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Development of an Appropriate Mixing Zone Using Turbidity and Sedimentation Predictions; Port Everglades Sand Bypass Project

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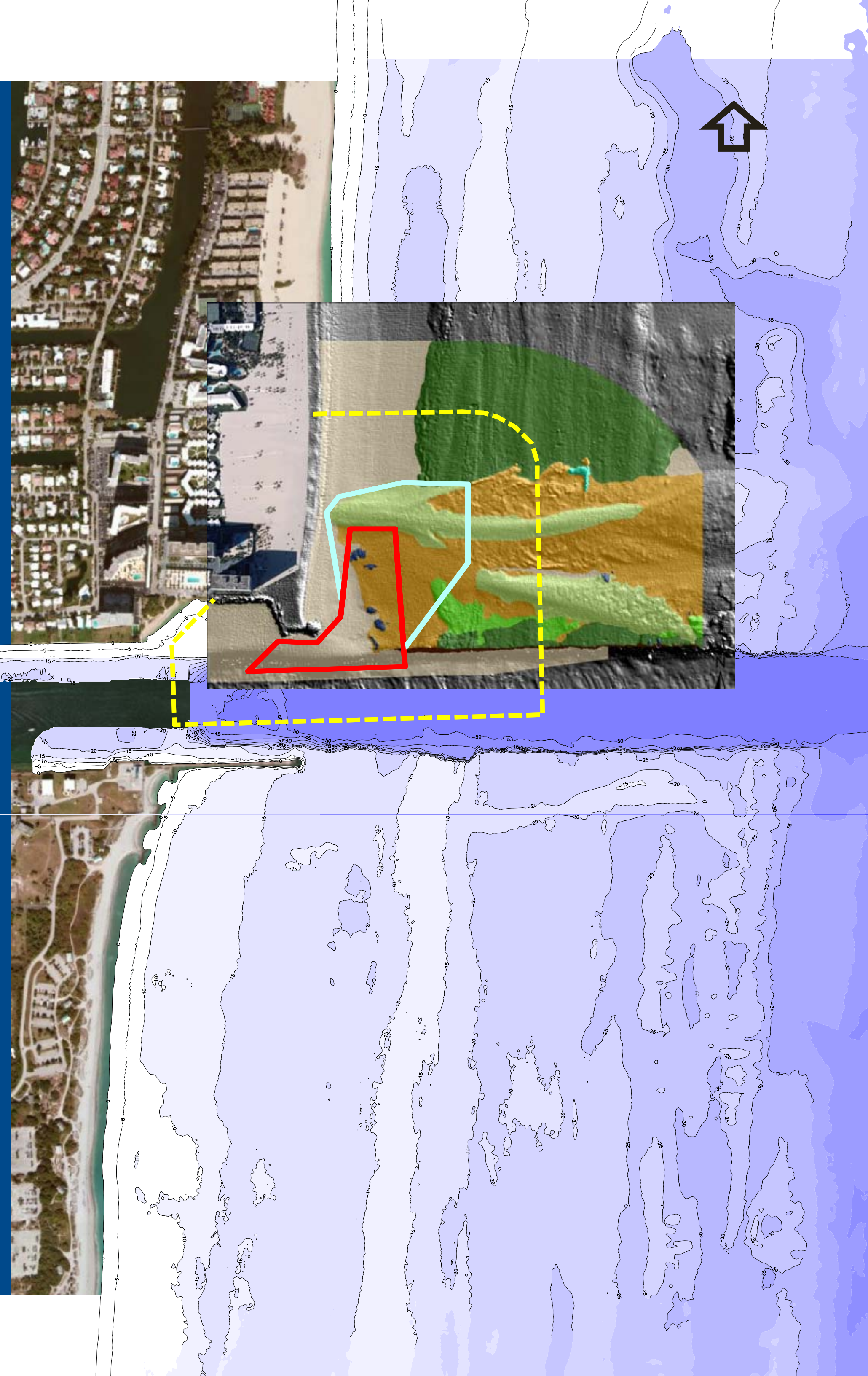
Project

- Excavate approximately 433,500 cy of rock, rubble, sand, silt, and clay
- Hydraulic and mechanical dredging
- Excavation will occur in complex hydrodynamic environment
- Adjacent to Nearshore Hardbottom Communities;
  - Direct Impacts (dredging)
  - Indirect impacts (sedimentation and turbidity)
  - Temporary and permanent hardbottom habitat loss (Scleractinian (stony) corals and Octocorals (soft))
  - Temporary and permanent seagrass and seagrass habitat loss

Problem

- Likely that a 150-meter mixing would not be feasible for planned construction
- Potential for WQ violations present risk and uncertainty to dredge production and project cost



Identify Appropriate Mixing Zone

- Inlet and Nearshore Water Movement
- Dredge Material Conditions
- Dredging and Sediment Spill Conditions
- Suspended Sediment Density/Movement and Sediment Accumulation
- Mixing Zone
- Hardbottom and Seagrass Habitat
- Resource Protection Measures

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Inlet Hydrodynamics

- Hydrodynamic model MIKE 21 HD to compute water levels and velocities
- Inlet and nearshore shelf currents
- Model calibrated and verified against measured inlet and nearshore current data (ADCP)

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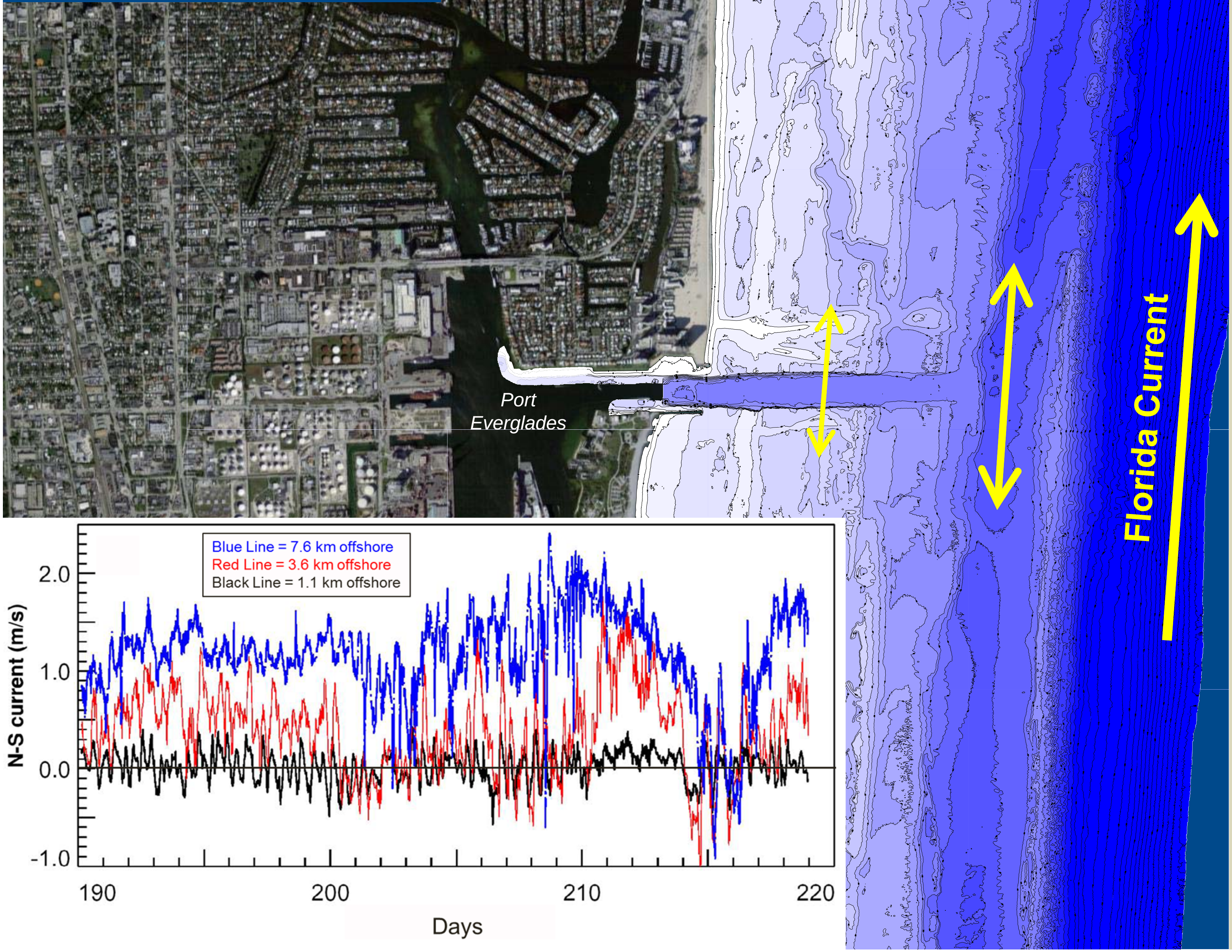
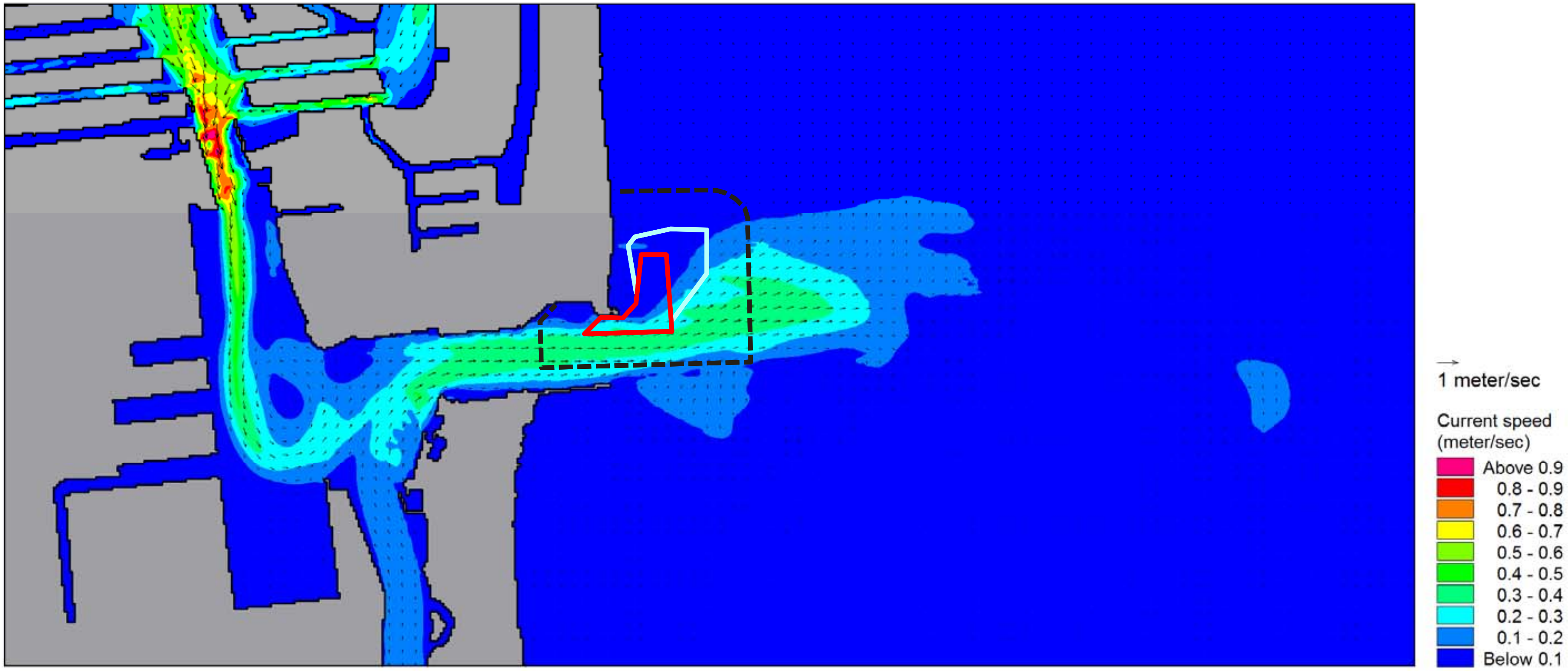
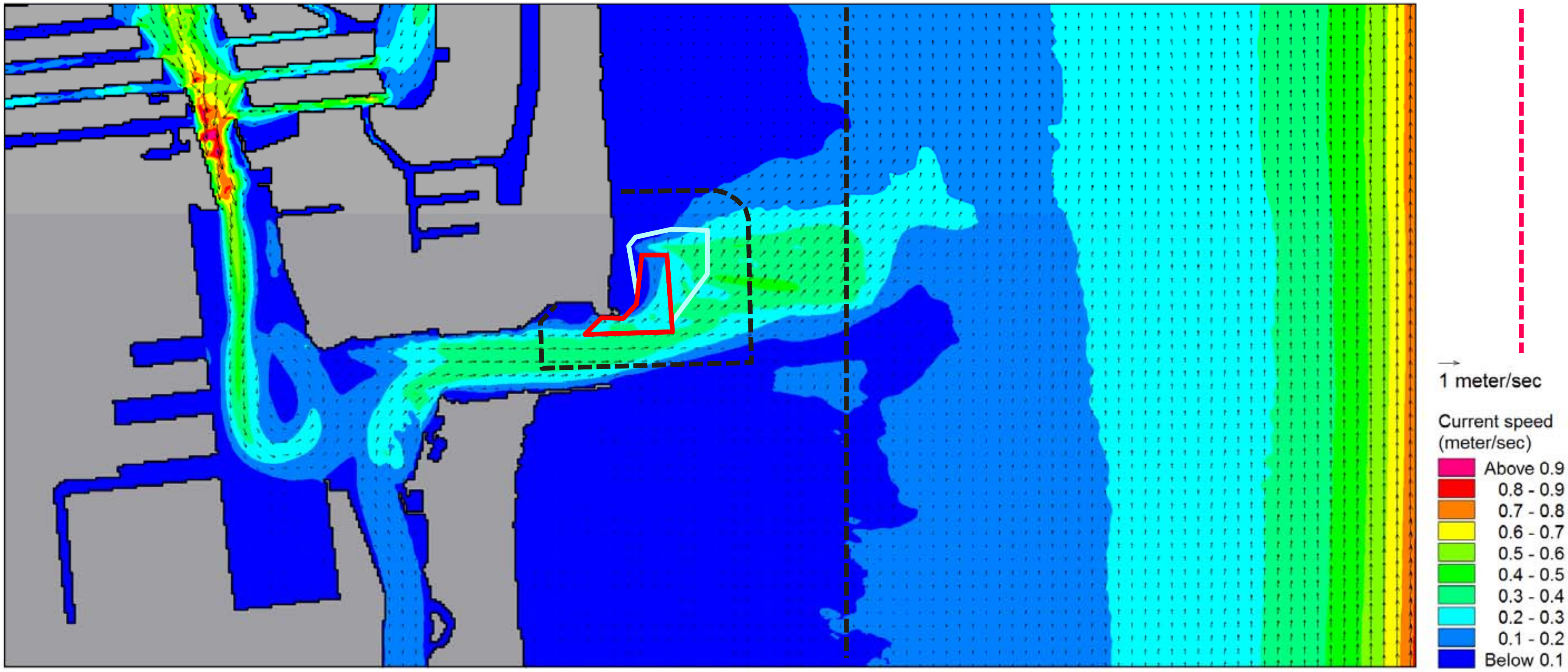
Shelf Currents



Peak Ebb (No Shelf Current)



Peak Ebb (Northward Shelf Current)



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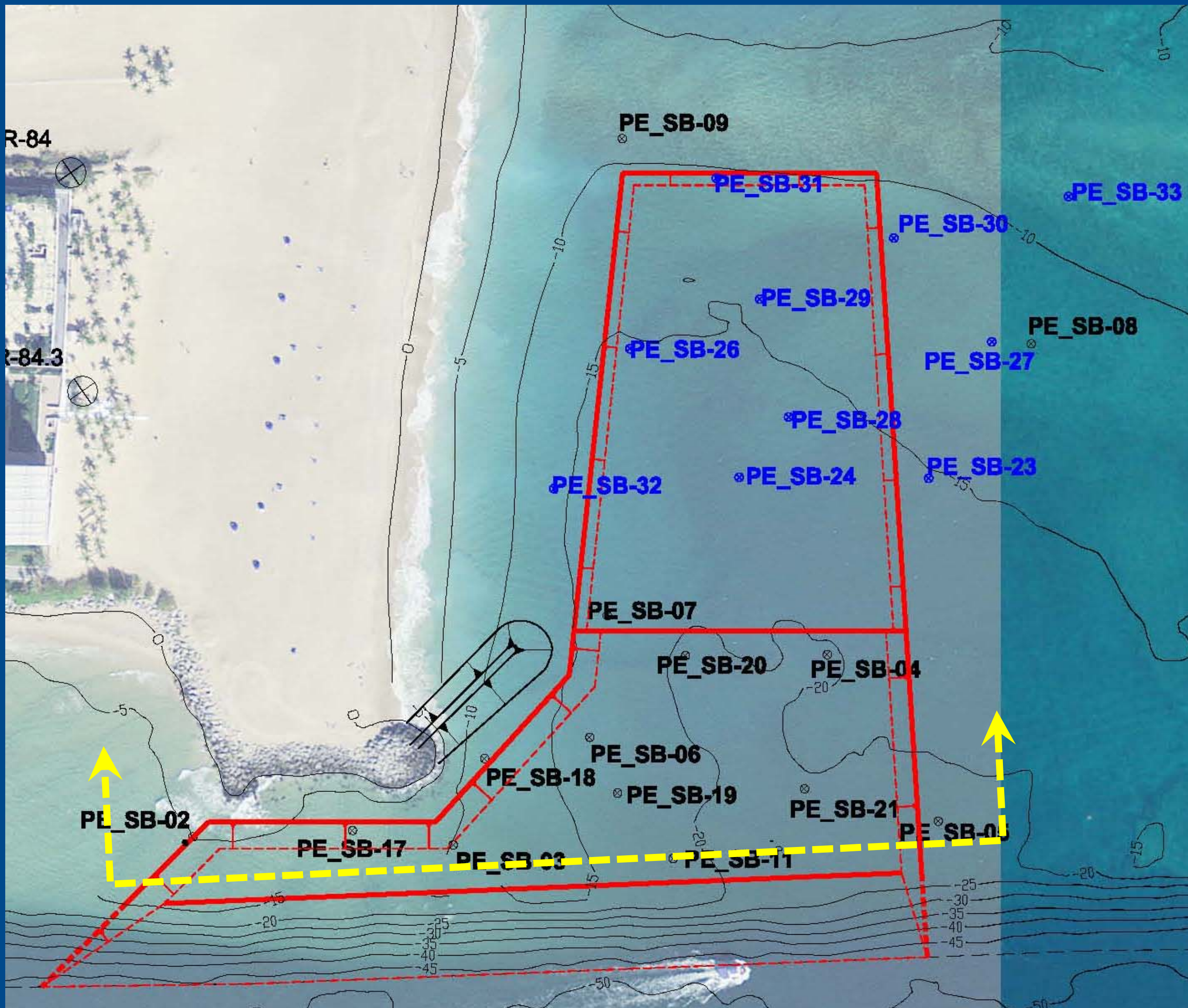
Dredge Material Characteristics



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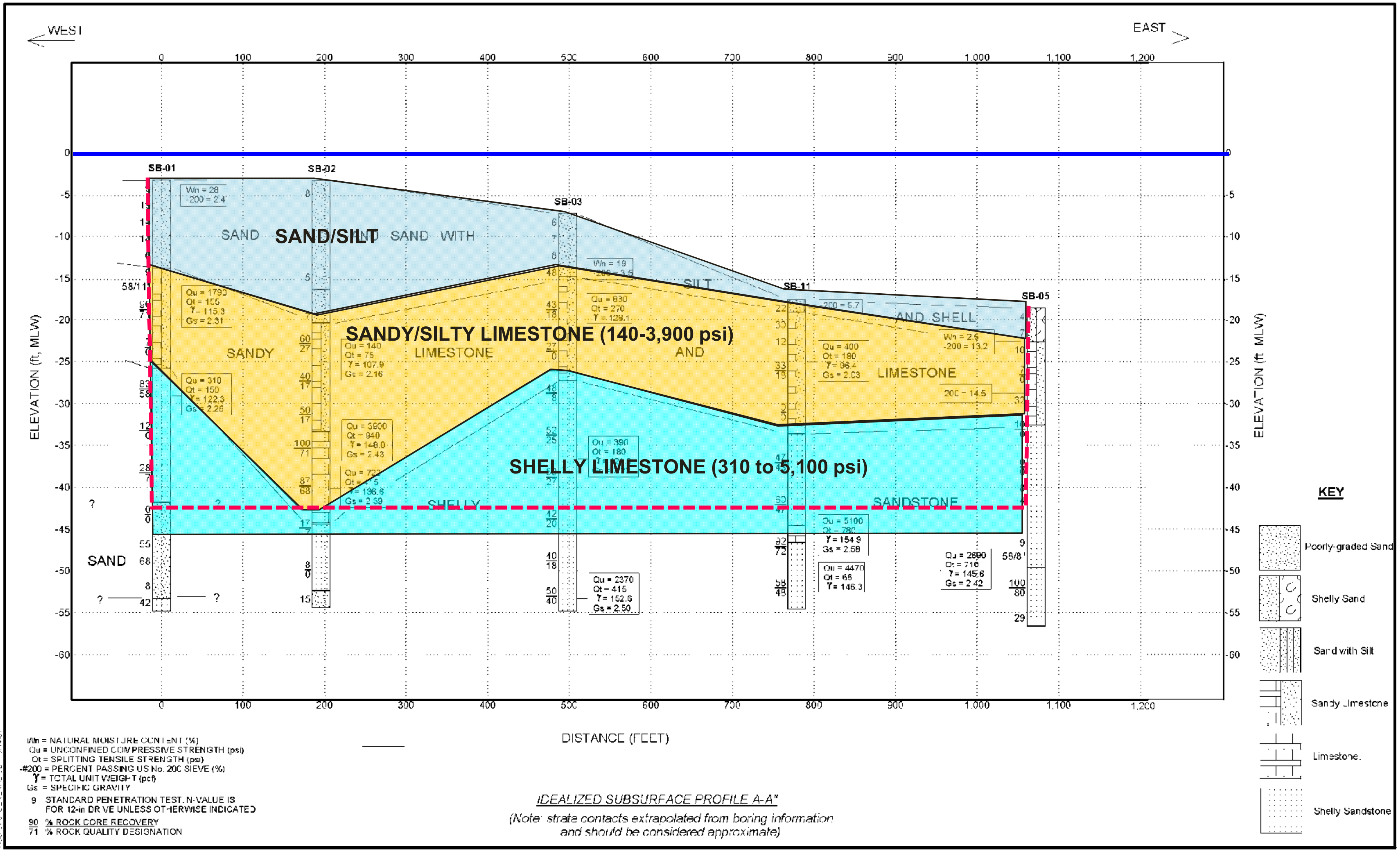
Dredge Material Characteristics (Sand Trap)



Dredge Material (Model Input)

- Total Volume = 433,500 yd^3
- Sand Trap = 333,500 yd^3
  - Rock = 222,200 yd^3
  - Sand = 104,200 yd^3
  - Materials passing No. 100 sieve (150 microns) = 17,800 yd^3
- Rubble Shoal = 100,000 yd^3
  - Rubble = 84,000 yd^3
  - Sand = 13,000 yd^3
  - Materials passing No. 100 sieve (150 microns) = 925 yd^3

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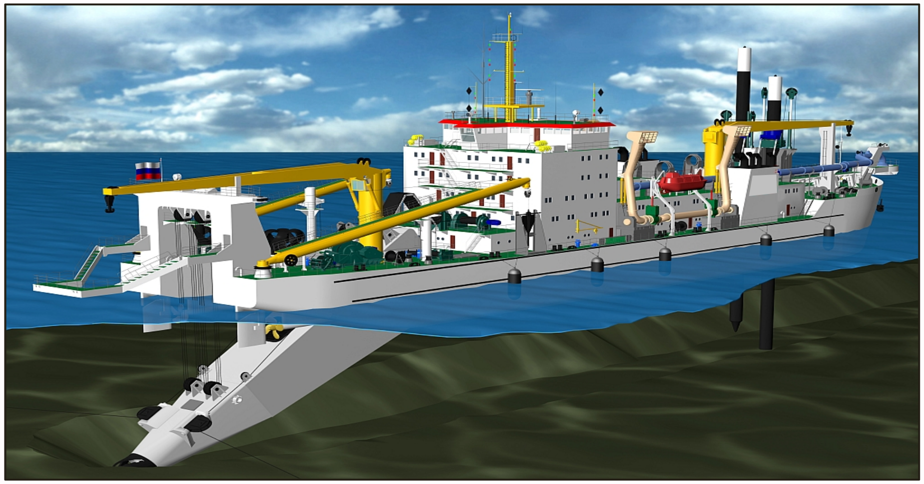
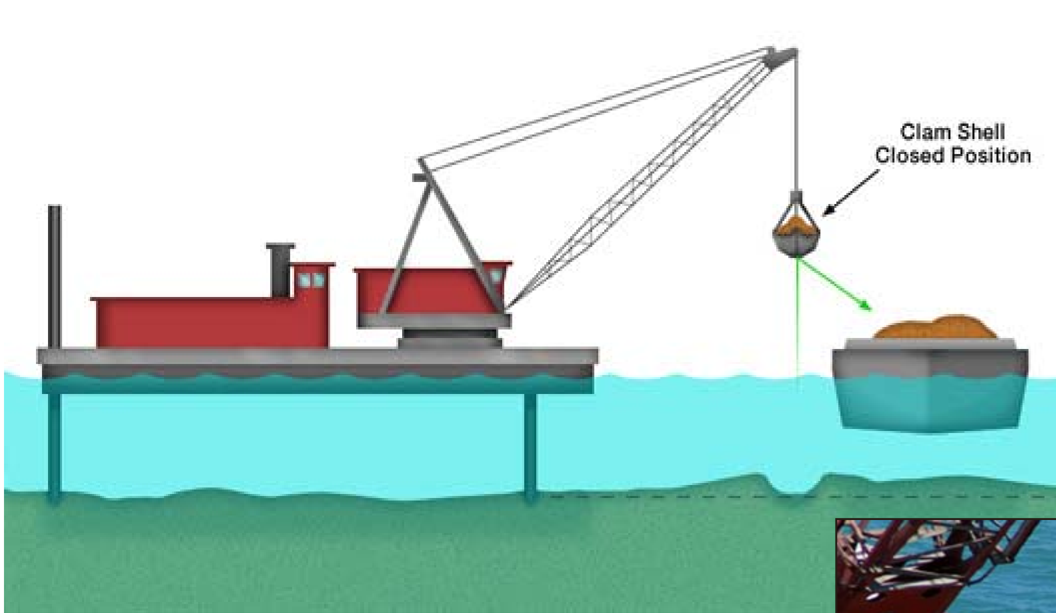
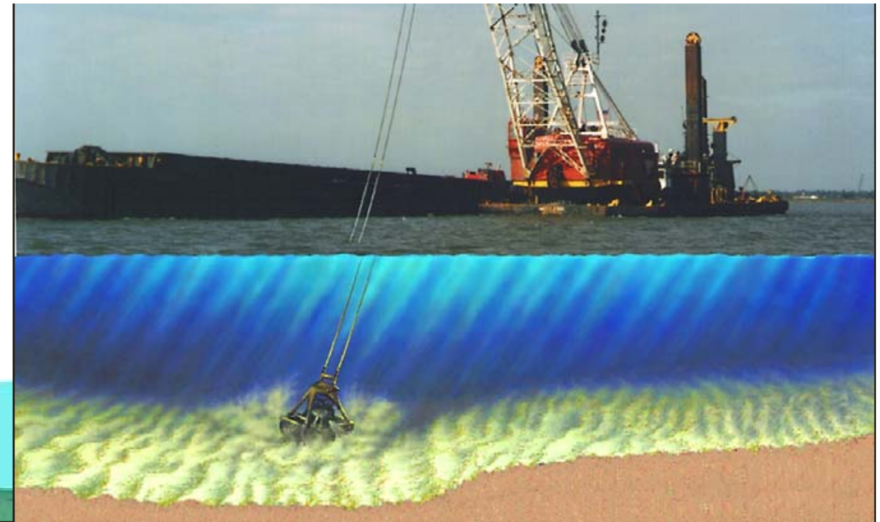
Dredging and Material Spill Conditions



Cutterhead Pipeline Dredge

Scow Loading for Offshore Disposal





Mechanical Dredge

Predict Extent of Dredge Plume

- Hydrodynamic model MIKE 21 HD to compute water levels and velocities
- Lagrangian approach in MIKE 21 PA tracks individual particles of different sizes, from different sources, spilled at different positions along the water column.
- 2D time series of suspended sediment concentration (SSC) and deposited mass for every sediment fraction
- Maximum/average values of sediment movement/distance from source
- Thickness of deposited sediment layer, time required to reach maximum thickness and associated average rate of sediment deposition

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PA Tracking Model Setup

- 104,200 yd^3 (Sand Trap) / 100,000 yd^3 (Spoil Shoal)
- Track three sediment classes: 40, 100 and 150 microns
- Spoil Shoal: Clam Shell Dredge:
  - 9,000 yd^3/day
  - dredge 18 hours/day
  - 540 bucket lifts/day
  - no scow spilling
- Sand Trap: Hydraulic Cutter-suction Dredge and Hydraulic Scow Loading:
  - 7,800 yd^3/day
  - dredging = 18 hrs/day
  - sediment spilled at cutterhead and scow
  - partial loading of scows
  - some scow overflow
  - assuming no spill during transport

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Model Setup

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Sediment Spilling: Cutterhead and Scow

Dredge Area	Total Volume to Remove (cy)	Time to Dredge (days)	Rate of spill at CSD cutterhead (kg/s)		Rate of Spill in Overflow (kg/s)	
			< #200	< #100	< #200	< #100
1	41,770	5.36	0.513	0.264	1.313	0.677
2	39,940	5.13	0.653	0.337	1.672	0.862
3	44,380	5.7	0.811	0.418	2.076	1.071
4	19,460	2.5	0.766	0.395	1.961	1.012
5	26,720	3.43	0.717	0.370	1.836	0.947
6	22,290	2.86	0.564	0.808	1.443	2.069
7	24,430	3.14	0.459	0.658	1.174	1.684
8	27,160	3.49	0.383	0.549	0.980	1.406
9	18,300	2.35	0.323	0.463	0.828	1.187
10	69,040	8.87	0.314	1.177	0.803	3.013

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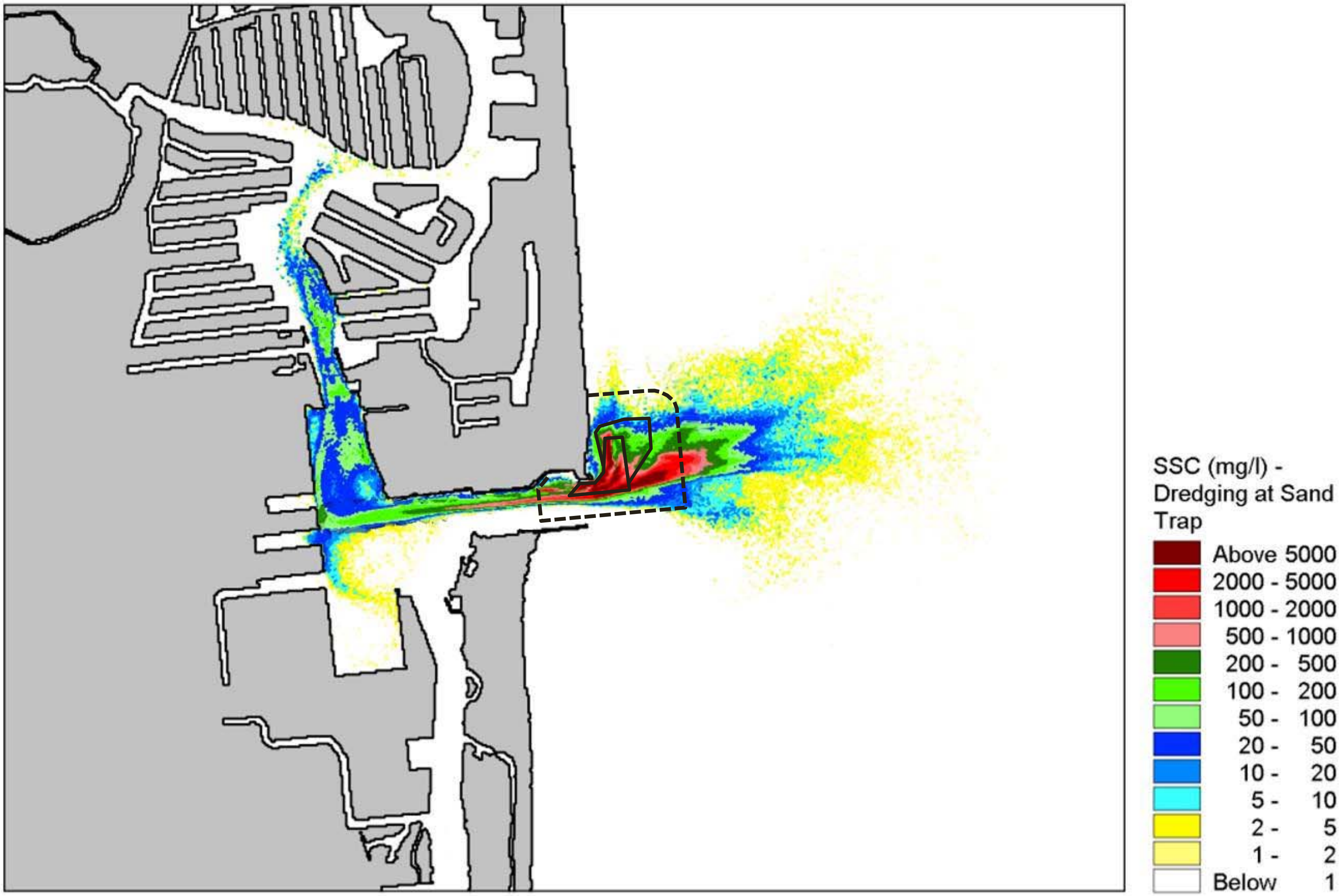
Maximum excursion of suspended sand trap sediments (no shelf current)



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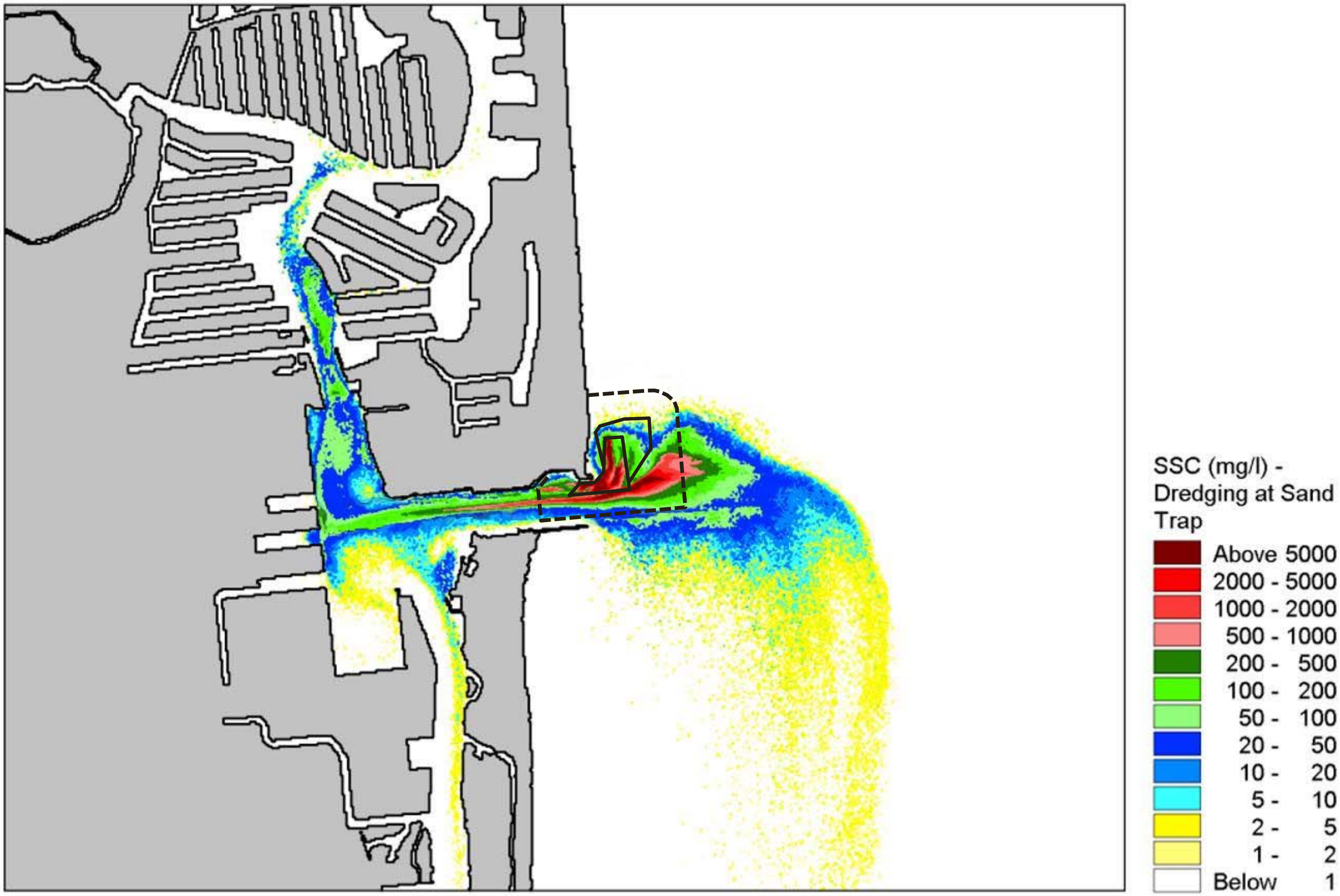
Maximum excursion of suspended sand trap sediments (northward shelf current)

Maximum excursion of suspended sand trap sediments (southward shelf current)



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Combined Maximum SSC for All Dredging Work

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Delineation of Mixing Zone:

- 29 NTU State Water Quality Standard
- SSC to NTU Relationship

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Delineation of Mixing Zone:

Reference	Relationship	TSS/SSC Units	SSC (min)	SSC (avg)	SSC (max)
Clarke and Wilbur (Lab/Various Field)	SSC = 1.4 to 6.7 (NTU)	mg/L	1.4	4.1	6.7
Ellison et al. (2009) (River)	SSC = 1.09*NTU^1.0774	mg/L		1.1	
Offshore Panama City (CPE; derived from MBC, 2000; Hartman, 1996, Malin et al., 1998, WDOE, 1997)	TSS = 2.6(NTU) (+/- 50%)	g/m3 or mg/L	1.3	2.6	3.9
Ballestero et al. (2010) (Stormwater Runoff)	SSC = 0.401(NTU)+53.9	mg/L		54.3	
Spear et al (2008) (Estuary, poor data)	SSC = 0.7674(NTU) + 55.391	mg/L		56.2	
Colley and Smith (2001) (River)	~1:1			1.0	
Holliday et al. (2003) (Stream/upland soils runoff)	1:1	mg/L		1.0	
NOAA (2013) (Biscane Bay)	TSS = 0.74 to 1.23 (NTU)	mg/L	0.7	1.0	1.2
Auckland Regional Council (2003) (Lab)	SSC = 3.7(NTU)+38.8	mg/L		42.5	
Lawton & Flores (2004) (Stream)	1:1 for < 50 mg/L	mg/L		1.0	
Gray et al. (2003) (River)	SSC = 1.797*NTU^0.905			1.8	
Calypso Pipeline Modeling (offshore Broward) URS, 2001	1	mg/L		1.0	

Range for most applicable 1 NTU = 0.7 to 6.7 mg/L

Average = 1 NTU = ~2.5 mg/L (or 29 NTU = ~72.5 mg/L)

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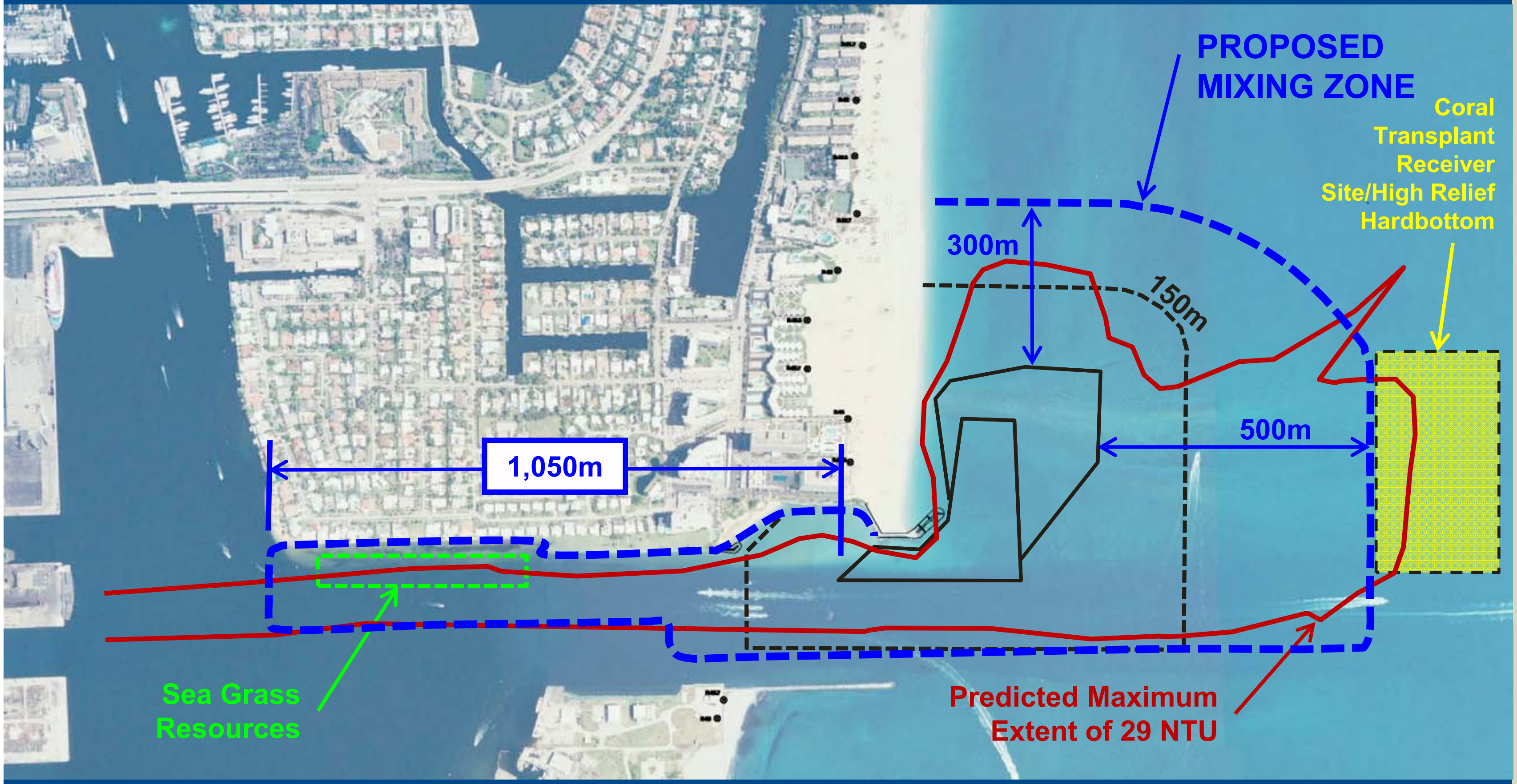
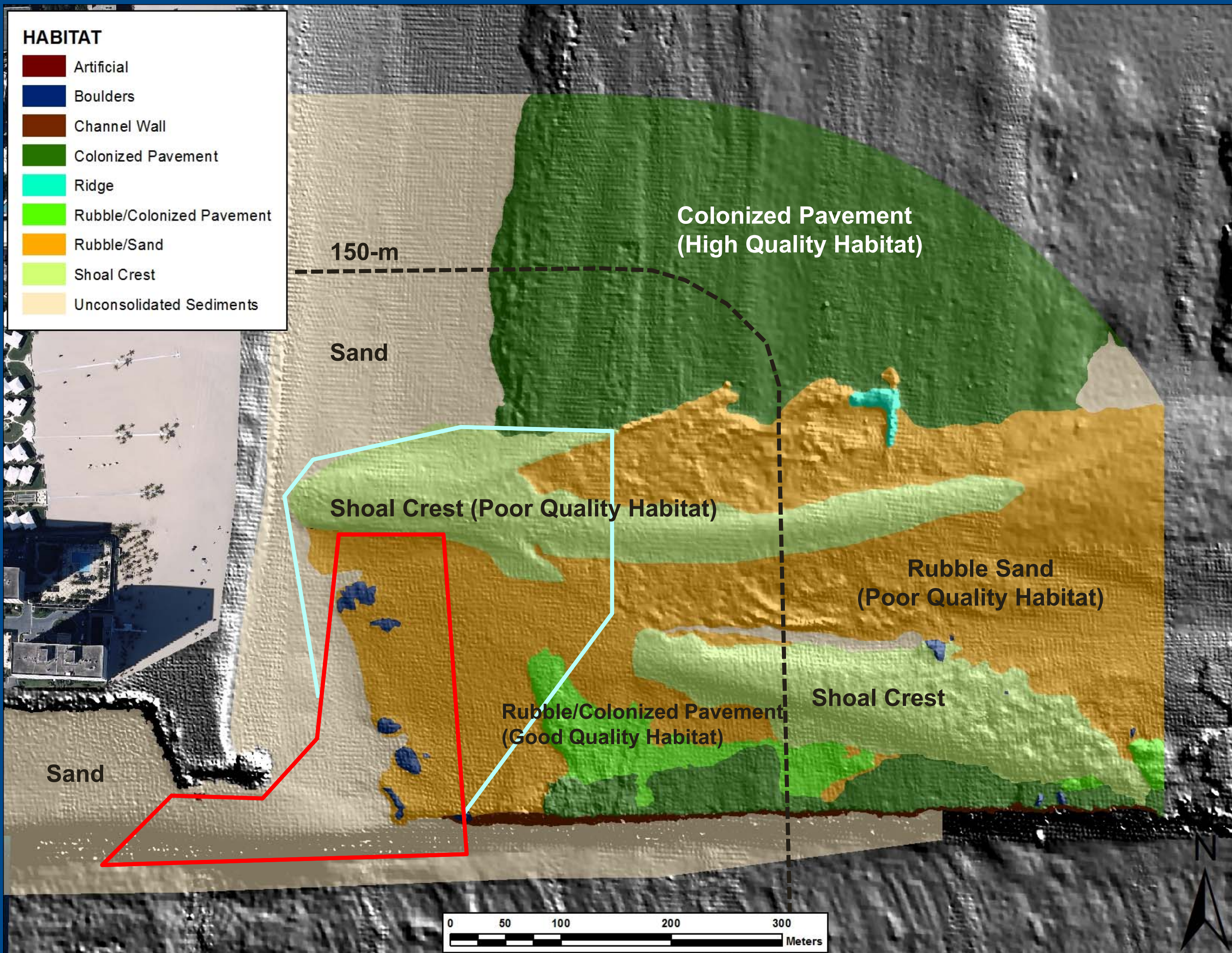
SSC Results Summary

- **Seven Flow Conditions**
- **Sand Trap and Spoil Shoal Dredging**

Proposed Mixing Zone



Adjacent Hardbottom Habitat



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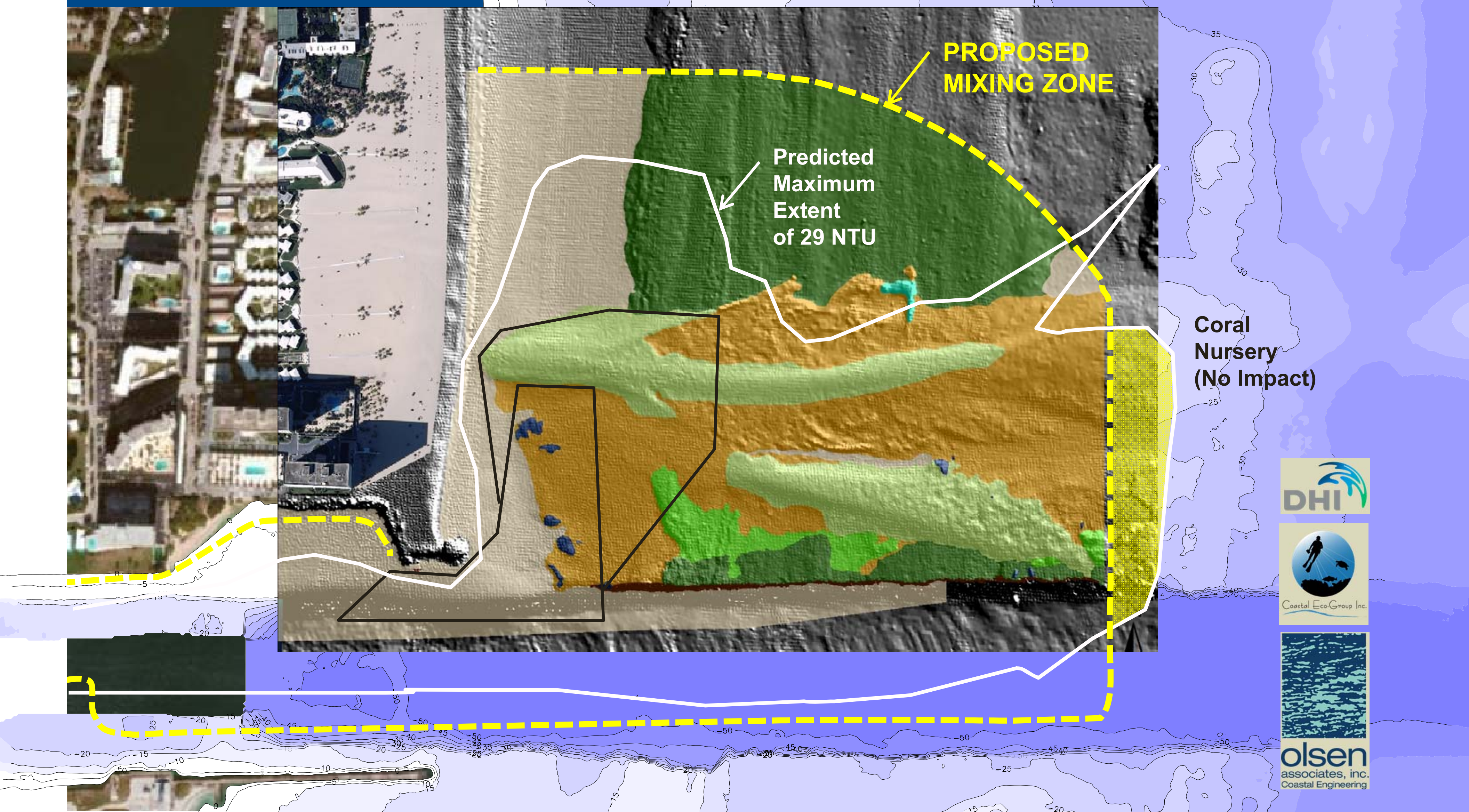
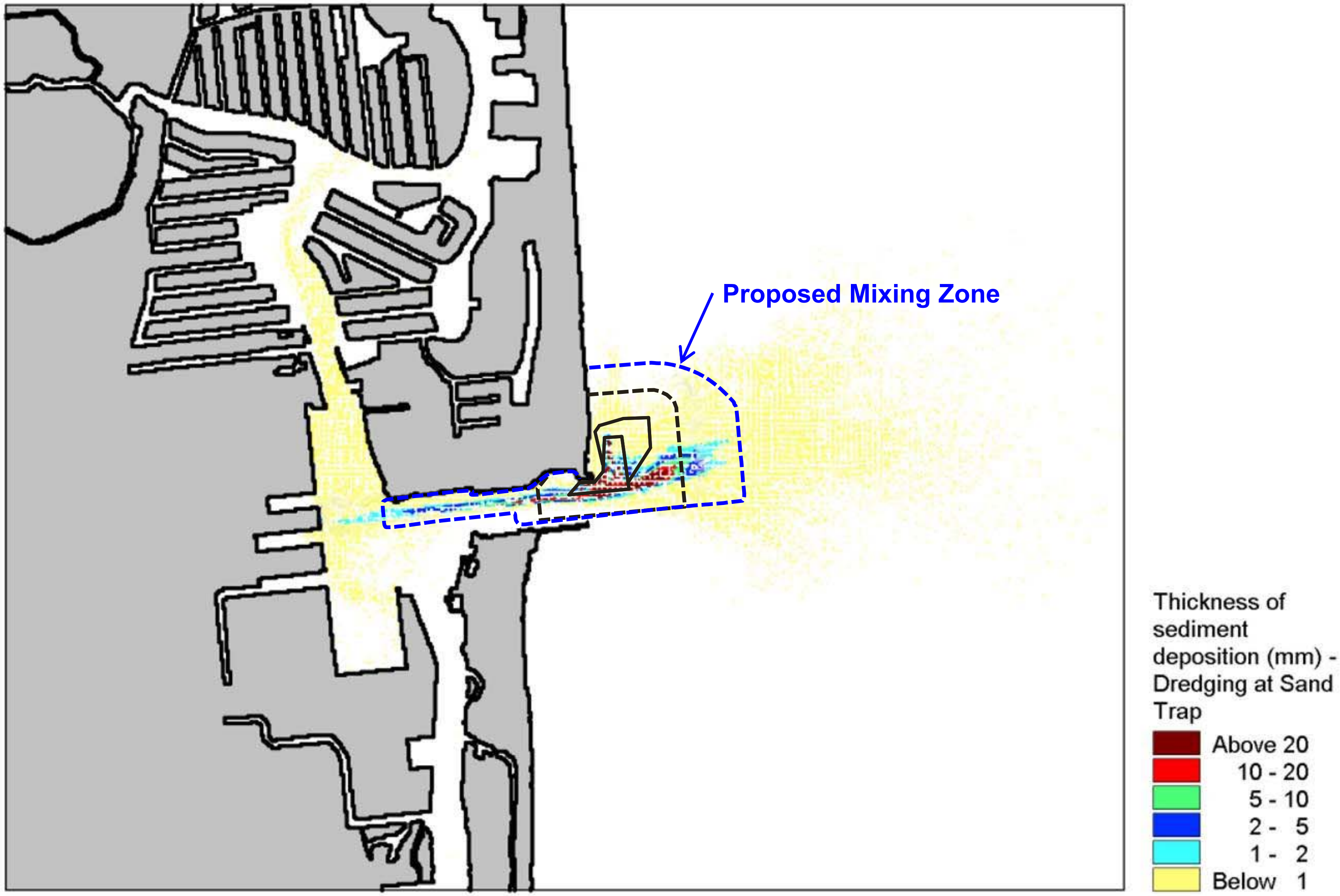
Proposed Mixing Zone



Sediment Thickness (mm)



Water Quality and HB/SG Protection Measures

- Coral Relocation within Proposed Mixing Zone
- Turbidity Monitoring
- Sediment Accumulation Monitoring
  - (Rubble/Sand and Consolidated Pavement)
- Mitigation based on expected permanent and temporary hardbottom loss:
  - Permanent: Loss of nearshore hardbottom habitat dominated by mobile rubble substrate and macroalgae/turf algae
  - Temporary: Reduction in recruitment and settlement rates for stony corals and soft corals Octocorals (soft) habitat
- Temporary impacts to seagrass habitat from elevated turbidity and sedimentation in mixing zone - monitored to prevent permanent impacts

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Summary/Closure

- 150-m mixing zone would not be feasible given hydrodynamic environment and expected turbidity and sedimentation associated with planned construction
- Expanded mixing zone will be implemented with coral relocation, mitigation and monitoring
- Risk to resources associated with model uncertainty will be managed through turbidity and sedimentation monitoring beyond mixing zone
- If turbidity exceedances are recorded beyond mixing zone, construction practices will be adjusted and/or assessments will be made for potential additional mitigation
- Monitoring data will be compared to model results to facilitate resource protection measures during future sand bypass events

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