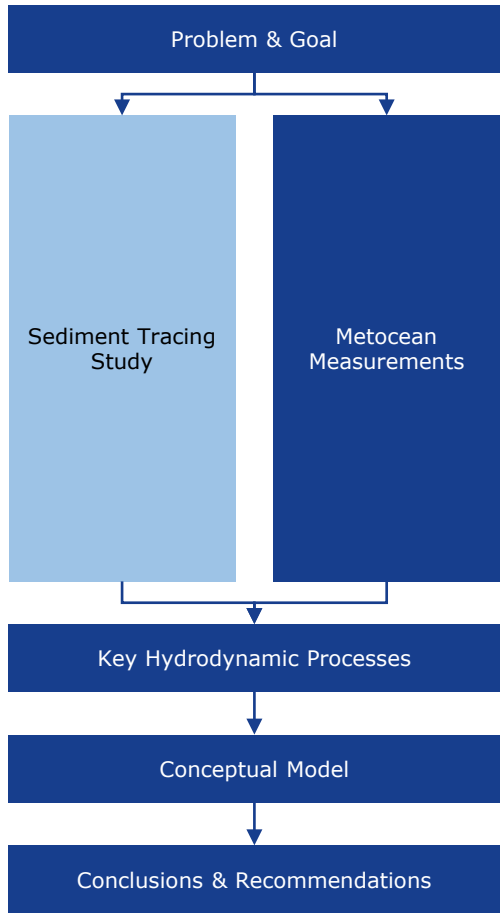




Tracer Results

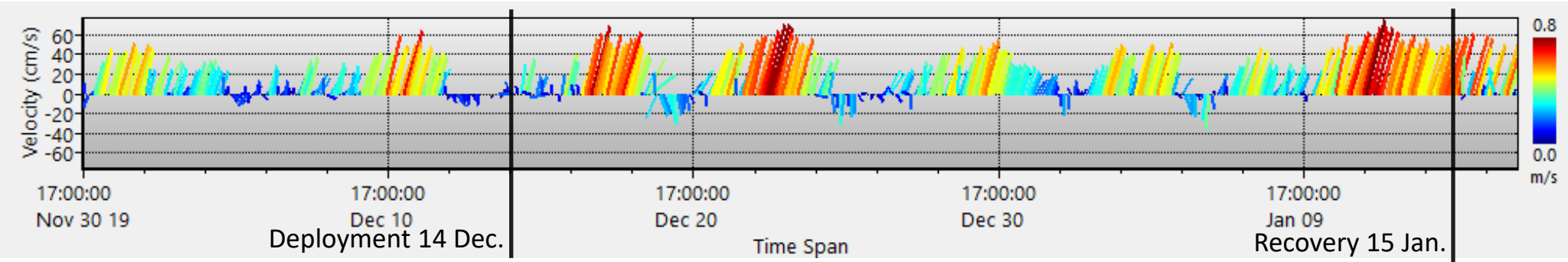
- Round 1: 2 weeks after tracer releases.
- Round 2: 5 weeks after tracer releases.
- Round 3: 9 weeks after tracer releases.
- Round 4: 32 weeks after tracer releases.

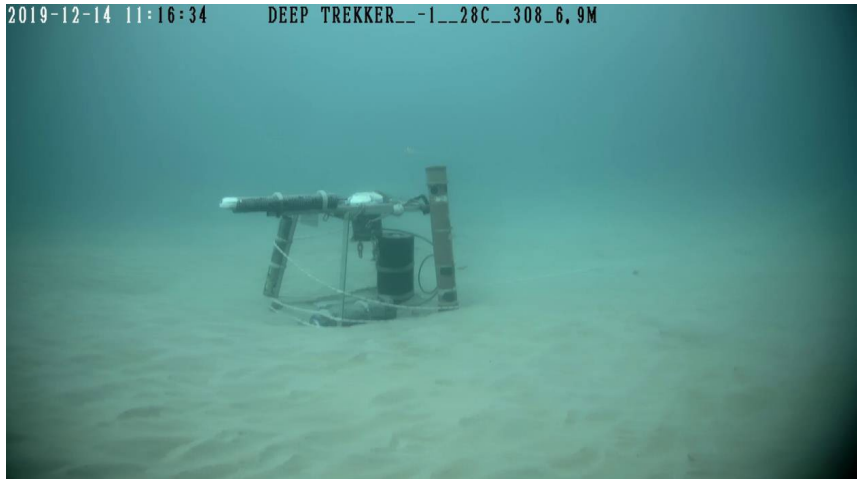


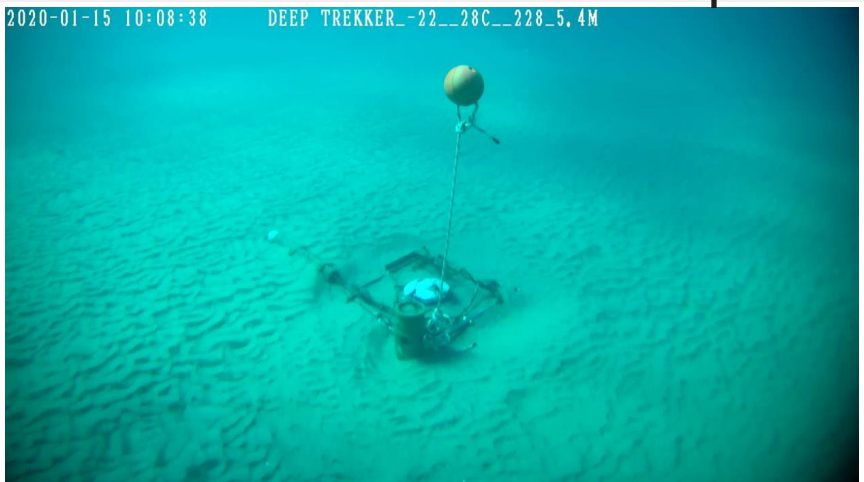


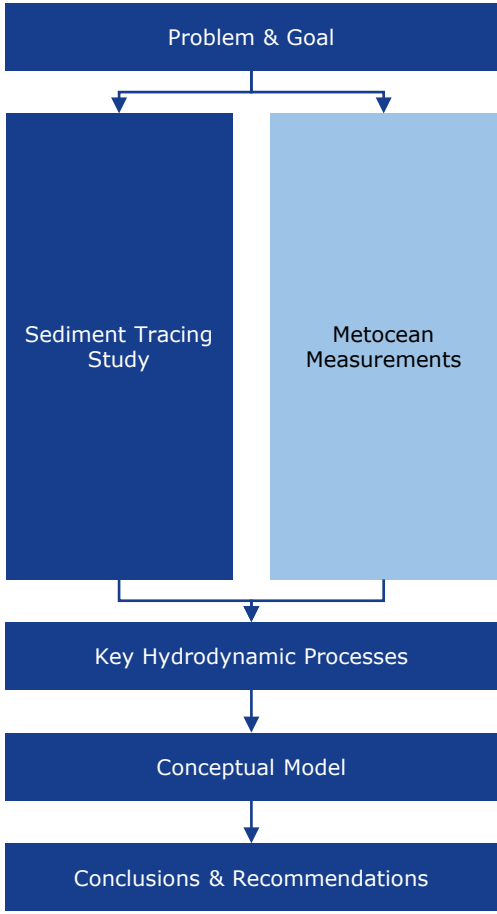
- Background ADCP to assess overall circulation
- Met., tide, SSC (mg/L), CTD (salinity)
- Currents – near-bed & water-column
- Waves

- Moorings for 7 mths. Nov. ‘19 to Jul. ’20.
- Mooring buried 0.8m (>2.5’) deployed 14 Dec.’19 to 15 Jan. ’20 in 25’ water depth due to 3 x Northeasterlies = V. active transport zone.



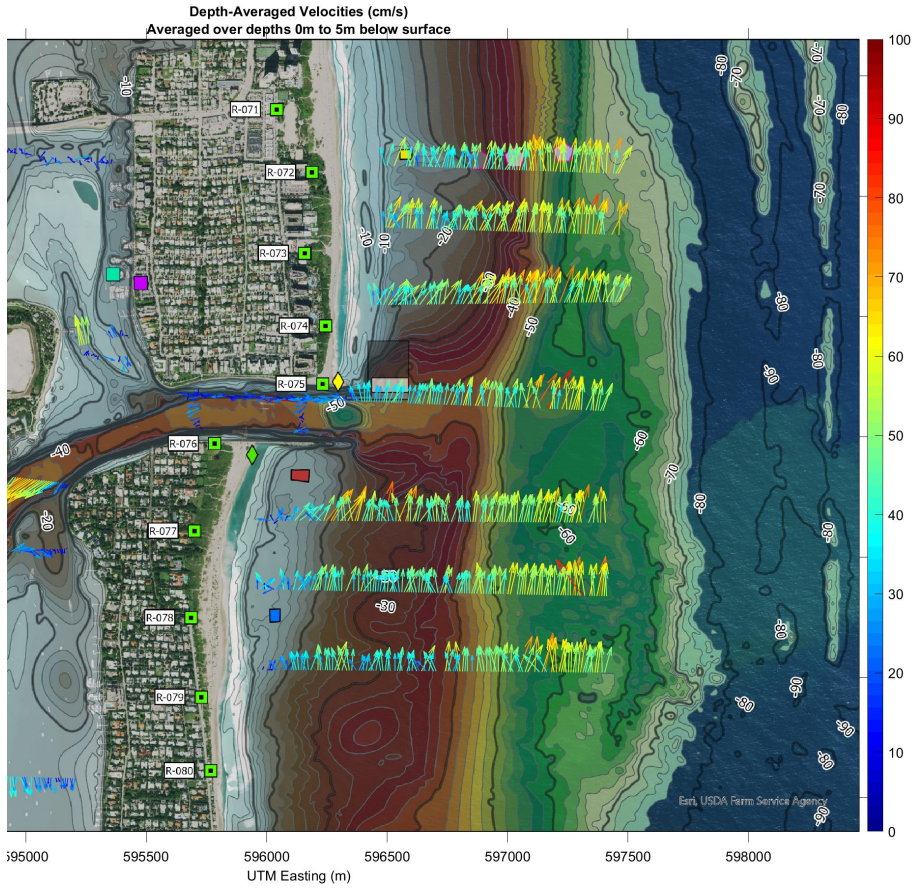




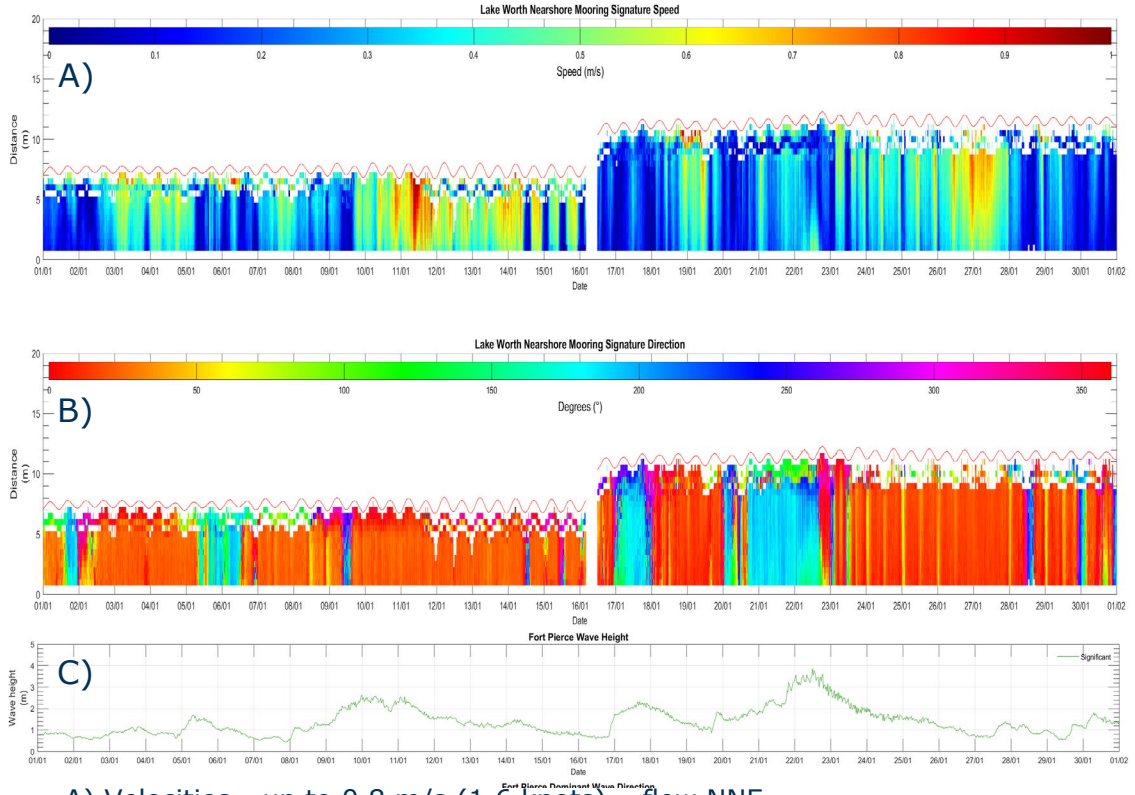


Florida Current (FC) & Northeasterlies

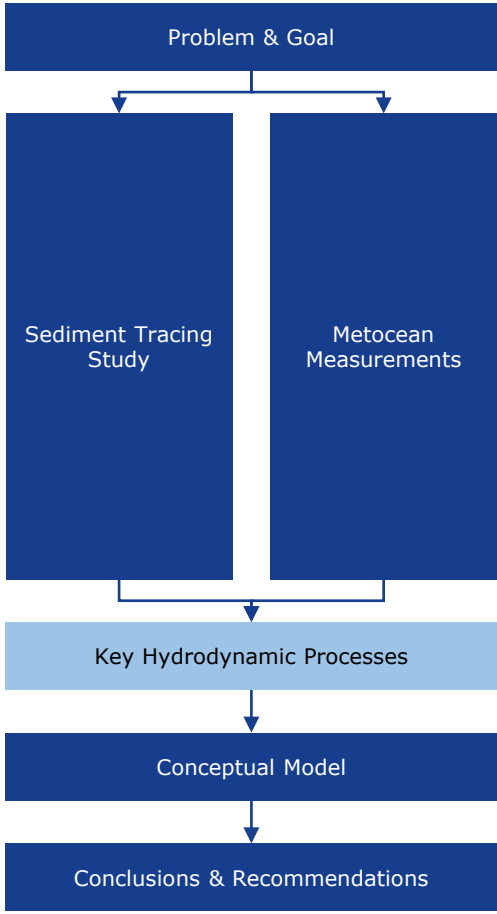
- North much of the time, alternates south from hours to days up to 5-6 days. Stronger in summer months
- Reversal could be a return flow, counter-current or displaced FC
- Up to 0.7 m/s (1.5 knots) within 150m of south jetty flow perpendicular to entrance channel = hazard for shipping
- Return flow close to south jetty & to north of inlet across relic ebb shoal



Slack tide in inlet surface ADCP
= FC flow to north only

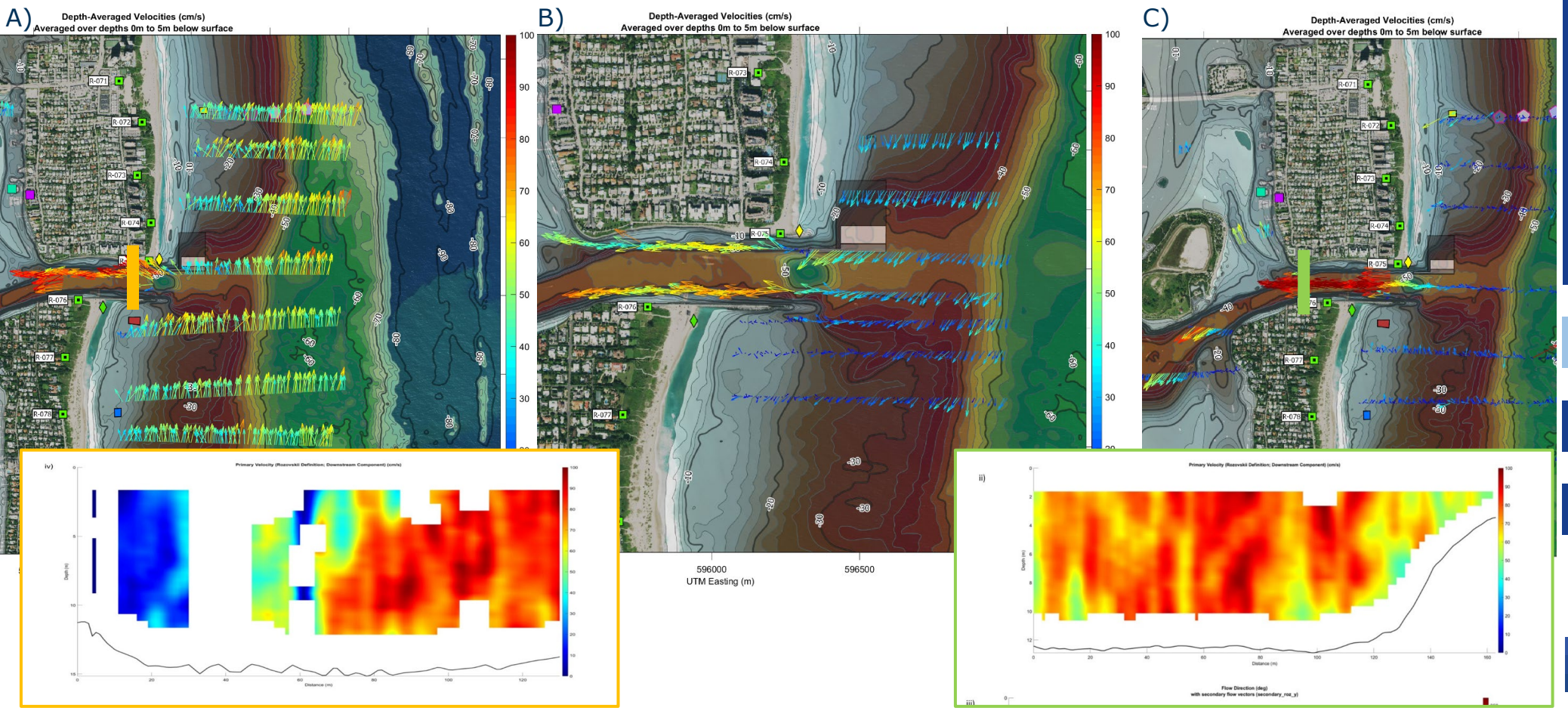


- A) Velocities - up to 0.8 m/s (1.6 knots) – flow NNE
- B) Direction – Red is North. Turquoise is South (yellow is ebb jet flow from inlet)
- C) Sig. wave height up to 3.5m, Northeasterly creates Southerly flow FC (or return or displaced offshore)



Flood Tide - Tidal Inlet

- A) Flood tide mainly enters from SE, enhanced by north flowing FC. Cross-channel plots highlight very uneven flow & v. high velocities adjacent to north jetty (middle image) confirming turbulence and scour
- B) Flow directly across the channel from north side of channel, across prograding bar shoal, creating shoaling on north side of channel.
- C) Merging of opposing flows, creates significant turbulence, scour hole, sand waves as flow twists and 'zig-zags' through inlet. Main vectors show flow directed oblique to main channel incl. to NW adjacent to north jetty



Problem & Goal

Sediment Tracing Study

Metocean Measurements

Key Hydrodynamic Processes

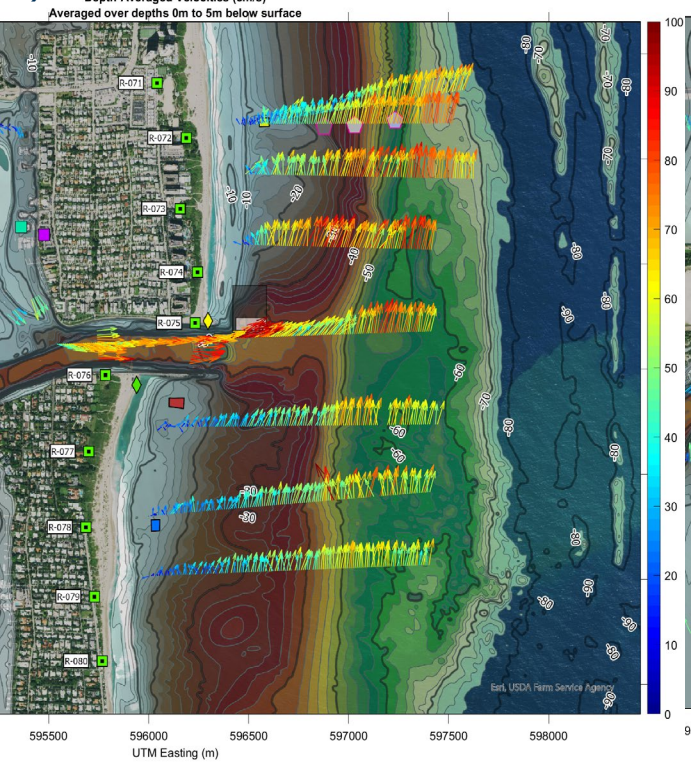
Conceptual Model

Conclusions & Recommendations

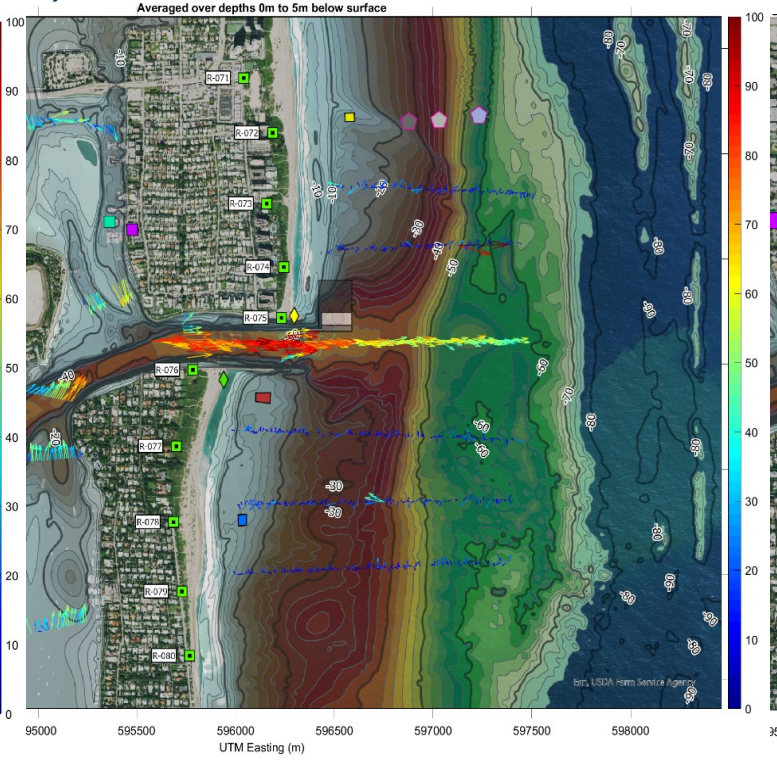
Ebb Tide - Tidal Inlet

- Perpendicular flow to FC/NE – at entrance channel ~ 1 m/s on ebb tide to W flowing across FC/NE at 0.7 m/s to N or S.
- A) Ebb jet deflected to NNE and combined with FC
- B) Ebb tide due E with no FC or NE
- C) Ebb tide jet deflected to SE with return flow due to NE and Coriolis forces (to the right)

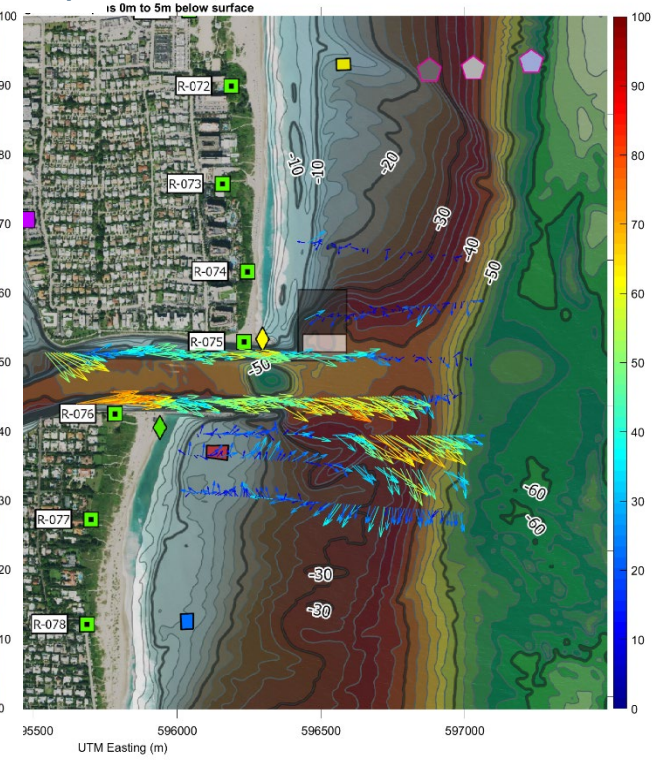
A)

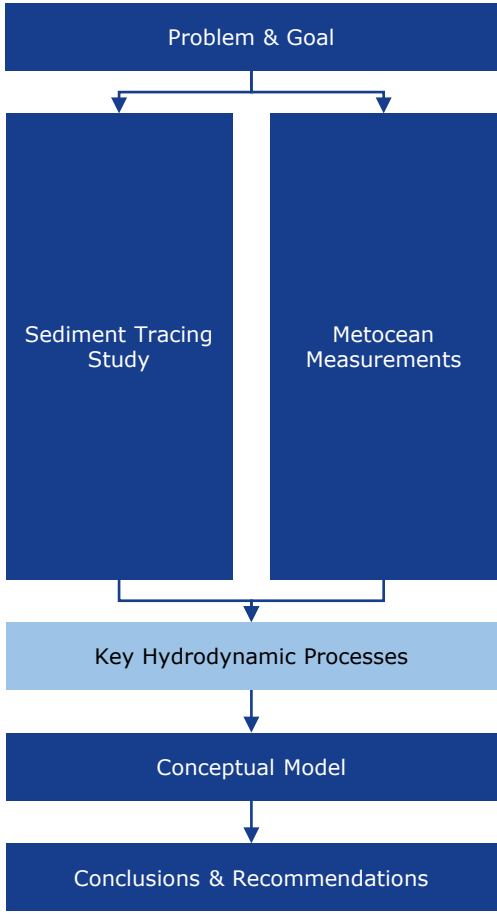


B)



C)

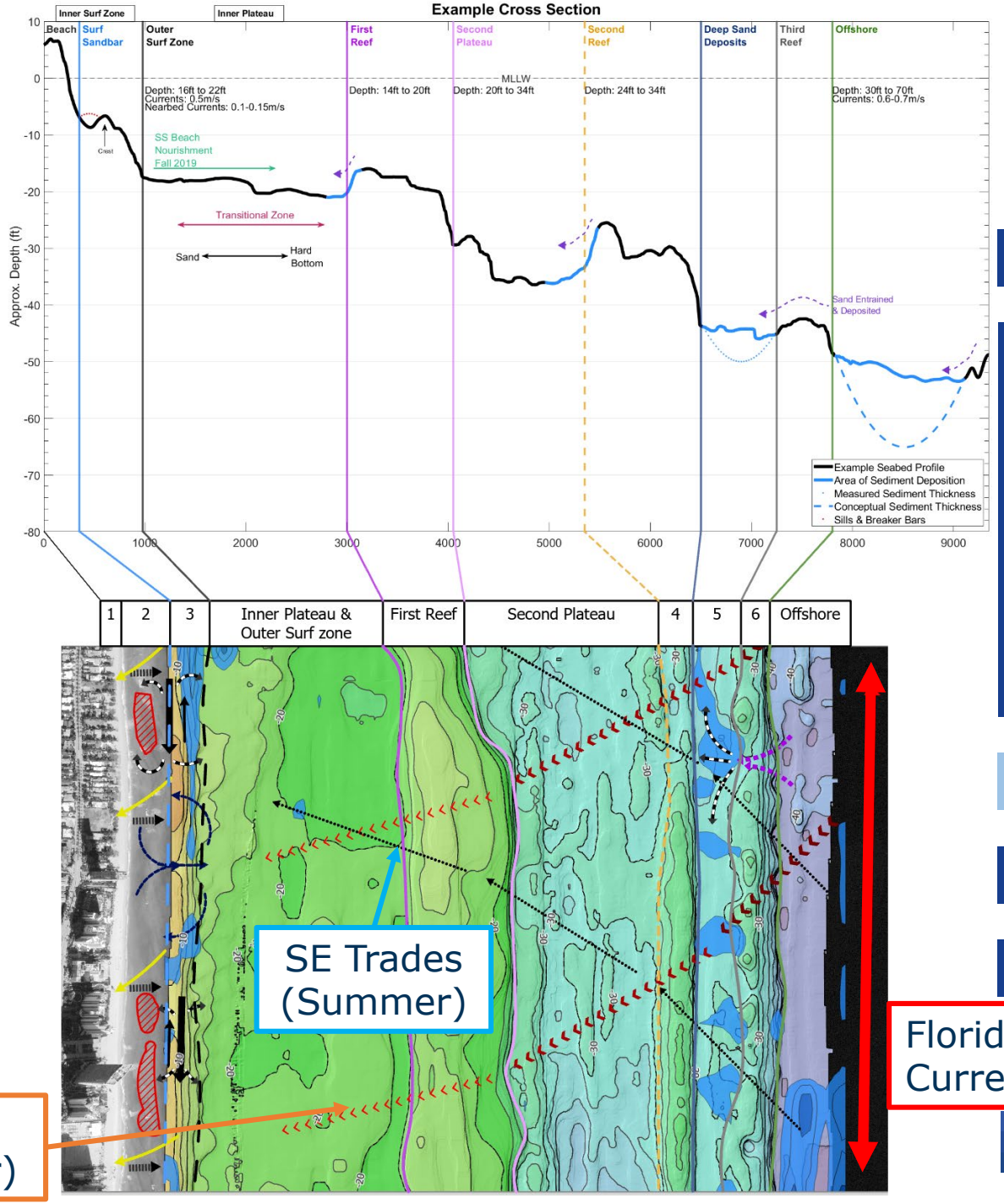


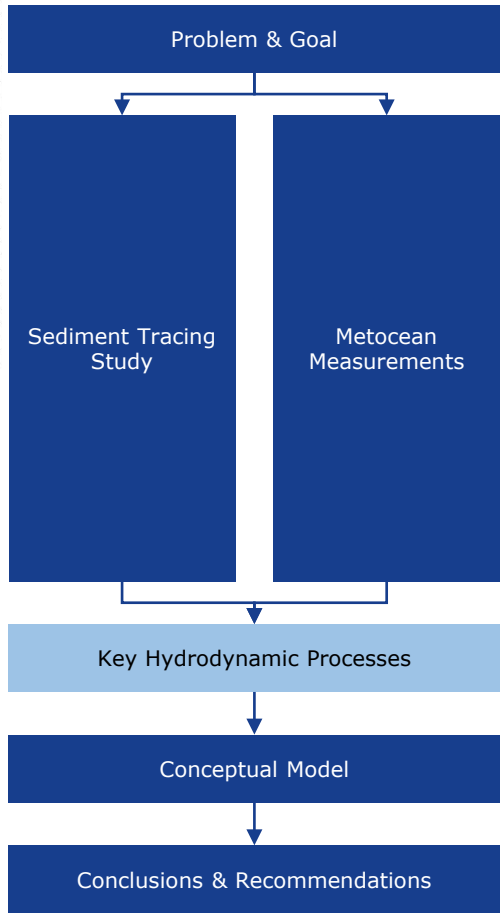


- Visualize how processes cross-shore and longshore
- 1. Wind-driven circulation
- 2. Wave-driven circulation
- 3. Waves (erosion/resuspension) in particular Northeasterlies
- 4. Florida Current (FC)
- 5. Tidal inlet – A) ebb tide jet & B) flood tide

- Processes oppose, perpendicular and combine = spatial and temporal variability & complexity

- Creates net sediment transport & shadowing with leeward areas & Shoaling





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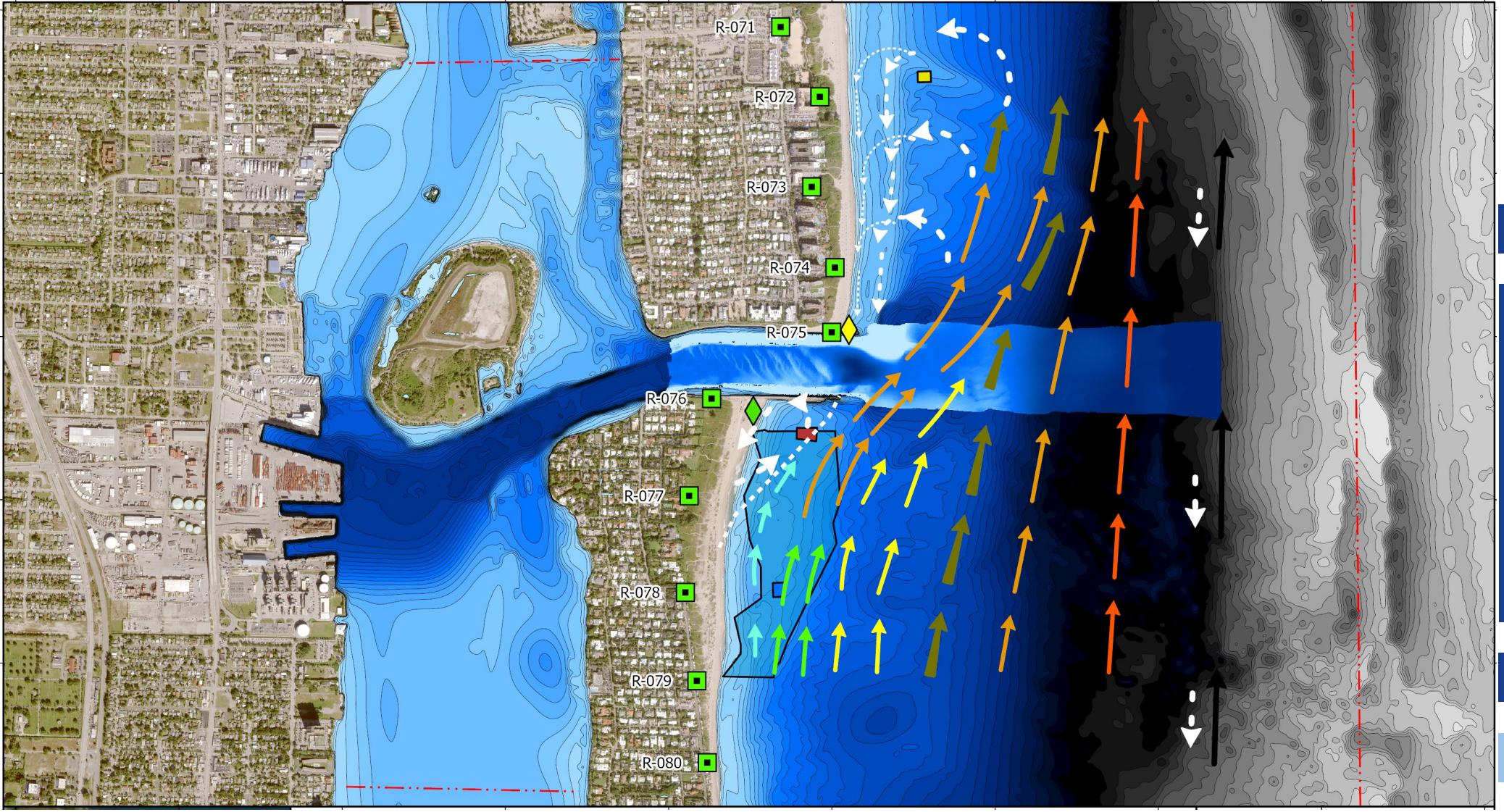

- Problem & Goal
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Conceptual Models

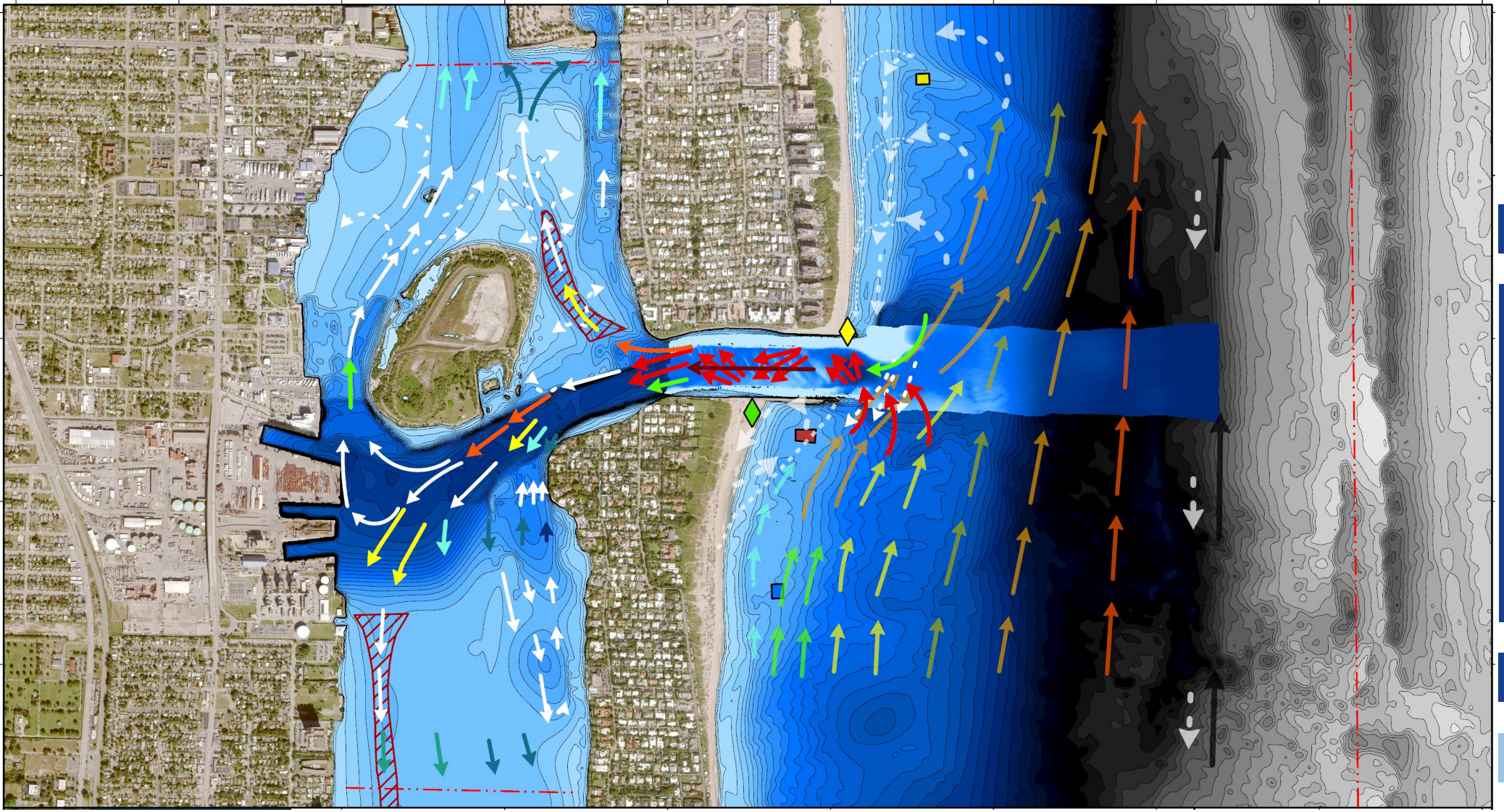
Florida Current

Flood Tide

Florida Current plus Ebb Tide

Weak Florida Current & no NE

Ebb Tide plus NE plus Coriolis forces



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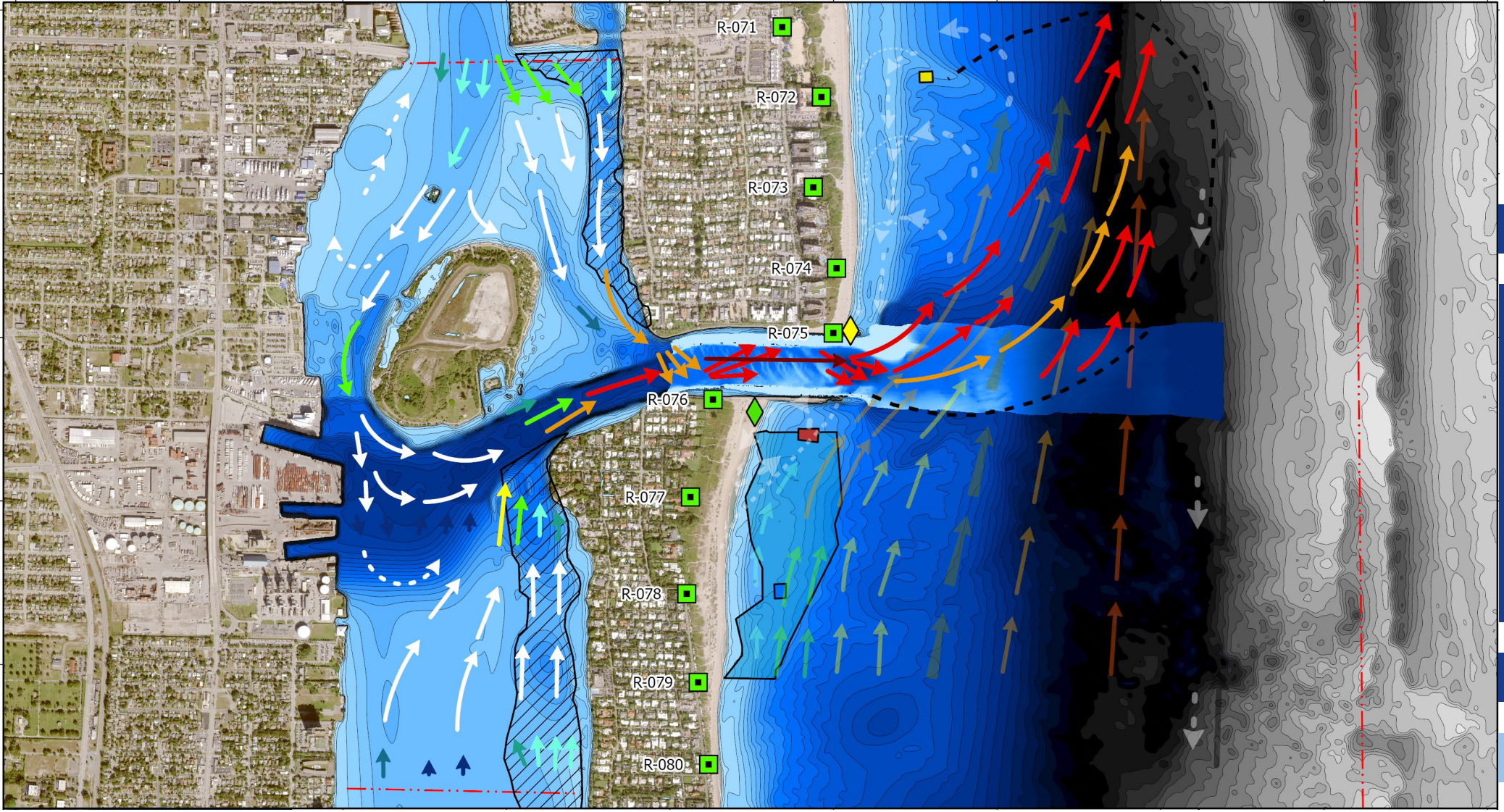

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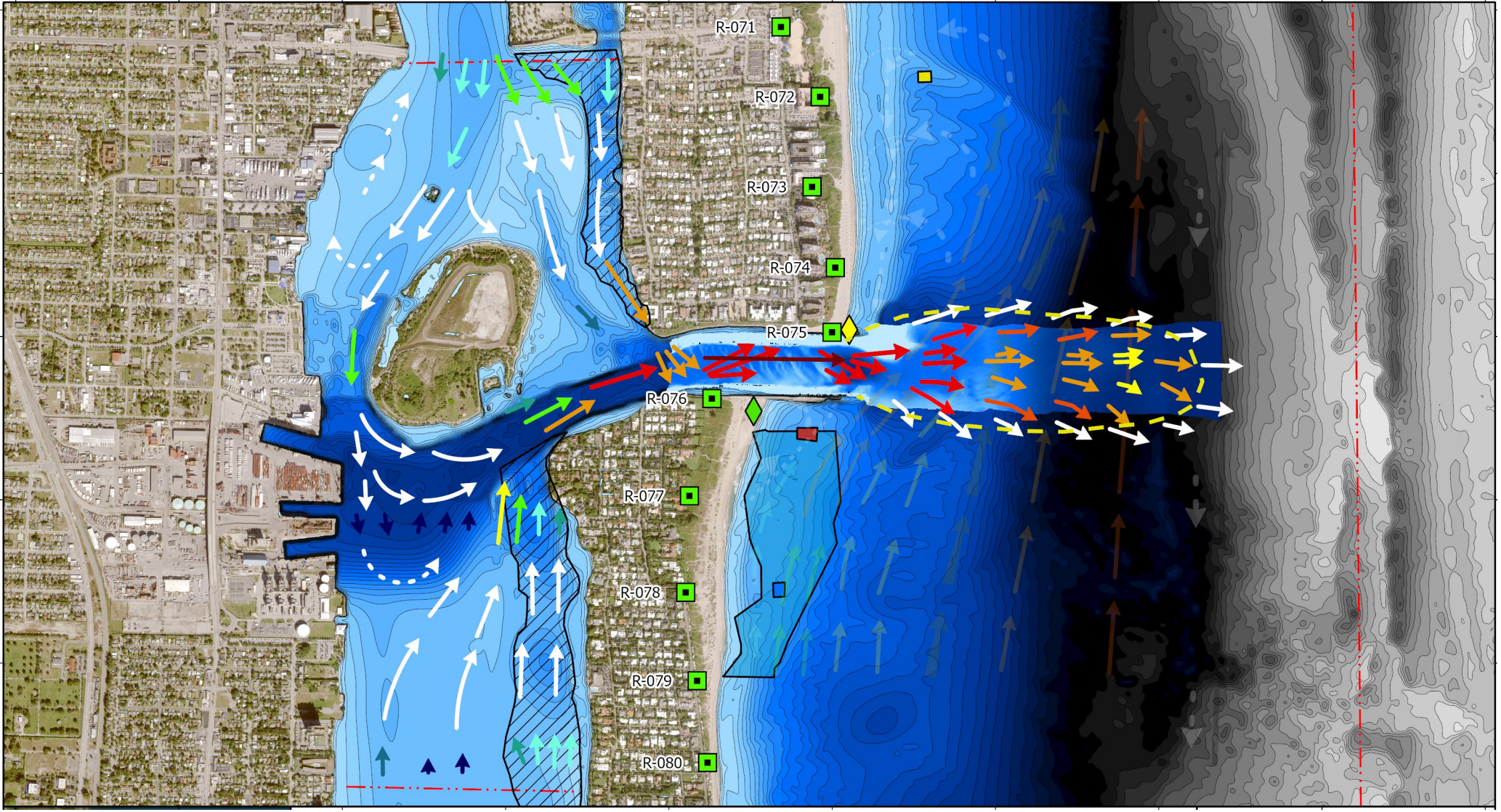

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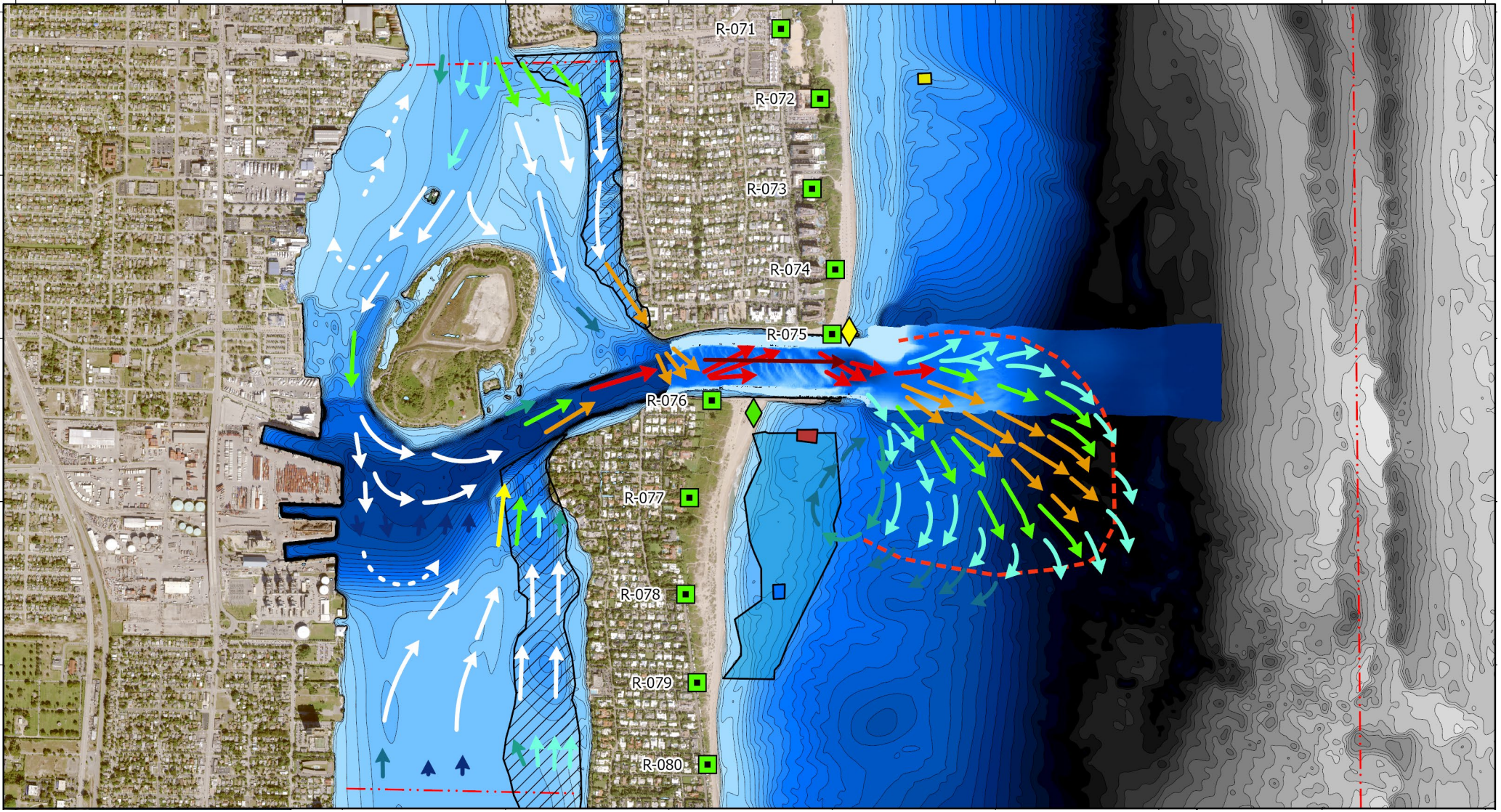

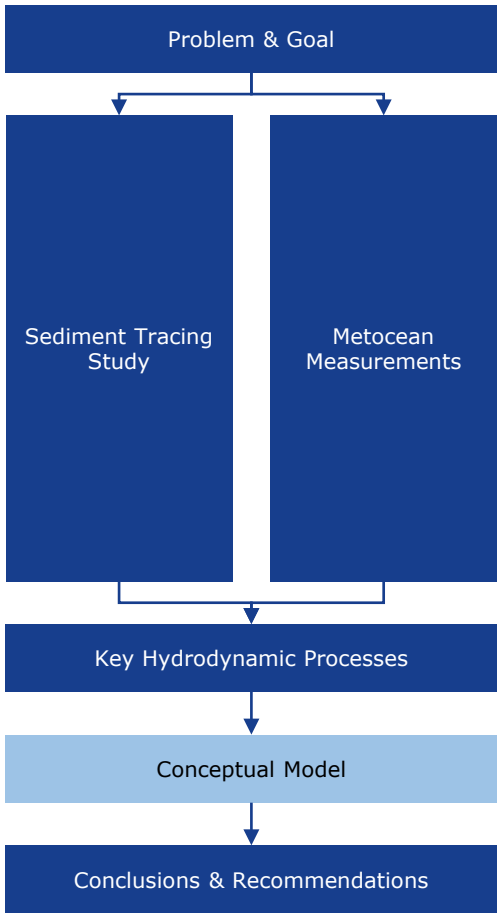

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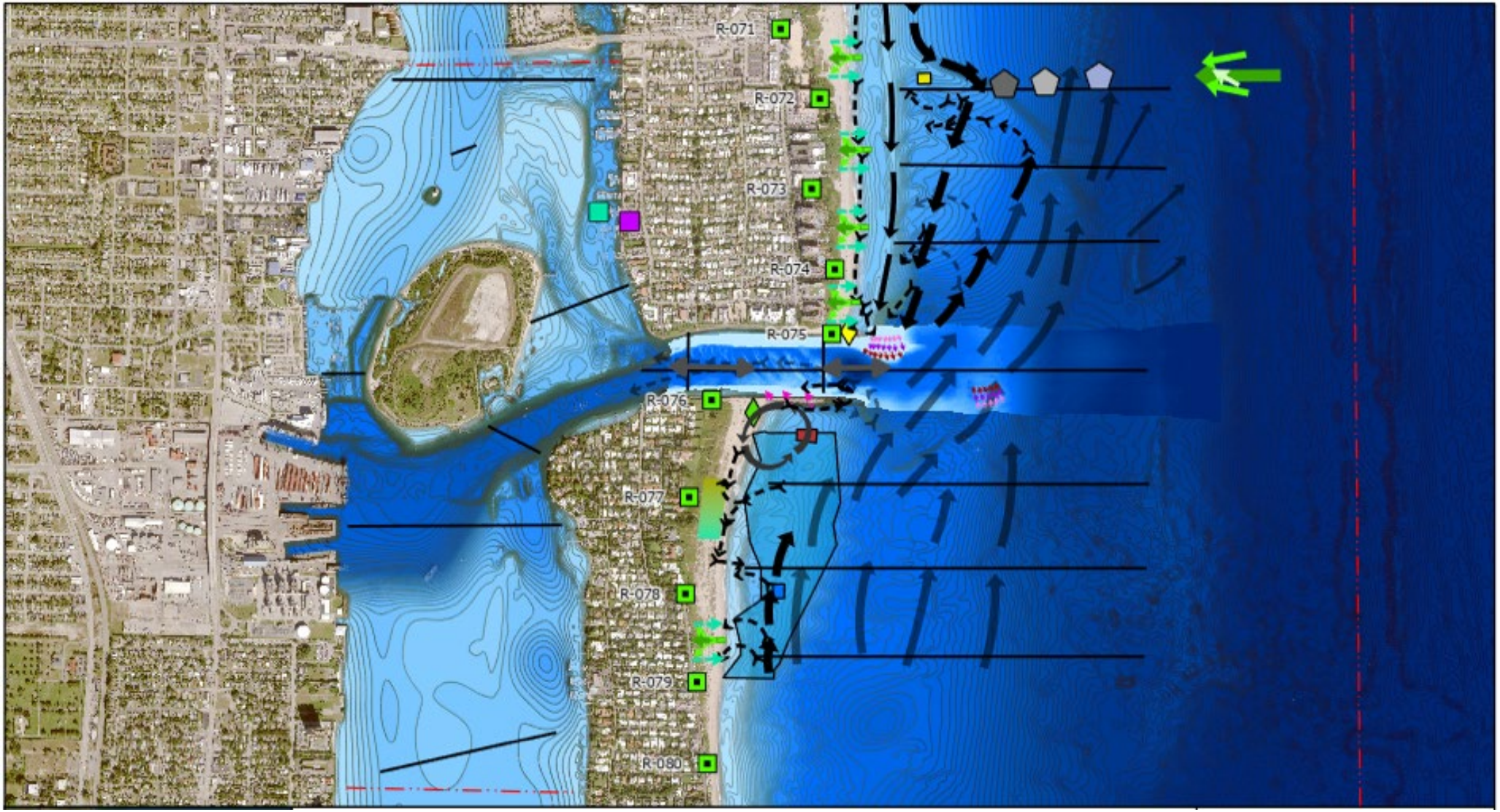
Strong Florida Current

NE Driving Sediment Around Inner & Outer Surf Zone

”Zig-Zag” in on Flood

Back out on Ebb



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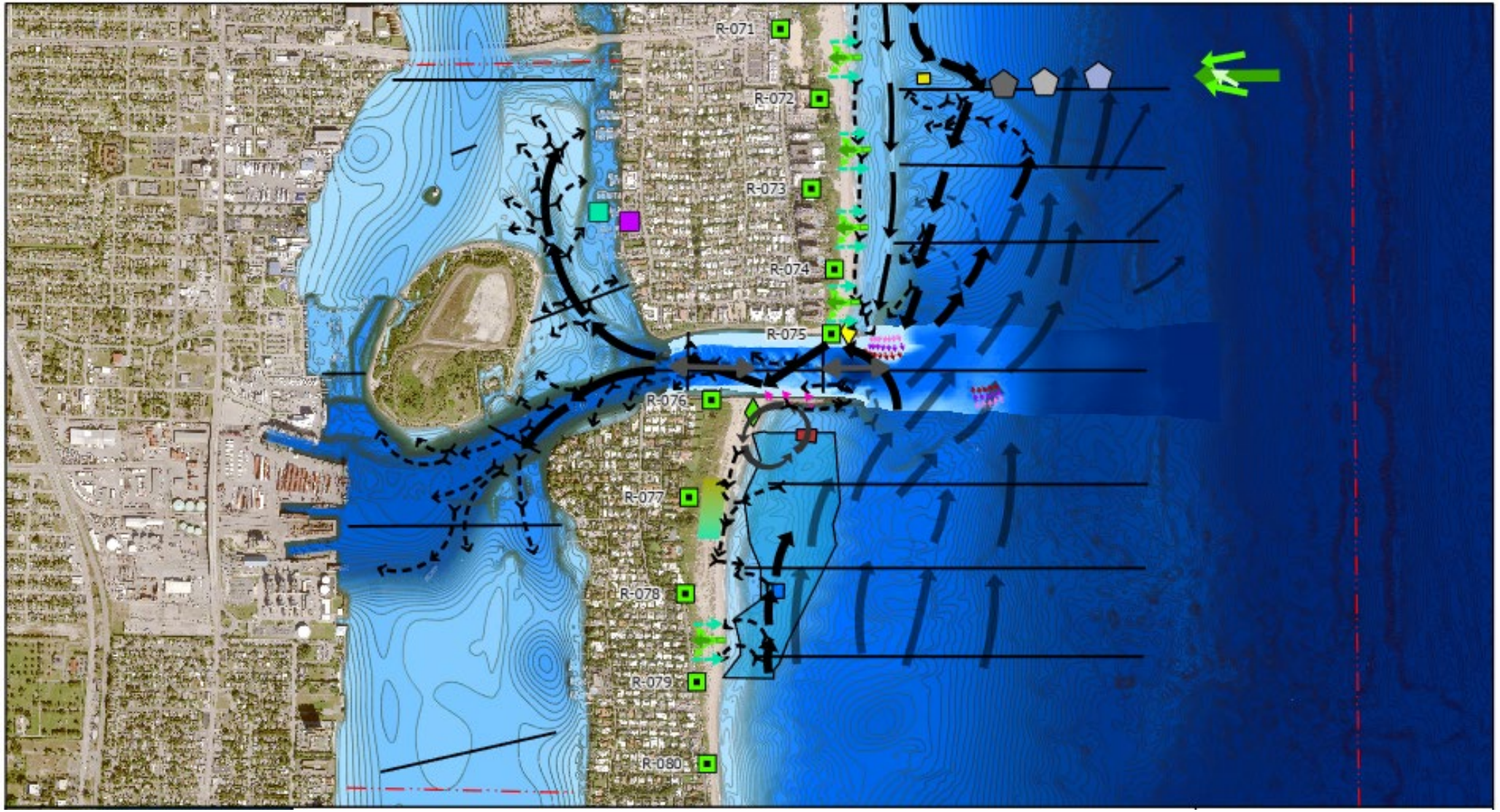
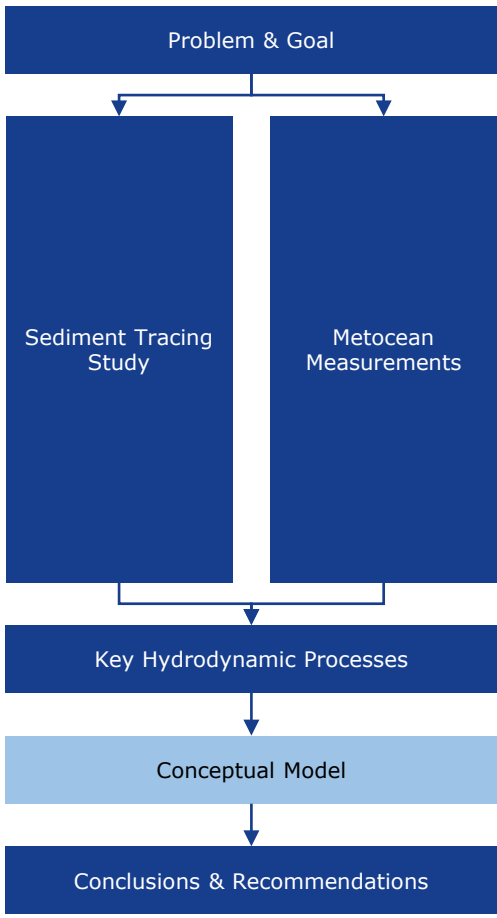
"Zig-Zag" in on Flood

Back out on Ebb





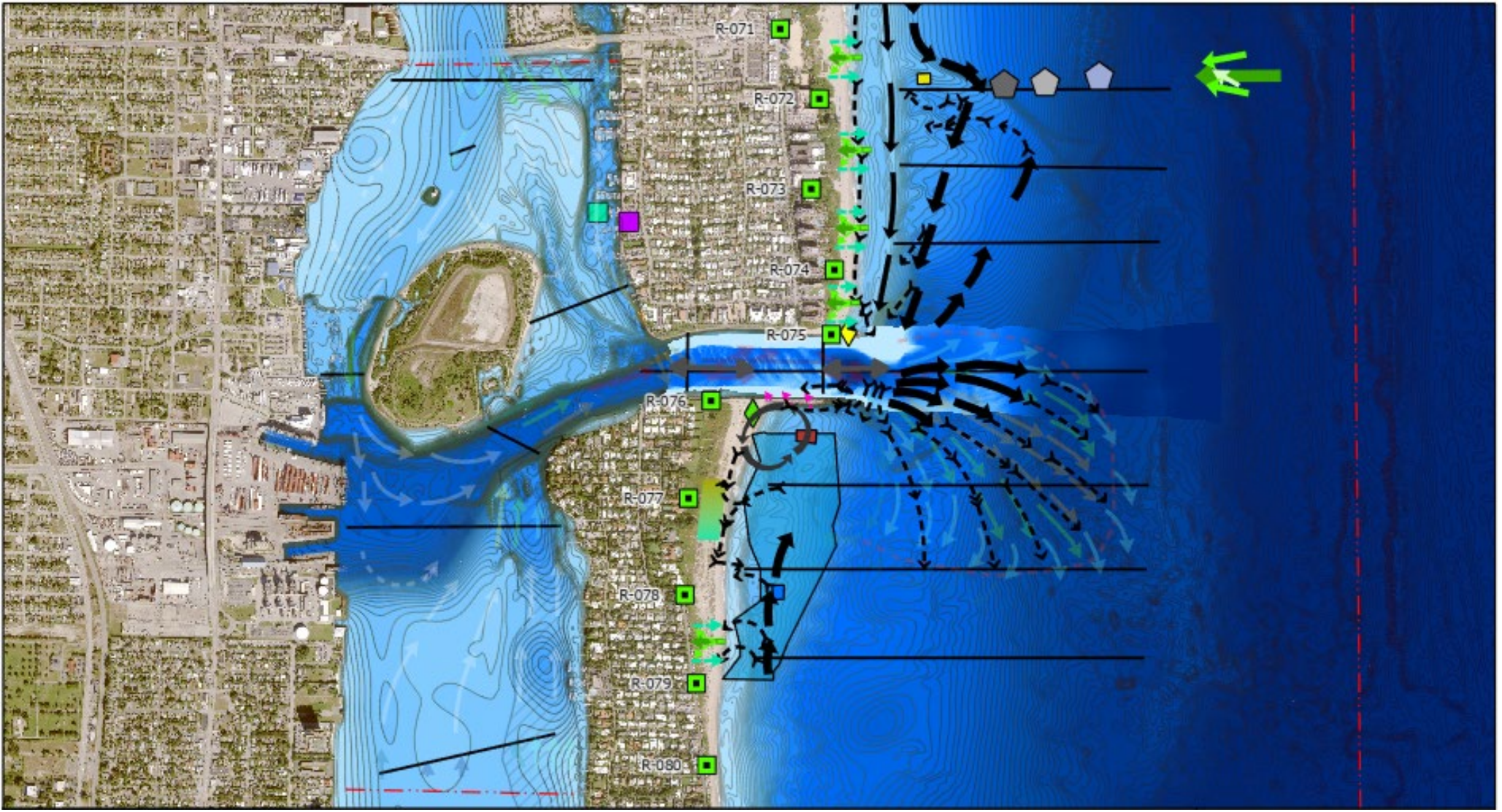
Sediment Transport Conceptual Models

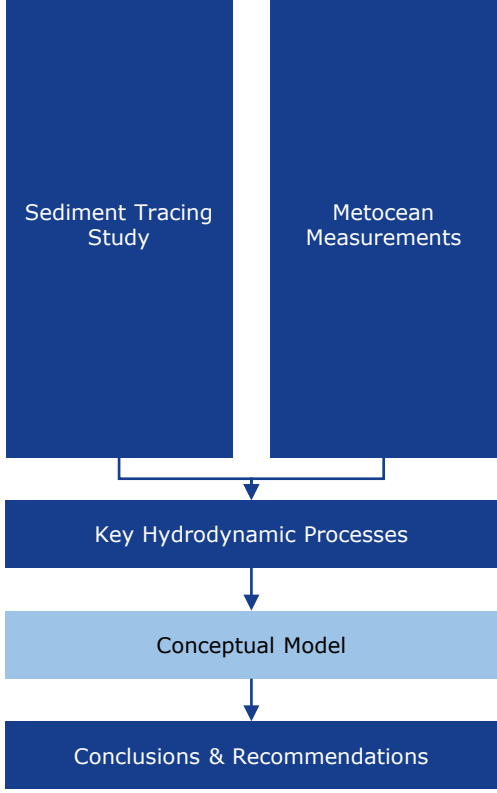
Strong Florida Current

NE Driving Sediment Around Inner & Outer Surf Zone

”Zig-Zag” in on Flood

Back out on Ebb





Sediment Transport Conceptual Models

Strong Florida Current

NE Driving Sediment Around Inner & Outer Surf Zone

”Zig-Zag” in on Flood

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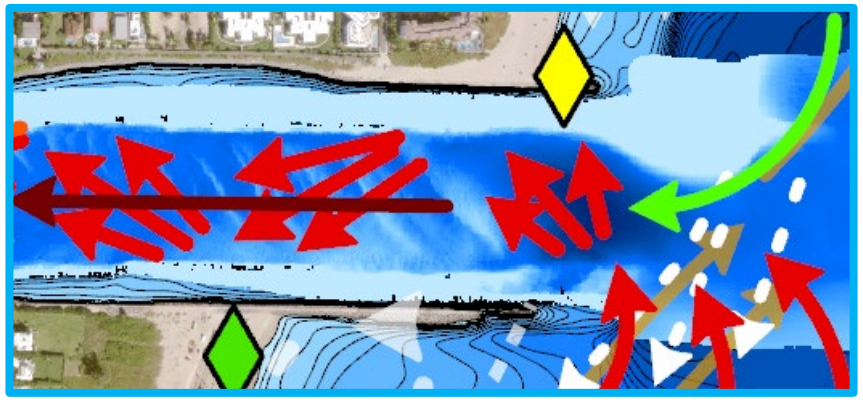
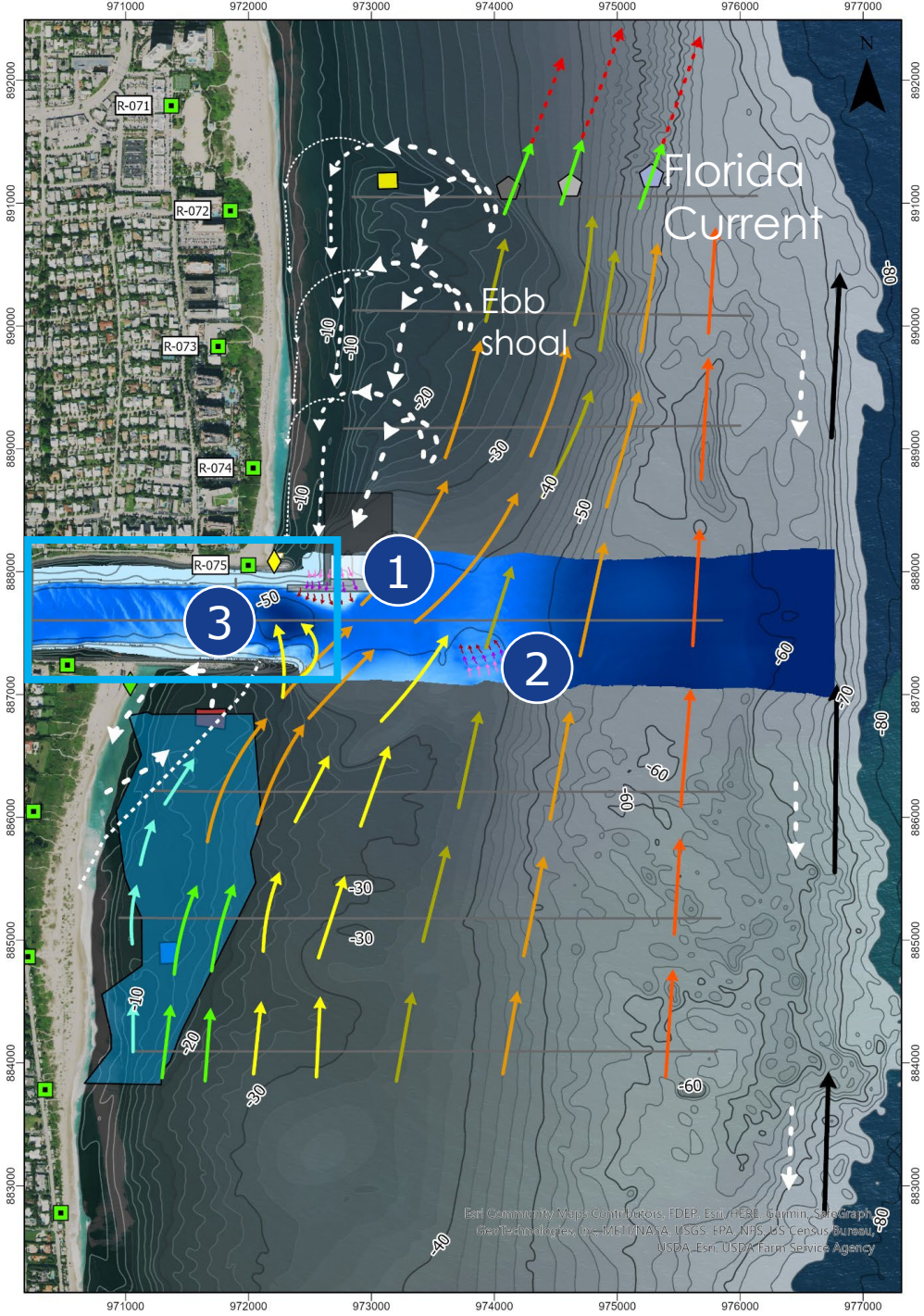
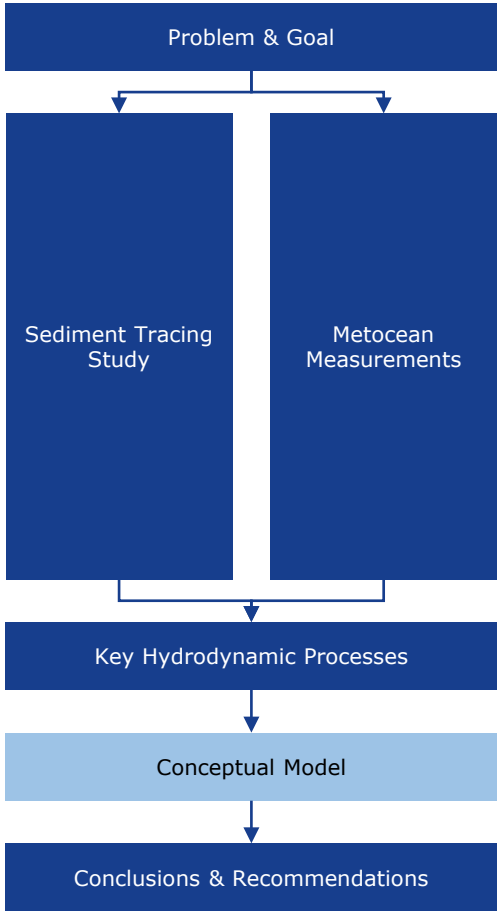
Hydrodynamic Sediment Drivers

- Florida current
- Nor'easters (wind and wave coming from NE)- counterclockwise alongshore sediment transport.
- Tidal ebb and flood through the inlet

- Scour hole inside the inlet caused by torsional flow caused by opposing flows, scouring happens on flood tide coming into inlet (like a tornado).
- The scoured sediment #3 (along with sediment north and south shoals #1,2) is carried into suspension into the inlet throat and redeposited into the finger shoals sand waves.

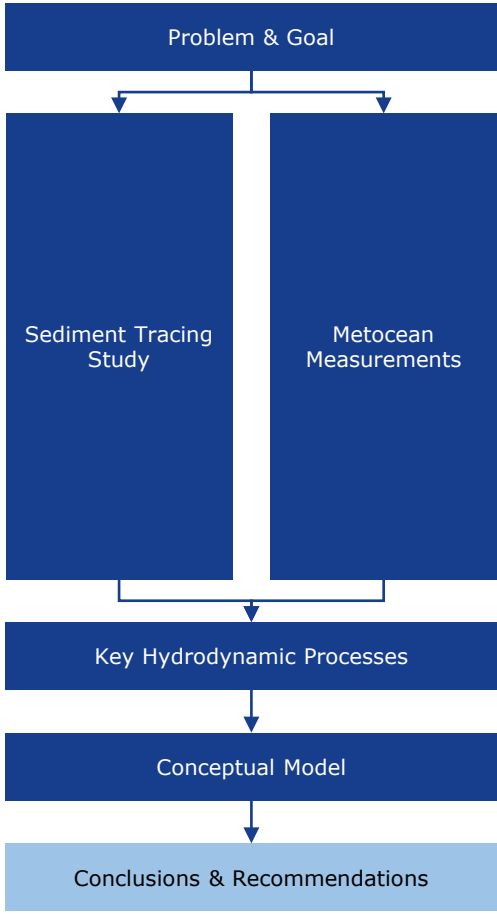






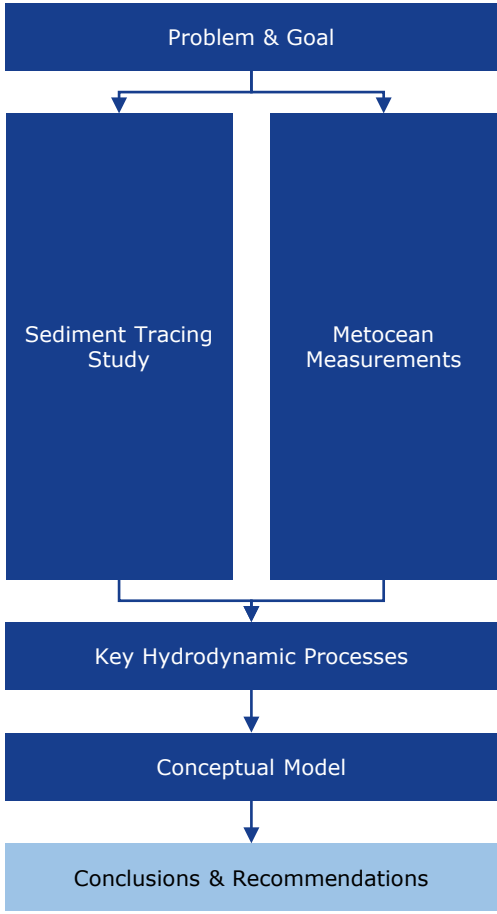
Conclusions

- Sand forming the prograding bar shoal on north side of channel is from north.
- Bar shoal erodes rapidly in a large storm (Northeasterly) and re-deposits via scour hole as finger shoals (sand waves) in inlet channel reducing navigable depth by minimum >4’.
- Sand transported from north via:
  - Gully/Gutter in Inner Surf Zone in moderate wind/wave events & strong FC to N/NNE (as return flow), and
  - Outer Surf Zone around relic ebb shoal (significant source) through Settling Basin in larger storms
- Sand returns to inlet from the south, during N/NNE FC & trade winds (summer)
- The flood-ebb tidal exchange E-W in the inlet forms a barrier for most sand transport N to S and S to N.
- Tidal flows >1m/s perpendicular to the FC flowing N/NNE at 0.7 m/s within 150m of south jetty creates a complex and dynamic shear zone exactly where vessels ‘crab’ to enter the entrance channel and significant turbulence & torsional flow in the inlet channel.
- Sand transported south on the north side of the channel appears to bypass the SBP.



Recommendations

- Based on a much improved 'system' understanding of LWI, in very simple terms, to reduce shoaling and increase the time between O&M dredging, sand needs to either be trapped and/or bypassed more efficiently.
- Surveys, dredging and pumping need to be linked to the metocean conditions when sand moves and accumulates.
- A number of further recommendations are made, as follows:
  - Fully evaluate the SBP efficiency to determine an accurate volume of sand not just base the volume bypassed on the number of hours the pump operates.
  - Extend the SBP intake or allow it to move to capture sediment from east of the current range and particularly to the east of the north jetty.
  - Expansion of the SB to the west and/or northwest, as considered in USACE 2014 Feasibility Study to capture sand earlier.
  - Lower the SB below the channel so it acts as a hollow to capture sand both in suspension and saltating.
  - Install a sand transfer pipe from within the SB in combination with above.
  - Undertake a new Regional sediment budget for LWI and its environs building on a better understanding of the system.
  - Consider realignment of the coastline including removal or reducing the relic ebb shoal to the north of LWI.
  - Consider more efficient dredging including working with nature.



Questions?