Risk Characterization from Sediment Released During Dredging Operations

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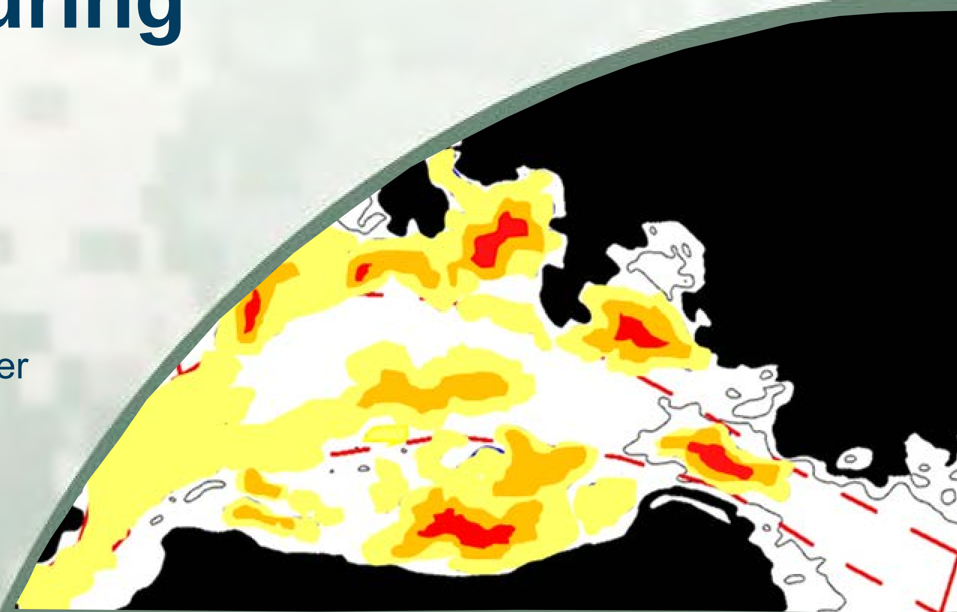

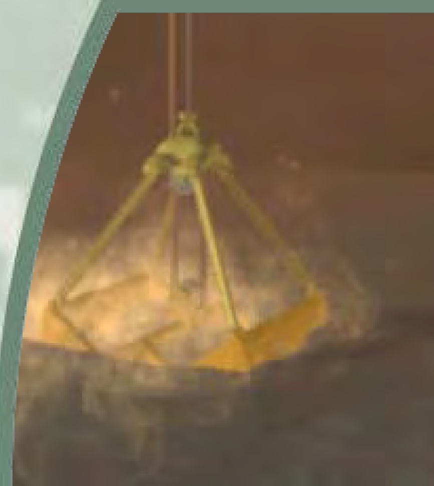

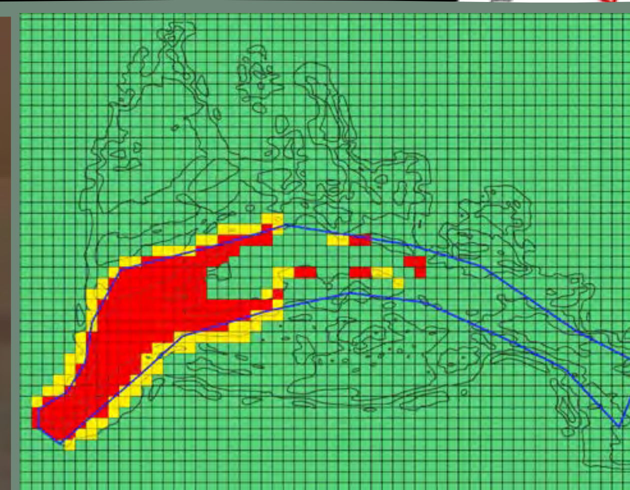

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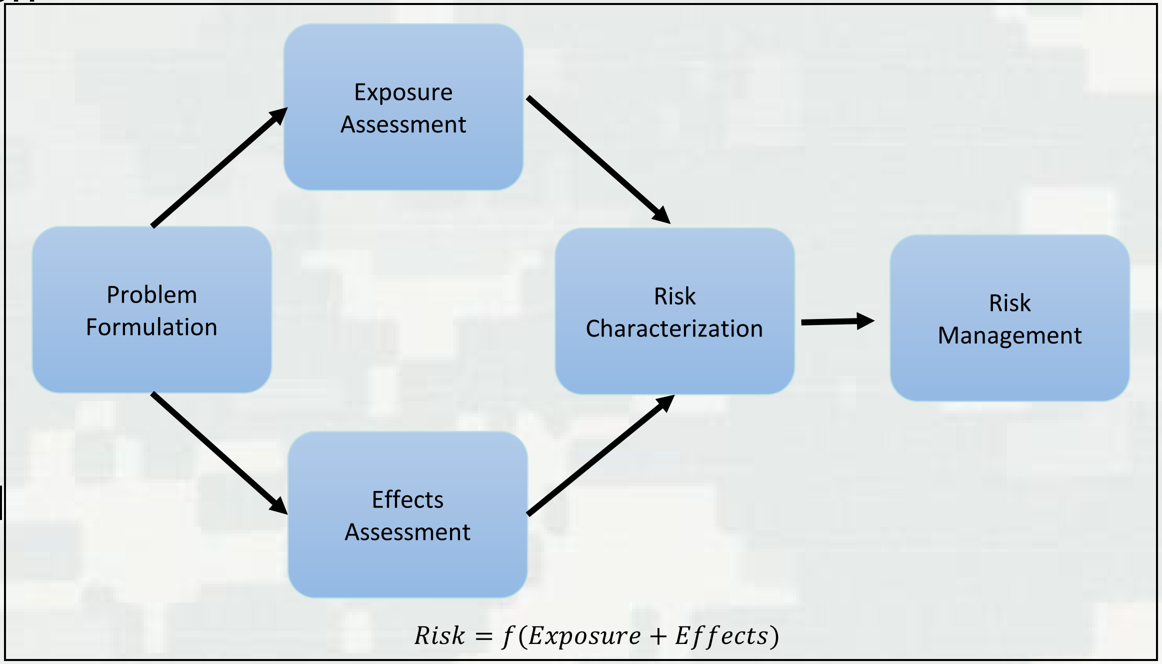
Risk Characterization/Management

- Dredge controls based on perceived risk can:
  - fail to provide the desired protection
  - Increased dredging cost without benefits
- Risk assessment based on system understanding can:
  - Improve habitat protection
  - Control costs
- Science-based risk characterization requires quantification of:
  - Exposure/dose
  - Effects/response
  - Support effective risk management
- This paper outlines a method for characterizing risk to sensitive species

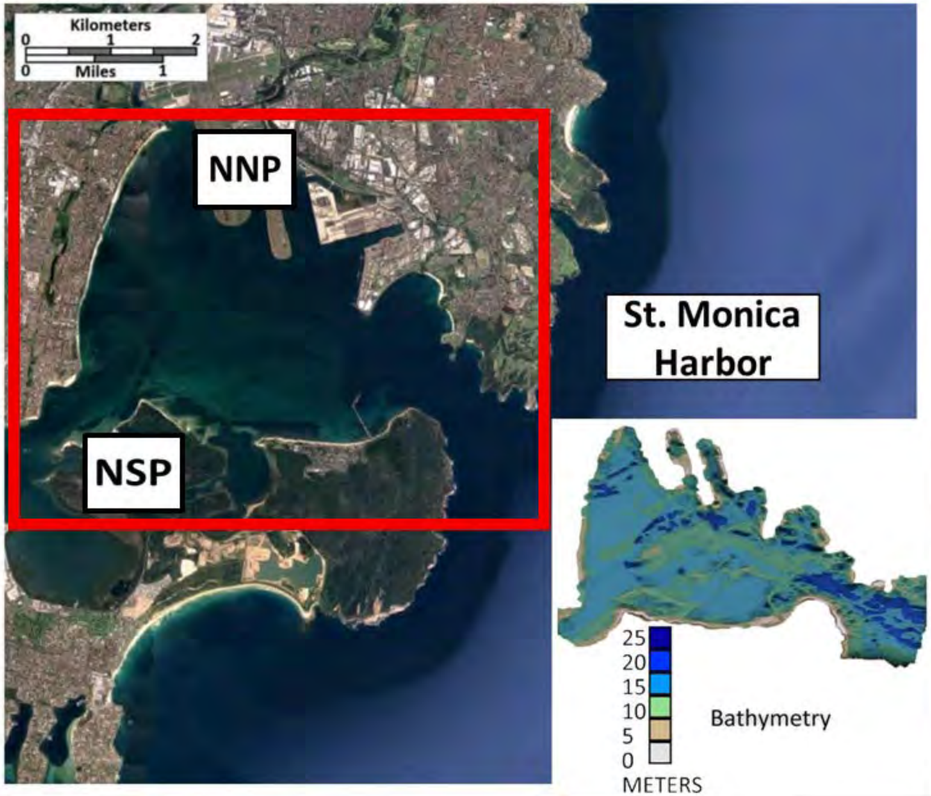


Methods

- Define extent of dredging operations
- Apply dredging models to quantify sediment loss during dredging operations
- Apply transport and fate models to quantify time- and spatially varying exposure mechanisms to sensitive species
    - TSS/turbidity
    - Total sedimentation
    - Sedimentation rates
- Literature review to quantify response of species to each exposure pathway (laboratory and field studies)
- Red/yellow/green light indicator for risk characterization to sensitive species over the domain
    - Red – significant mortality
    - Yellow – Significant effects, but recovery expected
    - Green – Nominal effects

Apra Harbor Site Description

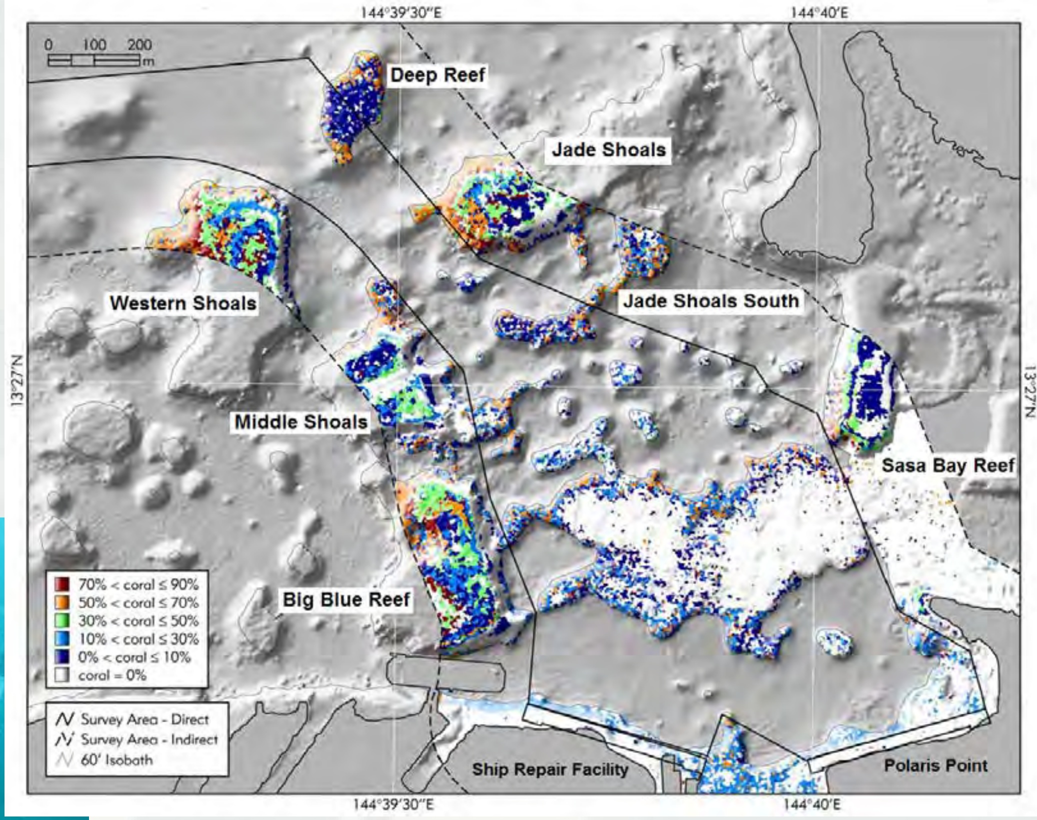
- Protected harbor studded with coral reefs
- Significant port for the U.S. Navy
- Potential harbor expansion would require some dredging
- Quantify exposure to coral habitat from dredging operations
- Both chiseling and dredging will be required to deepen/expand the harbor
- Coral reefs abut the proposed and existing channel
- Small currents (<5cm/s) and waves result in very clear water



This hypothetical case study is based on morphology for a medium-size harbor in New South Whales, Australia and is not intended to actually represent processes in this harbor

Site Description

- Coral surveyed within the dredge footprint and a 200 m perimeter – 1 m grid
- Shoals display the most abundant and diverse corals although coral exists at 50' water depth within the dredge footprint



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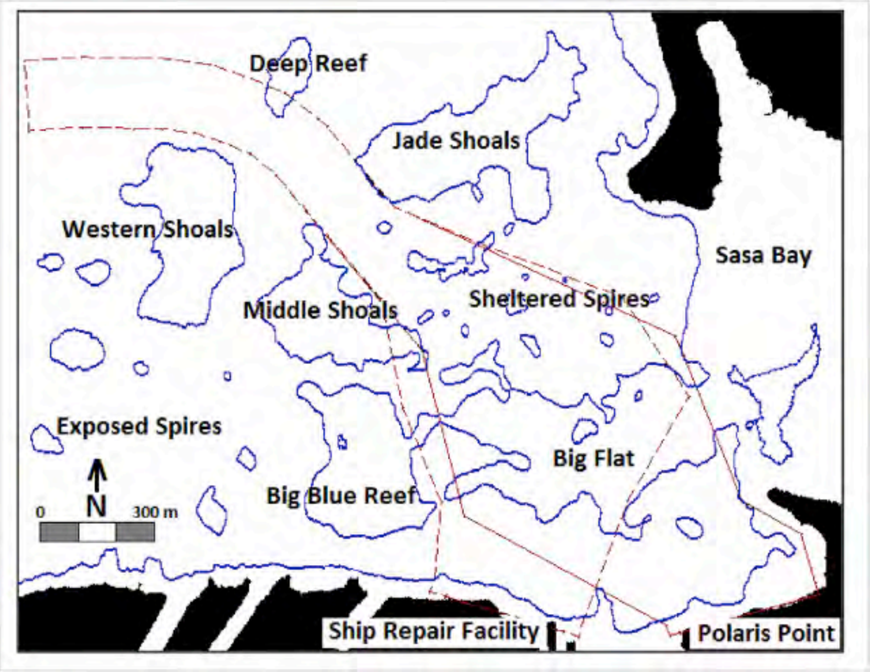
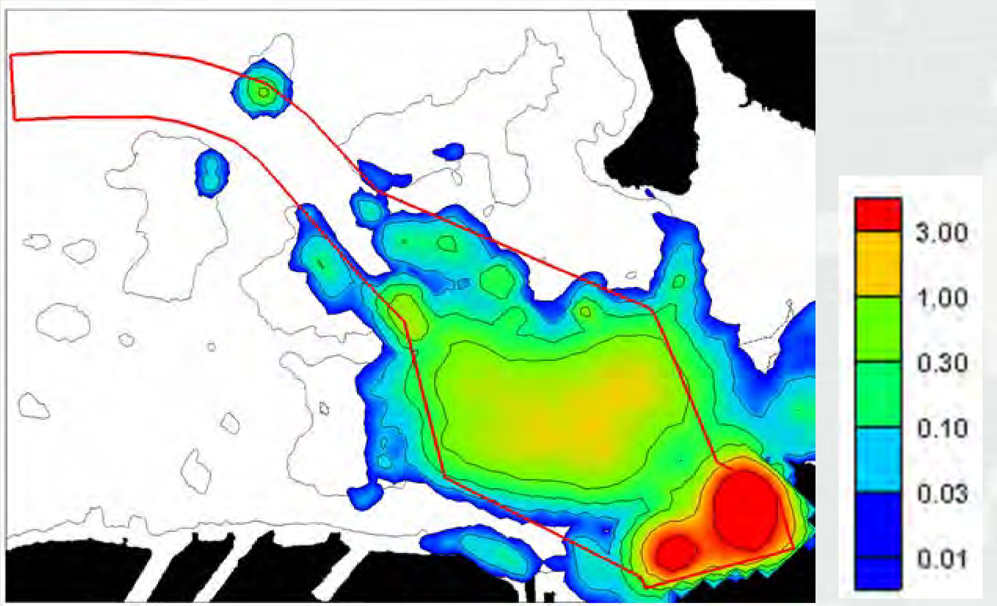
Dredge Scenarios

- Two possible dredging footprints evaluated for this project
- Majority of dredging (>80%) would occur nearshore at either Polaris Point (footprint 1) or Ship Repair Facility (footprint 2)
- Dredged material in the remainder of the dredge prism would consist of chiseled coral outcrop and debris



PTM Constituent Transport Model

- The PTM model is a Lagrangian particle tracking model designed for quantifying the transport and fate of sediments from dredging operations for multiple scenarios
- PTM accuracy is dependent on multiple factors including
  - Circulation and waves
  - Source strength
  - Settling velocities
  - Probability of deposition
- Circulation from validated 3-D hydrodynamic model
- Over 100 scenarios simulated for this application



Maximum Deposition at end of PPT footprint dredging (cm)

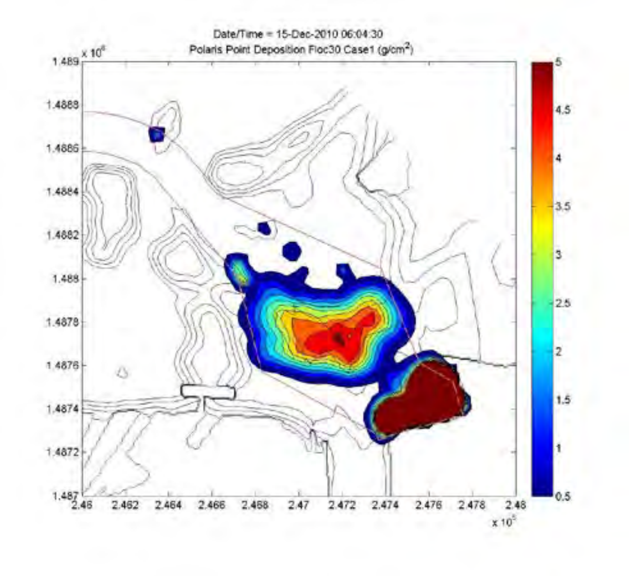
Modeling Scenarios

Case	Production Rate (yd^3/day)	Dredge Time for Alternative 1 (months)	% Loss	Silt Curtain Efficiency
1	1800	12	2	90%
2	1800	12	1	100%
3	1110	18	2	90%
4	1110	18	1	100%
5	1800	12	1	90%
6	1800	12	2	100%
7	1110	18	1	90%
8	1110	18	2	100%

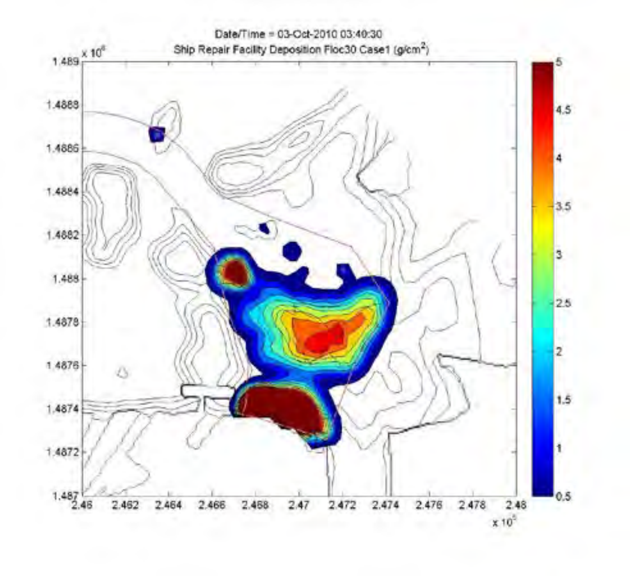
Cases 1 and 4 bracket the original maximum and minimum results and will be the focus of this presentation

Total Accumulation

Case 1: 1800 cyd - 2% loss - 90% effective silt curtain (Deposition in g/cm²)



Polaris Point

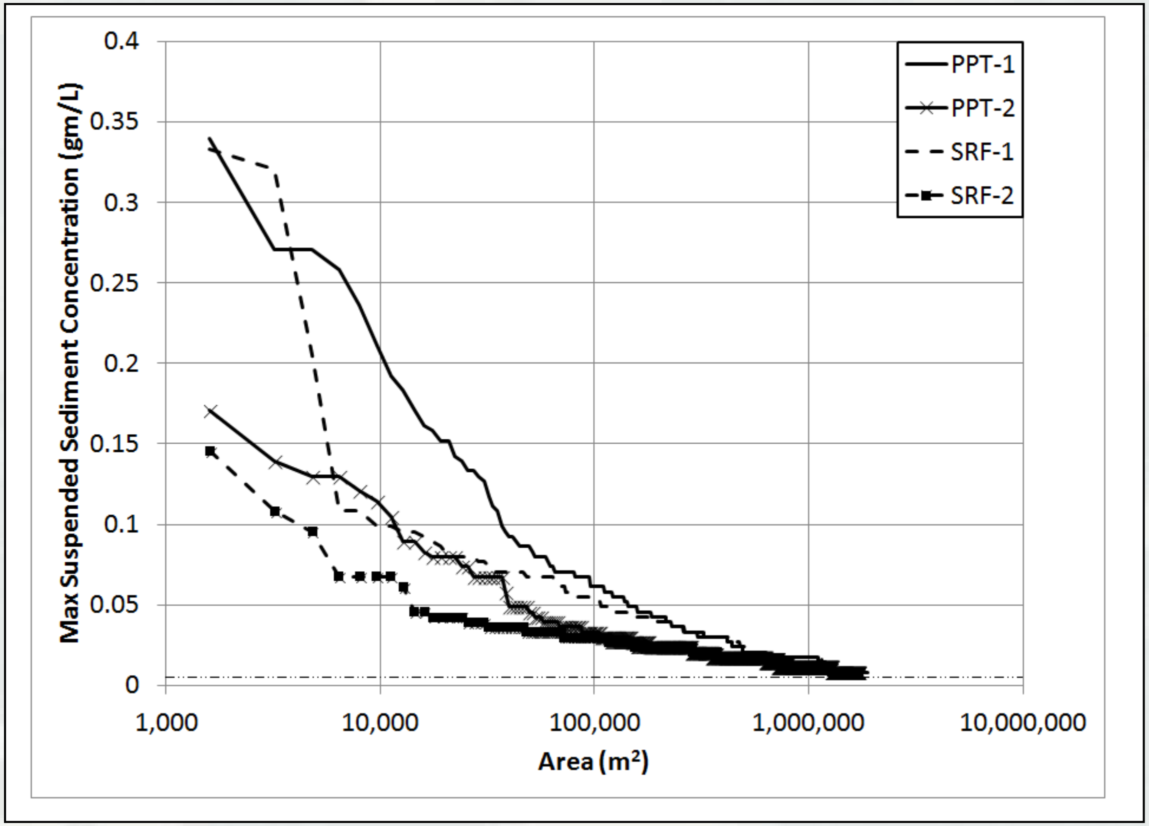


Ship Repair Facility

- The largest values are shown near Polaris Point and the Ship Repair Facility.
- The majority of the sediment settles and accumulates within the dredging footprint.

PTM Results

- Multiple exposure mechanisms evaluated (deposition, deposition rate, concentration time series, and peak concentration)
- Exposure quantities coupled and analyzed with known coral effects data to characterize risk to the coral from each potential dredging operation



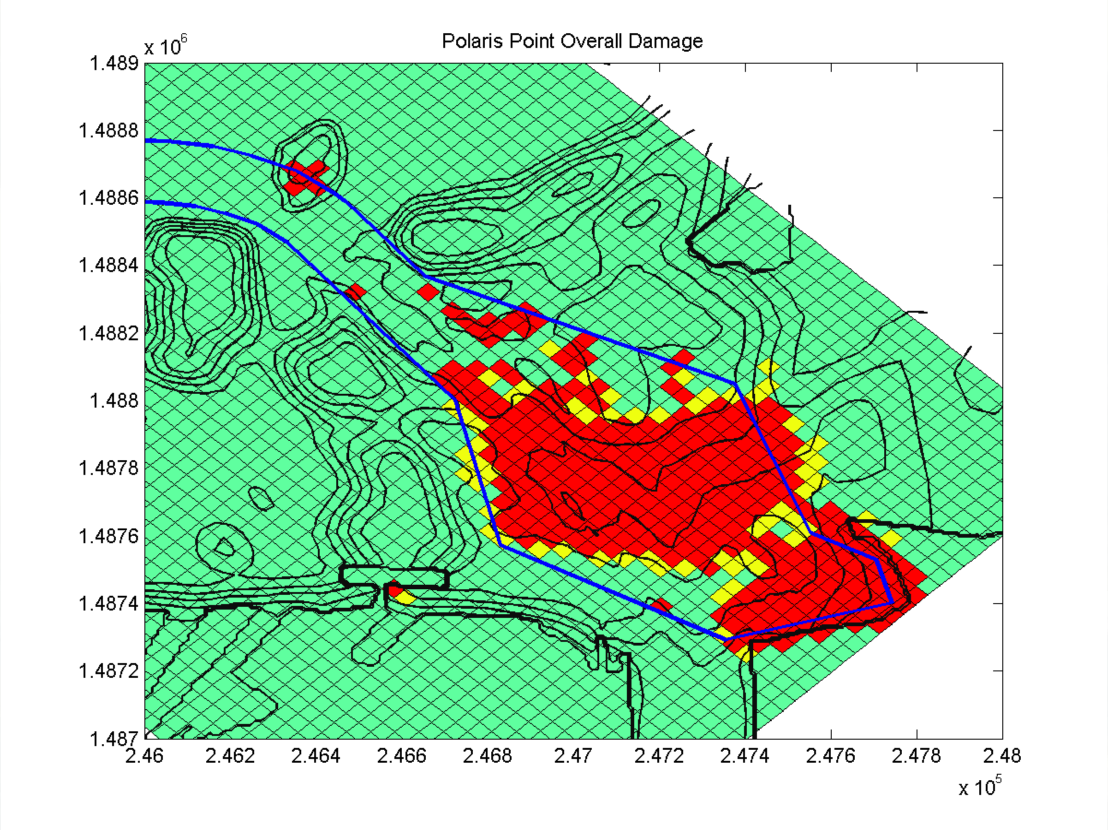
Peak suspended sediment concentration experienced at any time during the dredging operation

Effects From Exposure to Sediment

Basis for selection of sediment deposition, deposition rate, and turbidity thresholds applied in the modeling exercise to establish stoplight indicator criteria.

Effect level	Location or species	Exposure	Description	Reference
Sediment deposition (cm)				
Lethal	*Porites astreoides*	>1 cm	Full or partial colony mortality	Bak, 1978
Sublethal	Curacao	>1 cm	All corals except *P. astreoides* able to reject dredged sediment accumulations	Bak, 1978
	Porites sp.	Burial 20 h	Discoloration and bleaching with full recovery after 1 month	Wesseling et al., 1999
	8 massive species	Burial at 200 mg cm^{-2} for 6 wks	All removed at least 50% of sand within 1000 min	Riegl, 1995
No effect	*Porites* sp.	Burial 6 h	No effect	Wesseling et al., 1999
Sedimentation rate (mg cm^{-2} d^{-1})				
Lethal	Guam	160–200	Low coral cover (2%) and <10 species	Randall and Birkeland, 1978
	Acropora millepora	83	Full colony mortality at 12 weeks. Partial mortality began at 4 weeks.	Flores et al., 2012
	Worldwide	>50	Severe to catastrophic	Pastorok and Bilyard, 1985
Sublethal	Indonesia	57.5	Dead coral cover = 21%. Mortality index = 0.43	Edinger et al., 1998
	Palau, Micronesia	40 (>2 wks)	Mucus production, partial bleaching	Fabricius et al., 2007
	Worldwide	10–50	Moderate to severe	Pastorok and Bilyard, 1985
	Guam	5–32	>100 coral species	Randall and Birkeland, 1978
	Worldwide	>10	Chronic exposure considered "high"	Rogers, 1990
Minimal or no effect	*Siderastrea siderea*	10	No effect	Torres and Morelock, 2002
	Worldwide	1–10	Natural reefs not subject to stress	Rogers, 1990
	Worldwide	1–10	Slight to moderate	Pastorok and Bilyard, 1985
Suspended sediment concentration (mg l^{-1})				
Lethal	Singapore	>25 for >5% of the time or >10 for >20% of the time	Major impact	PIANC/UNEP 2010
Sublethal	Worldwide	>10	Chronic exposure considered "high"	Rogers, 1990
Minimal or no effect	Worldwide	<10	Natural reefs not subject to stress	Rogers, 1990
	Singapore	>5 for <1% of the time	No impact	PIANC/UNEP, 2010

Coral Reef Predicted Damage Plots

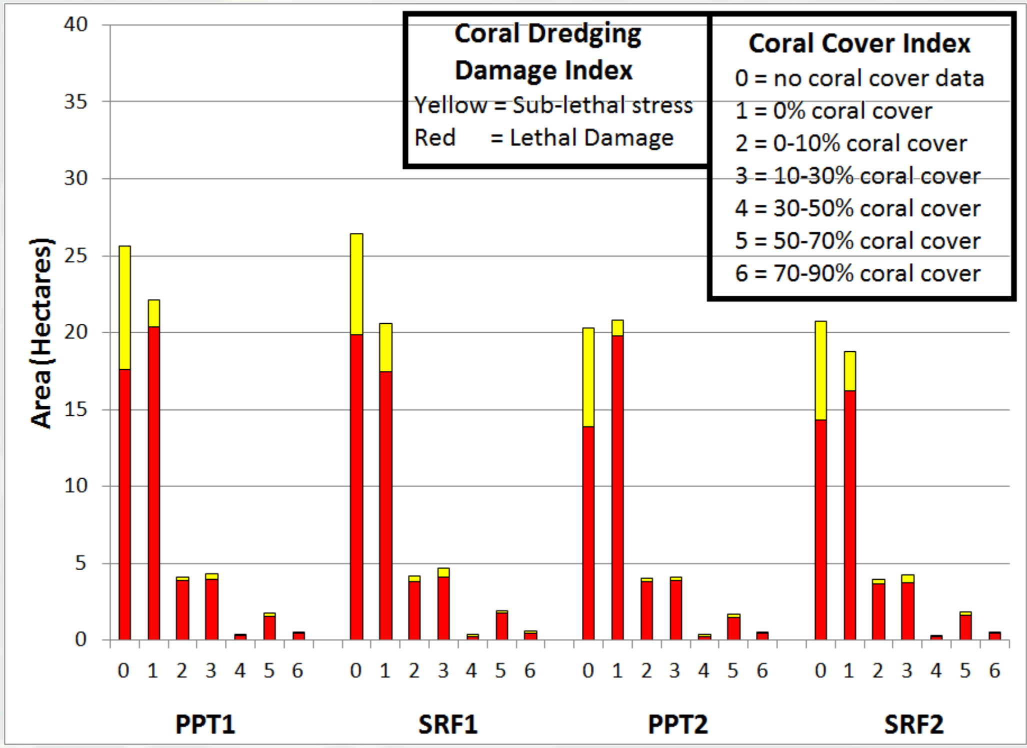


By consulting with Coral Reef biologists, ultimately the goal is to take exposure information combined with effects information and predict risk.

Green – Safe
Yellow – In danger
Red – Destroyed

Risk Characterization

- Results of risk characterization for four scenarios presented here
- The majority of “Lethal Damage” coral is within the dredge footprint.
- Some “Lethal Damage” coral lies to the west of the footprint in regions where coral is not diverse or concentrated
- Majority of diverse coral reefs are not effected by the dredging unless they are within the dredge footprint



Summary

- Exposure due to dredging operations was bracketed and paired with detailed effects data.
- Results showed that neither berthing alternative produced an overwhelming evidence for a specific preference based on risk due to resuspended dredge material.

However, more importantly…

- Coupling a Lagrangian exposure model and associated effects data to address risk to sensitive species provides a robust framework for managing risk and costs simultaneously
- Results can be used to:
  - Institute appropriate dredging controls to reduce risk
  - Develop mitigation plans