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Investigating Sediment Color Change Dynamics to Promote Beneficial Use Applications

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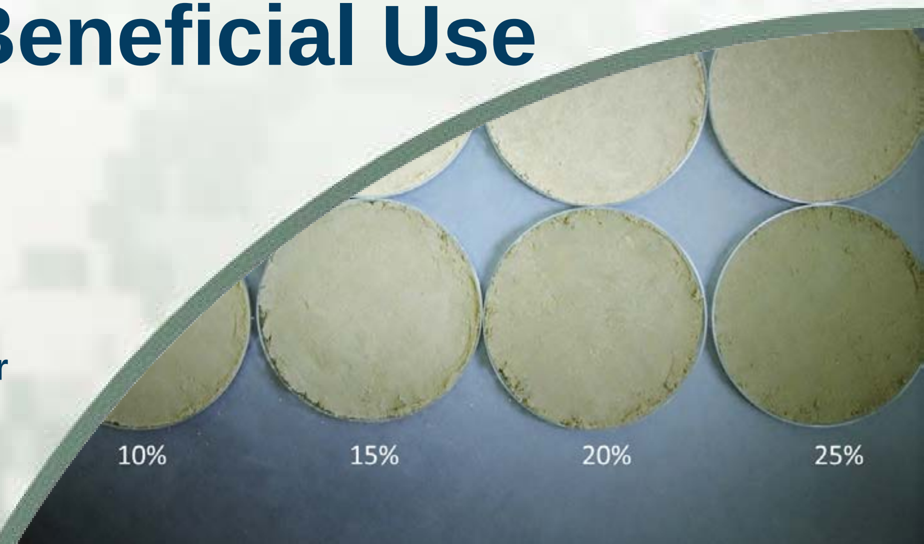

DOER

Engineering With Nature

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Clean sediments are a valuable but limited global resource

INSIGHTS

PERSPECTIVES

ENVIRONMENT

A looming tragedy of the sand commons

Increasing sand extraction, trade, and consumption pose global sustainability challenges

The World is Running Out of Sand

The little-known exploitation of this seemingly infinite resource could wreak political and environmental havoc

Need to utilize available sediments for beach nourishment, wetland creation, barrier islands, other beneficial use (BU) applications during dredging

Introduction

Dredged Material

Beneficial Use = Productive Use

Wetland creation

Shoreline enhancement

Marsh stabilization

Construction

Sediment color limits BU

Dark materials not allowed

Light materials applicable for BU

Sediment colors change post placement

Case study displays color change occurring after placement (USACE 2013).

Why sediment color matters

- Sediment colors limit beneficial use applications due to a variety of aesthetic and habitat suitability concerns.
- Aesthetics - users want white, consistent, sandy beaches
- Habitat - vulnerable species may be impacted by changes in sediment conditions (i.e., color)

T&E species habitat

- Color effects on temperature and habitat suitability → emphasis on sea turtles and other species
- Ackerman et al. (1992) darker materials absorbed more solar radiation → higher temperatures.
- Sediment color and temperature can change sea turtle brood sex ratios, potentially impacting sea turtle populations (Nordstrom, 2005)
- Milton et al. (1997) beach nourishment benefit sea turtle nesting habitat, avoid increasing or decreasing temps.
- Crain et al., (1995) project managers consider potential sediment color changes during planning and implementing of beneficial use projects

Sediment color limits BU opportunities - A poorly defined problem

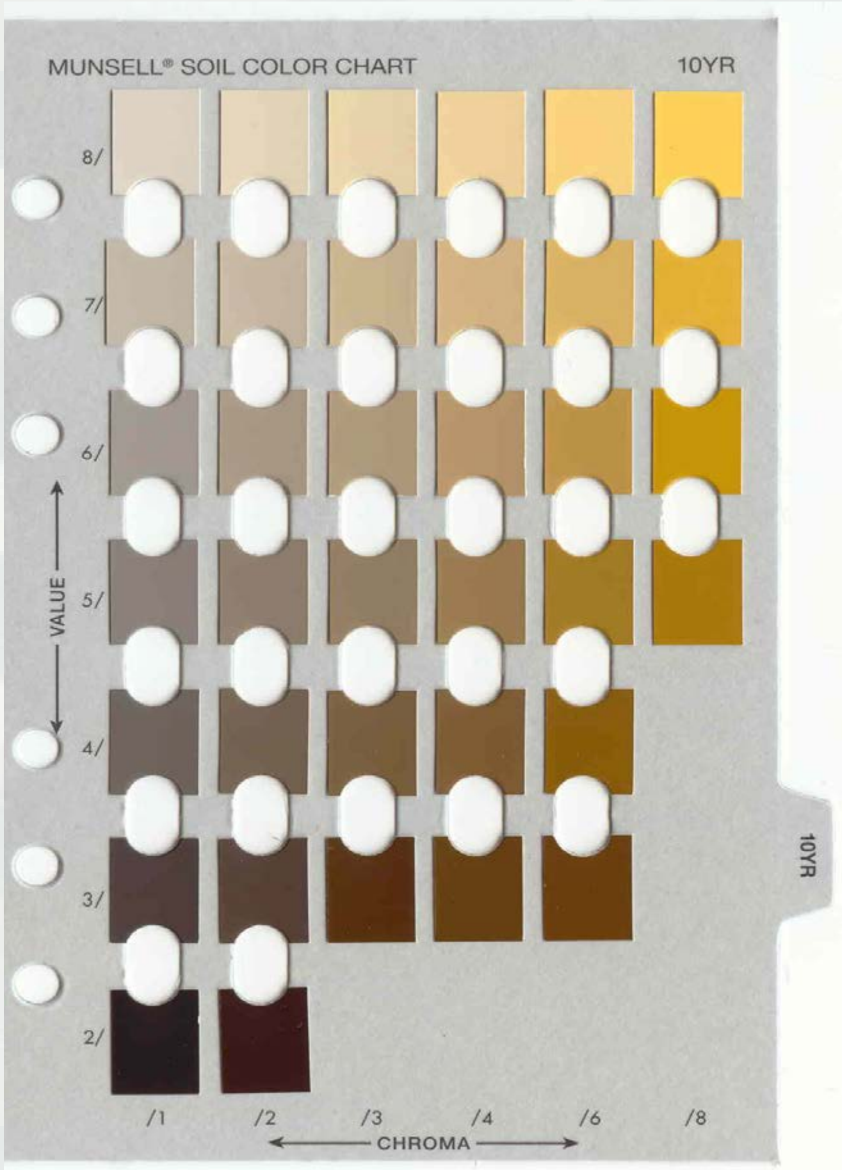
Most BU permits require sediment “compatibility”
But few identify quantitative metrics
None account for post placement color changes

Region	Size (mm)	Silt (%)	Shell (%)	$CaCO_3$ (%)	Color	Hue	Value	Chroma	Citation
United States	X				X				USACE (1995)
United States	X			X					Stauble (1991)
Orange FL	0.35-0.65	<2.0	<2.0		X		>7.0	<1.0	FLDEP (2012)
Miami FL	0.3-0.55	<5.0	<60		X	2.5YR-5Y	6-8	≤3.0	USACE (2016)
Duval FL	0.18-0.40	≤5.0	≤0.5	≤018	X	2.5YR-7.5YR	≥5.0	≤2.0	FLDEP (2015)
North Carolina	X			X					NCDCM (2013)
California	X			X	X				CGS (2005)
Galveston TX	X				X	X	X	X	Frey et al. (2016)
Jefferson TX	X			X	X	X	X	X	LGA (2016)
Virginia	X								USACE (2008)
Massachusetts	X								MDEP (2007)
Mississippi	X			X	X	X	X	X	USACE (2009)

Aspects of Sediment Color

- Munsell® color notation system
- Color system embodies three aspects
  - ►Hue - the spectral color of a sediment; chromatic composition of light reflected by an object
  - ►Value - sediment lightness or darkness
  - ►Chroma - the strength of sediment color (bright or muted)

Sediment Color



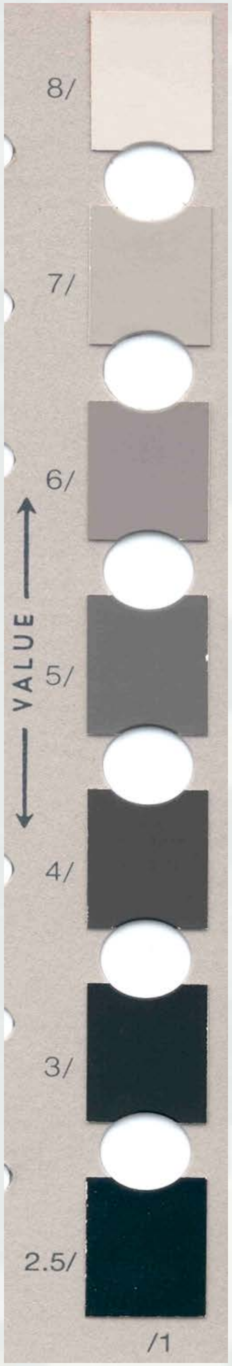
Value

Lightness or Darkness of Spectral Color

Higher value colors more desirable for placement

"White sand beaches"

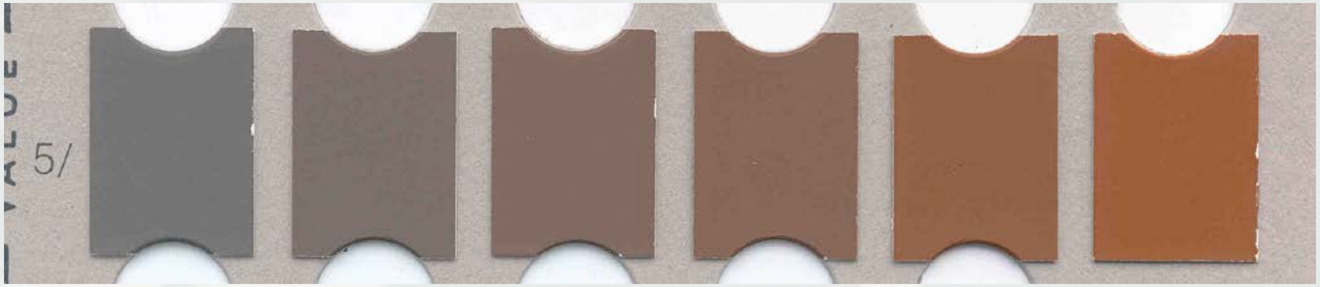
- 10/0 - Pure White
- 5/0 - "Gray"
- 0/0 - Pure Black



Chroma

- ***Chroma*** - relative purity or strength of the spectral color

Increasing strength of color →



← Increasing grayness

- Lower chroma desired for placement

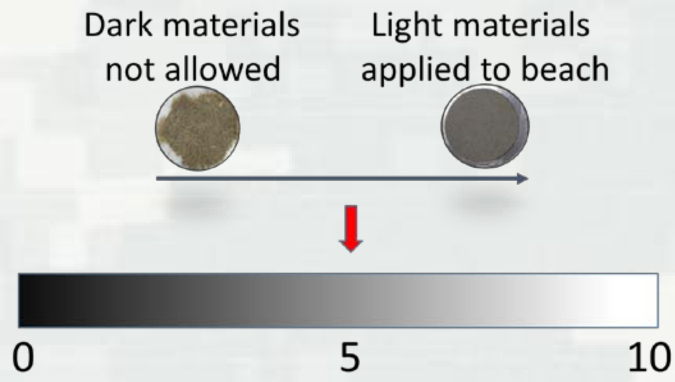
[redacted]

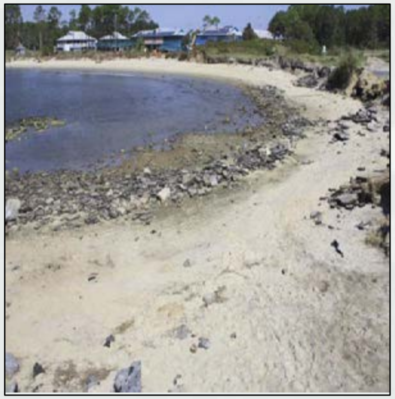
Field reports → sediments lighten over time

But → limited data available

We investigated sediment capacity to

change color (brighten) following placement ➔ increase BU applications





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Research Objective

What if:

We knew why and how much sediments brighten or shift color after placement?

Then we could:

Potentially take advantage of more dredged material previously considered incompatible.

Research Methods

Step 1: Gather sediments from practitioners in the field

Step 2: Laboratory procedure to examine POTENTIAL SEDIMENT COLOR CHANGE DYNAMICS

Step 3: Investigate potential BLEACHING EFFECTS

Step 4: Investigate the INFLUENCE OF FINES on sediment color change

Step 5: Develop holistic sediment color change potential model

Step 6: Investigate field testing opportunities and develop additional guidance

Gather sediments from practitioners in the field and characterize

Sediment sample location, texture class, mean size (µm), D_{50} (µm), and mineral composition as percent weight of quartz (Q), carbonates (C) and feldspars (F).

	Source	***Location***	***Texture***	***Mean size***	D_{50}	***Q***	***C***	***F***
FL1	Siesta Key, FL	Offshore borrow area	Medium sand	359	348	41	59	0
TX1	Galveston, TX	Galveston entrance channel	Fine sand	262	193	71	13	16
FL2	Egmont Key, FL	Tampa entrance channel	Coarse sand	419	425	49	36	3
CA1	Ventura, CA	Ventura harbor	Medium sand	228	236	35	1	64
CA2	Huntington Harbor, CA	Tidal wetland placement	Fine sand	161	174	24	0	52
FL3	Miami, FL	Offshore borrow area	Coarse sand	562	581	38	62	0
MD1	Ocean City, MD	Offshore shoal area	Medium sand	327	338	77	0	22
PA1	Philadelphia, PA	Offshore borrow area	Medium sand	325	340	97	0	3
AL1	Jackson, AL	Tombigbee river channel	Medium sand	314	332	100	<1	0

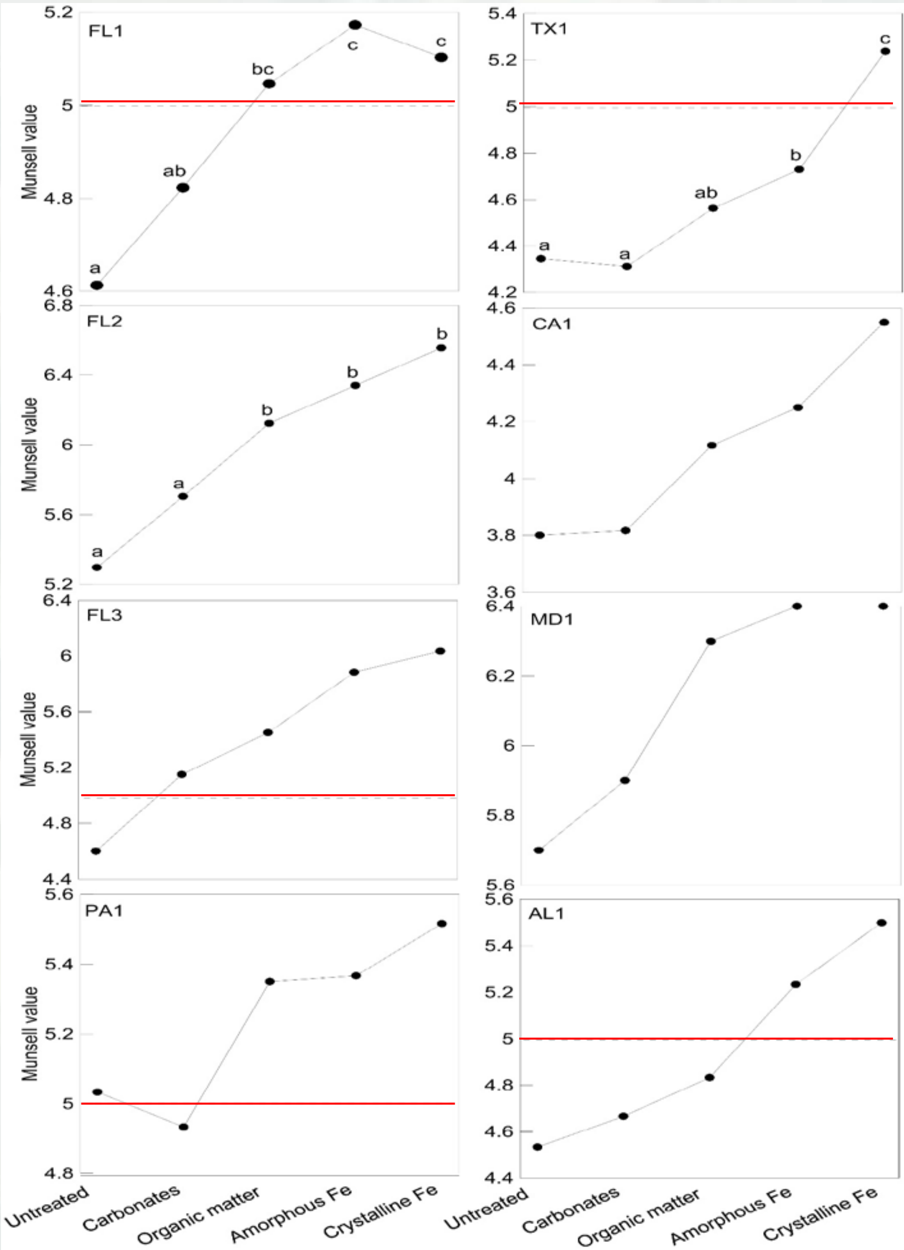
Chemical Treatments

Laboratory procedure to remove certain constituents (carbonates, organic matter, iron)

Sample ID	Moist Value				
	Original	Acetate	H2O2	1hr Dith	4hr Dith
1	4.7	4.9	5.1	5.2	5.1
2	4.6	4.7	5.0	5.1	4.9
3	4.7	4.9	5.1	5.1	5.1
4	4.7	5.0	5.2	5.6	5.5
5	4.4	4.8	4.9	4.9	5.0
6	4.4	4.3	4.6	4.9	5.4
7	4.4	4.4	4.6	4.9	5.3
8	4.4	4.4	4.5	4.7	4.8
9	4.2	4.2	4.6	4.5	5.5
10	4.2	4.9	5.3	5.5	6.2
11	4.6	5.0	5.6	5.8	5.6
12	5.6	6.4	6.3	6.7	6.8
13	6.2	6.1	6.9	6.8	6.9
14	6.0	6.1	6.6	6.9	7.3

Problematic	Non-problematic

Used as a proxy to simulate potential color changes under natural conditions



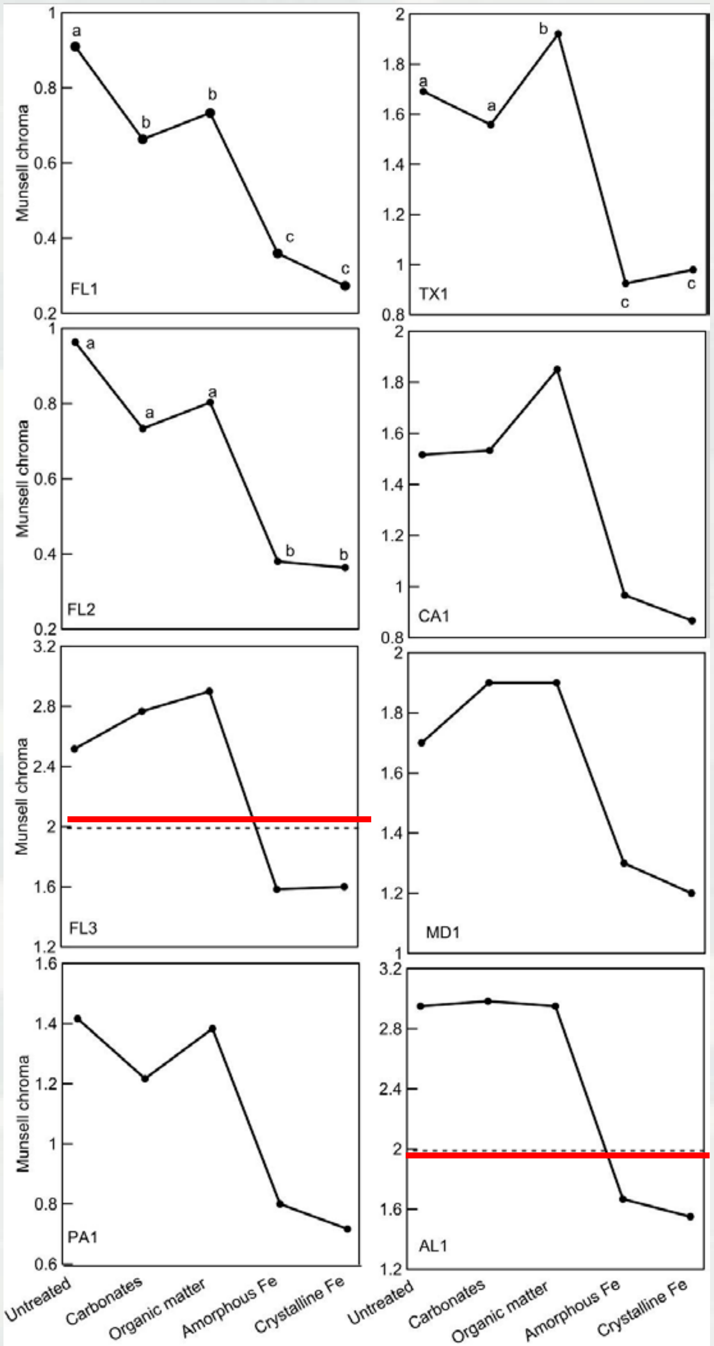
Chemical Treatments

Laboratory procedure to alter sediment color constituents:

Carbonates, organic matter, iron

Sediment value increased by over 1.0 unit following treatment

→ Sediments "lightened" becoming more applicable for BU



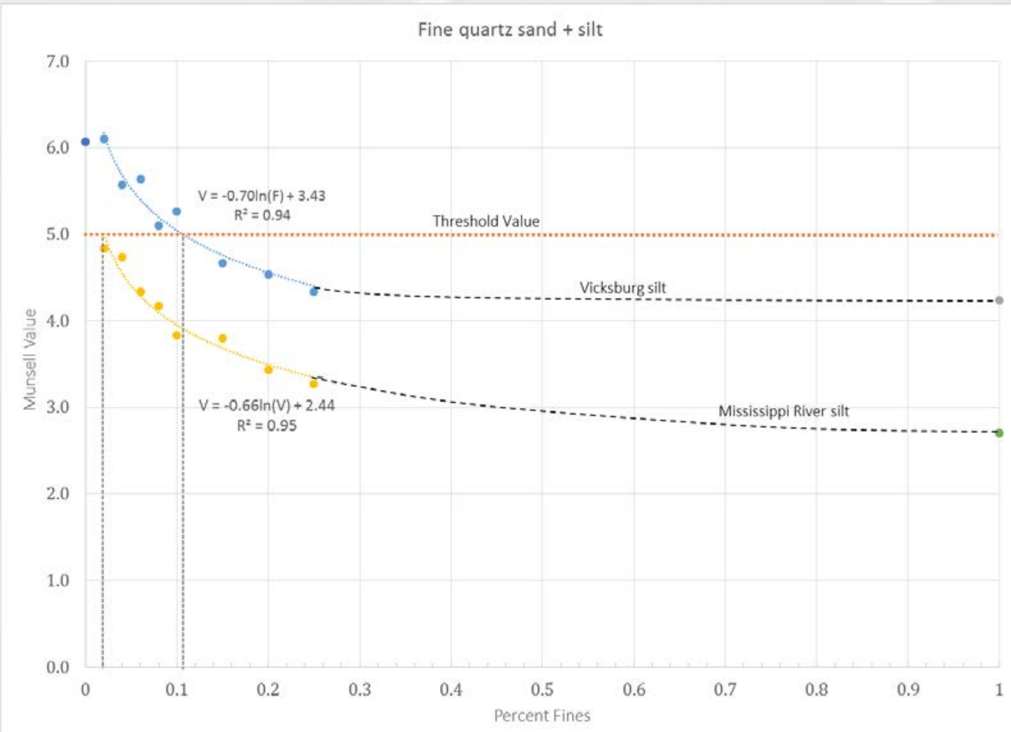
Chroma also decreased resulting in more desirable BU sediment characteristics

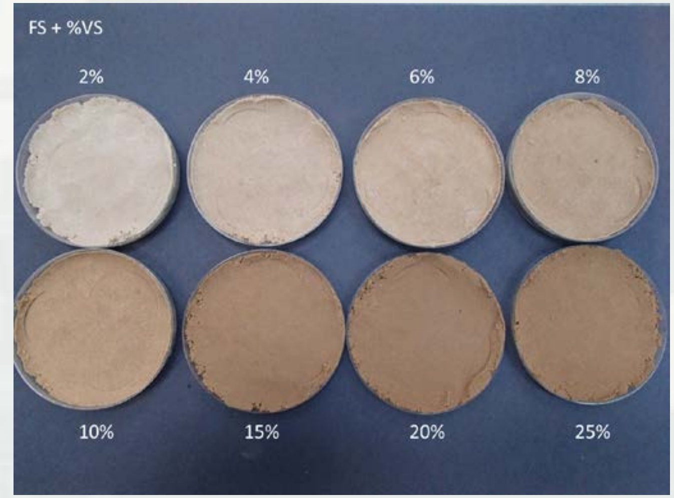
Color change potential

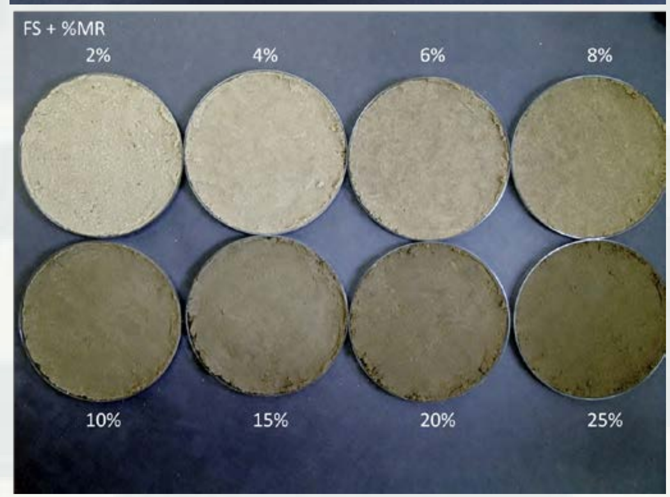
Most sediments (all but one) surpassed regulatory thresholds during the study

Influence of Fines

Investigate the influence of fines on Munsell Value (sediment brightness)





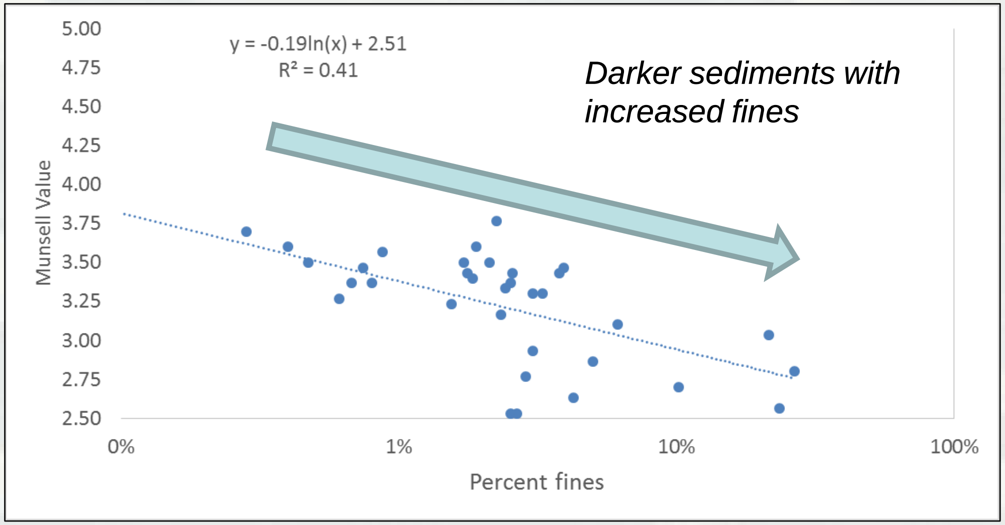


- Finer sediments often “darker” in color
- Increased fines decreased to threshold values with 2% and 11% fines content
- Greatest changes occur < 10% fines

Influence of Fines

Investigate the influence of fines on Munsell Value (sediment brightness)

Similar relationship to experiments



Field data provided by Coraggio Maglio (SWG)

Field data from dredging projects

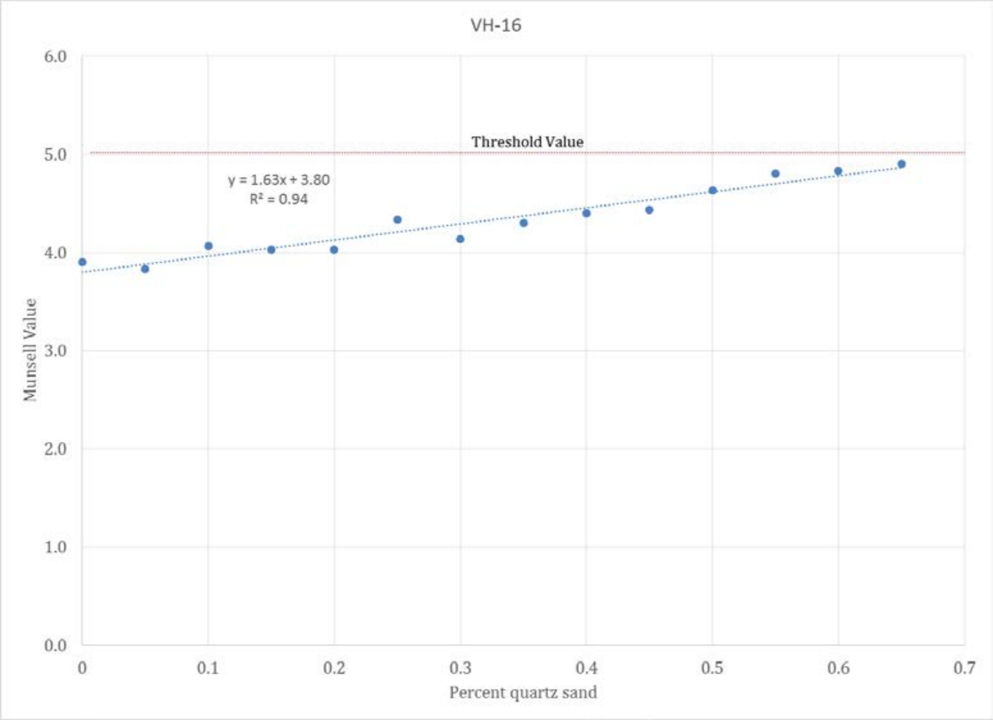
1st project to quantify color shifts between the various sample points in dredging process

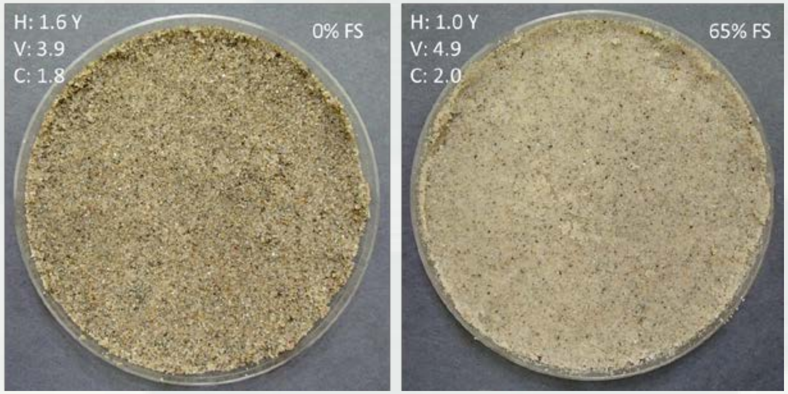
Low initial Munsell Value "lightened" during the dredging and placement process

More data to be added from Ship Isl. restoration project (BOEM-USACE-SAJ-RSM)

Influence of mixing

Investigate the influence of mixing (dilution) on sediment brightness



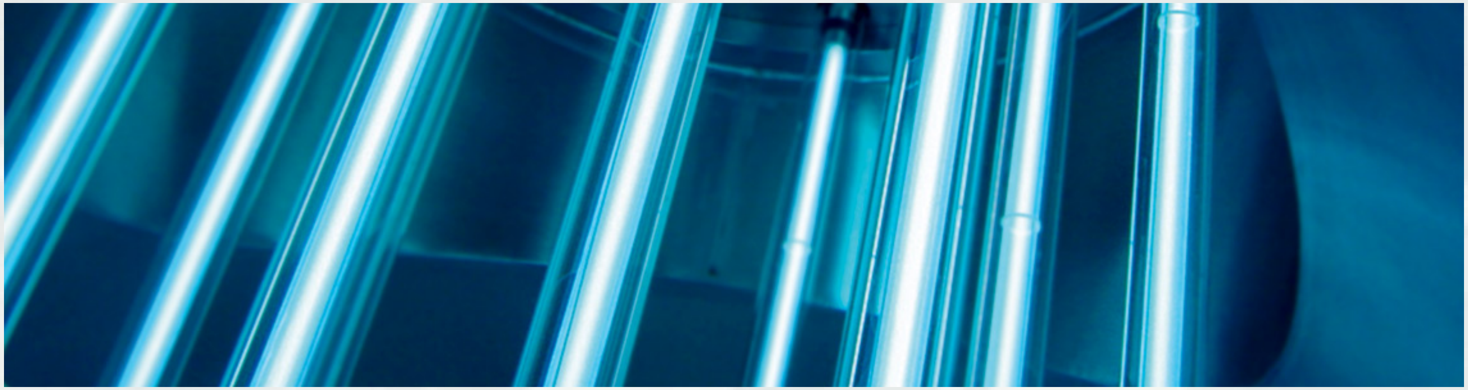


- Clean, fine sand added to dark sands
- Sediment color improved after 65% mixture
- Implication: mixing of darker nourishment sand with bright native sand results in acceptable colors for BU

Influence of solar bleaching

Investigate the influence of solar bleaching on sediment brightness

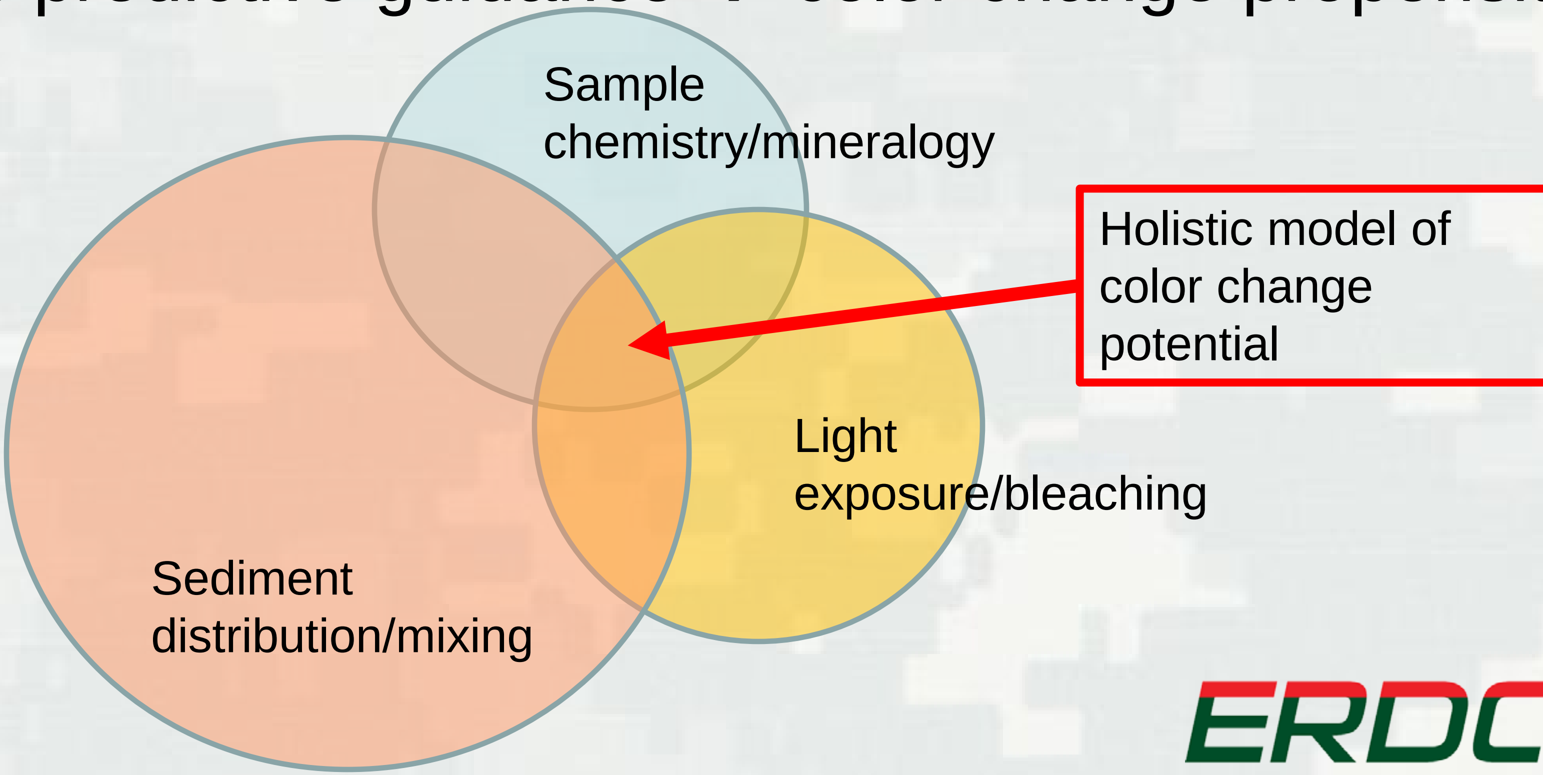
Preliminary result: Exposure to high intensity light resulted in color change within 4 weeks of exposure. Additional experiments in progress.



Color Change Index

Synthesize bleaching, mixing, and chemistry effects into holistic model

Develop predictive guidance → color change propensity



Primary takeaways

1. Issue of sediment color remains poorly defined, but limits DM use
2. Agencies take (overly?) conservative approach in using dredged material for nourishment projects
3. Ability to predict color change dynamics allows for relaxation of fine sediment and color thresholds
   - Expands available volume of an already scarce resource
   - Reduces costs (scarcity and offshore disposal distance)

Conclusions

1. Color improvements associated with removal of carbonates, organic matter and iron oxides.
   - Proxy measures for the potential color change
2. Bleaching had similar effects → need more research on bleaching mechanisms
3. Sediment mixing and the % of fines has important implications for sediment color
4. Additional guidance being developed for sediment color change potentials
5. Incorporating sediment color changes into dredging operations can increase the BU of limited sediment resources while addressing aesthetic and habitat concerns

Additional information

Journal of Coastal Research	00	0	000–000	Coconut Creek, Florida	Month 0000

Potential Color Change Dynamics of Beneficial Use Sediments

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ABSTRACT

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Sediment color is important in determining aesthetic and habitat suitability for beach nourishment projects; however, sediment derived from dredging operations must meet locally established color compatibility requirements (*i.e.* cannot be too dark). Often, potential sediment sources are close to meeting specified thresholds, and previous observations suggest that sediments may lighten over time following beach nourishment. This work seeks to characterize the degree of color change potential based on the removal of constituents affecting sediment color. Thus, a sequential chemical treatment was developed to examine color changes associated with the removal of carbonates, organic matter, and iron oxide coatings from sediments collected from eight U.S. Army Corps of Engineers dredging operations. The results show that Munsell values increased by an average of 1.0 unit (became lighter in color) upon removal of these secondary constituents. In addition, five of the eight sediments examined surpassed established color thresholds (Munsell value $\geq$ 5) from their pretreated state. This procedure is meant to serve as a proxy for removal of these constituents by natural processes. Study findings suggest that sediments with initially unacceptable color, and high capacity for color change, may increase potential use of limited sediment resources. Future work will further relate color shifts to sediment composition, sediment mixing, and solar bleaching to predict sediment color changes under real-world scenarios.

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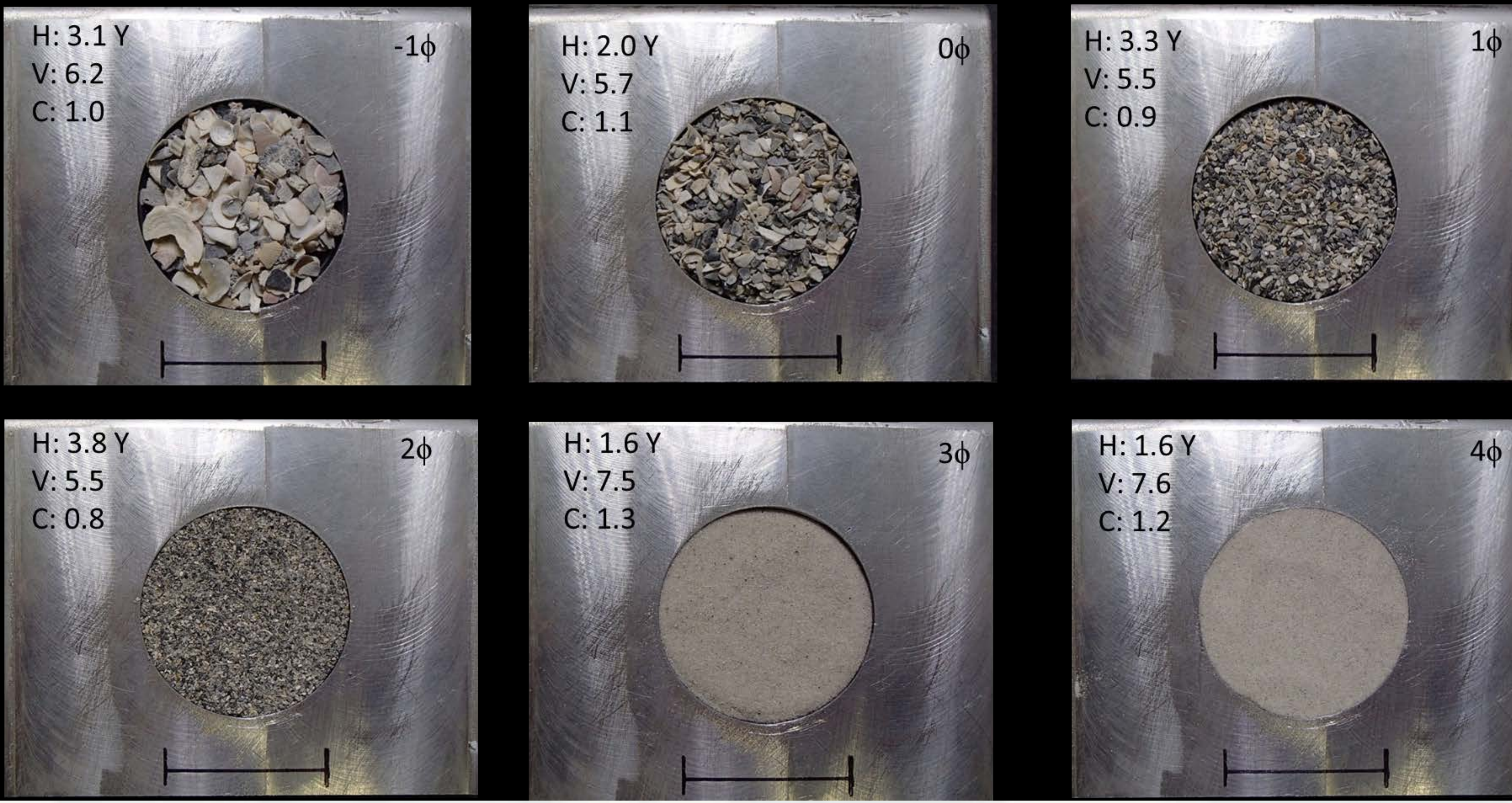
Supplemental Slides

EK-10

BULK COLORATION - H: 2.6 Y; V: 6.4; C: 1.0



BULK COLORATION - H: 0.9 Y; V: 5.6; C: 2.1