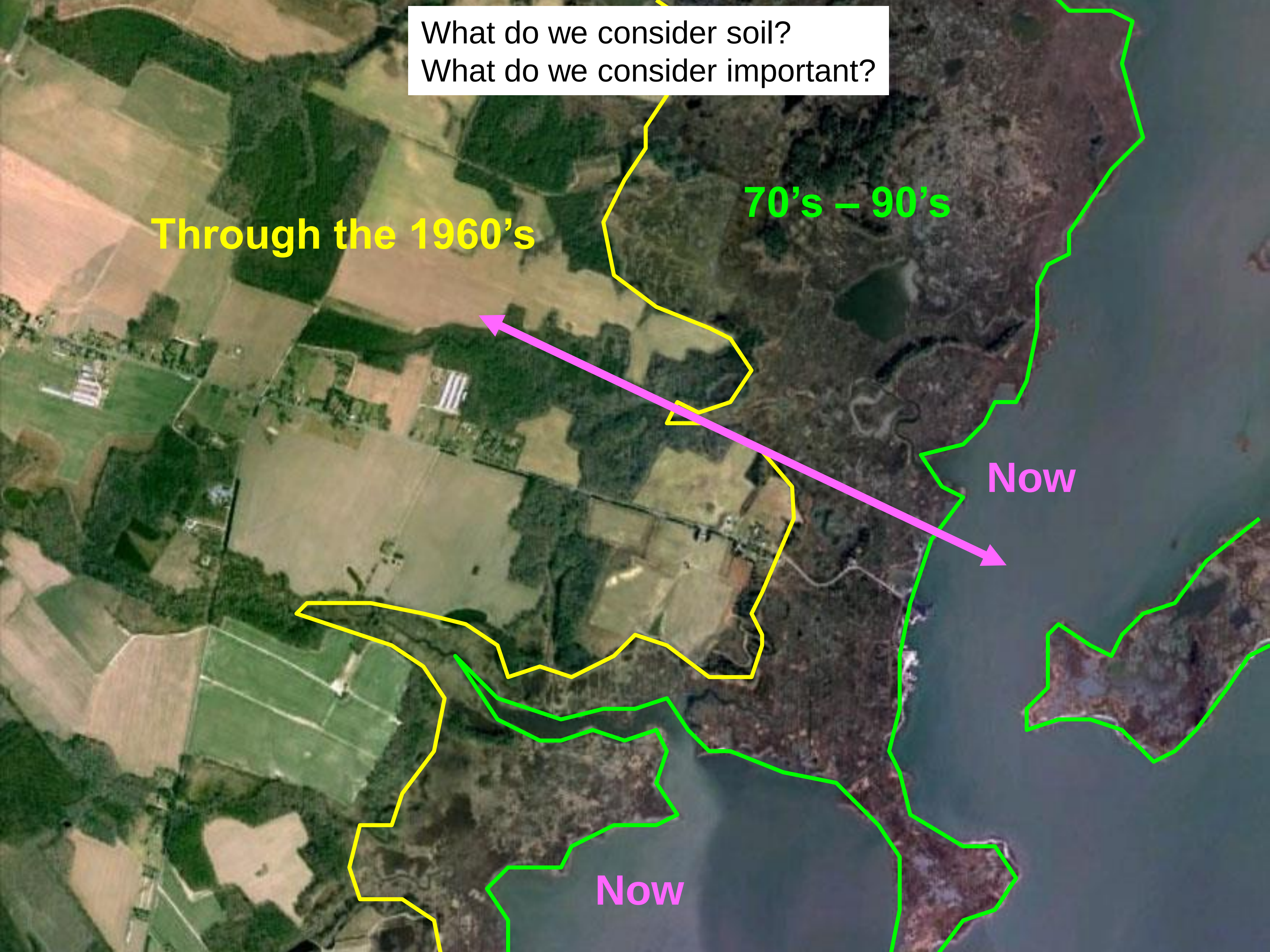
A History of Subaqueous Soil Survey

2018 Coastal Zone Soil Survey (CZSS) Work Planning Conference
Savannah, GA – January 8th – 12th, 2018

Martin C. Rabenhorst – Univ. of Maryland

Mark H. Stolt – Univ. of Rhode Island

DEPARTMENT OF ENVIRONMENTAL SCIENCE & TECHNOLOGY
College of Agriculture & Natural Resources
www.enst.umd.edu


What do we consider soil?
What do we consider important?
Through the 1960's
70's – 90's
Now
Now

Early Background

- VonPost (1862)
  - first description of under water (subaqueous soils)
  - “gyttja” and “dy”
    - Gyttja – coprogenic
    - Dy – enriched with dark organics
  - Although his concept of “soils” differed from ours, he was the first to use this terminology
- Mortimer (1950)
  - Under water soils in freshwater lakes
  - Recognized biogeochemical depth functions
  - Nothing especially pedological – but he did use the term “soil”
- W. Kubiena (1953)
  - Comprehensive soil classification system for Europe
  - Included “the neglected sub-aqueous soils”
    - true subaqueous soils that were always covered with water
    - peat-forming Histosols in emergent wetlands, bogs, or forests
    - Introduced horizonation of subaqueous soil profiles
    - No evidence of this system being used
- Muckenhausen (1965)
  - Drawing from Kubiena’s work, developed classification system for Germany
  - No evidence used in mapping
- F. Ponnamperuma (1972) *“The Chemistry of Submerged Soils” Adv. Agron.*
  - IRRI's principal soil chemist from 1961 to 1985
  - Argued that soils permanently or substantially under water be recognized as soils citing
    - Pedogenic processes
    - Presence of soil horizons with differing properties

Despite all this…..

- *Soil Taxonomy* (Soil Survey Staff, 1975) stated:
  - Soil, … is the collection of natural bodies on the earth's surface, in places modified or even made by man of earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. **Its upper limit is air or shallow water. At its margins it grades to deep water** or to barren areas of rock or ice.
- For the most part subaqueous materials were excluded by
  - their permanent saturation beneath “deep” water.
  - the primary requirement that they be able to support rooted plants.
- Most, but not all, were deterred.

George P. Demas, Ph.D.
1958 - 1999

- MS – 1982
- NRCS – Soil Survey Project Leader
- Pioneer in Subaqueous Soils
- PhD – 1998

AWARDS

- USDA – ***Secretary's Honor Award*** for Scientific Research
- Soil Sci. Soc. of America – ***Emil Truog Award*** – Soil Science Outstanding Dissertation Award (1999)

George Demas

- Early conversations

George Demas

- Early conversations

George Demas

- Early conversations
- 1993 – SSH (initial concept paper)
  - Submerged Soils: A new frontier in Soil Survey. Demas, G. P. 1993. Soil Survey Horizons. 34: 44-47.

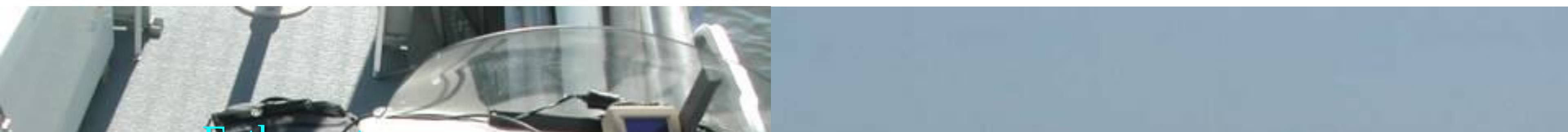
George Demas – Contributions

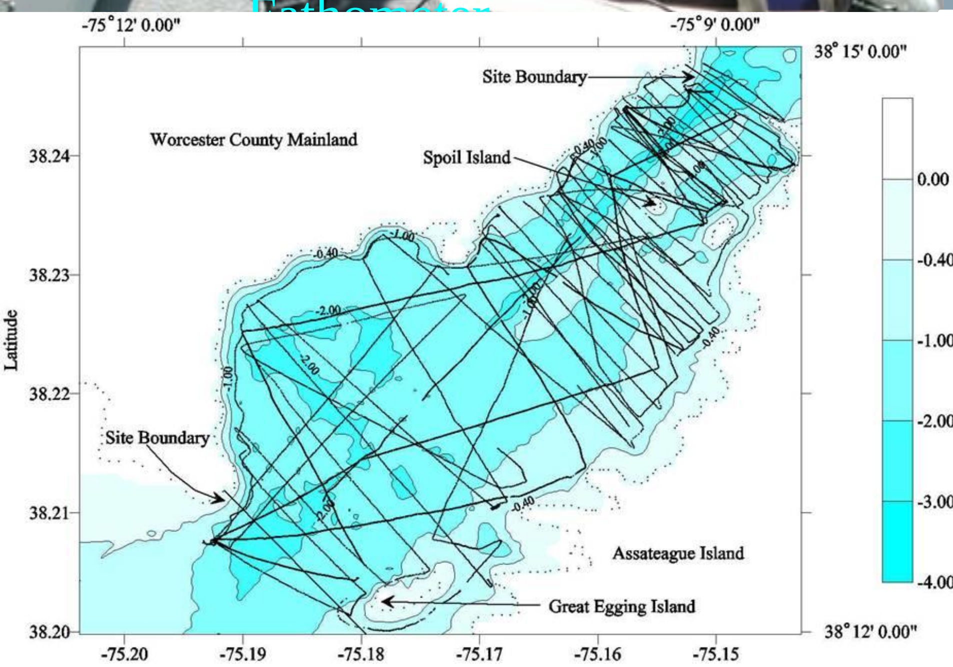
Worked to help revise the definition of Soils

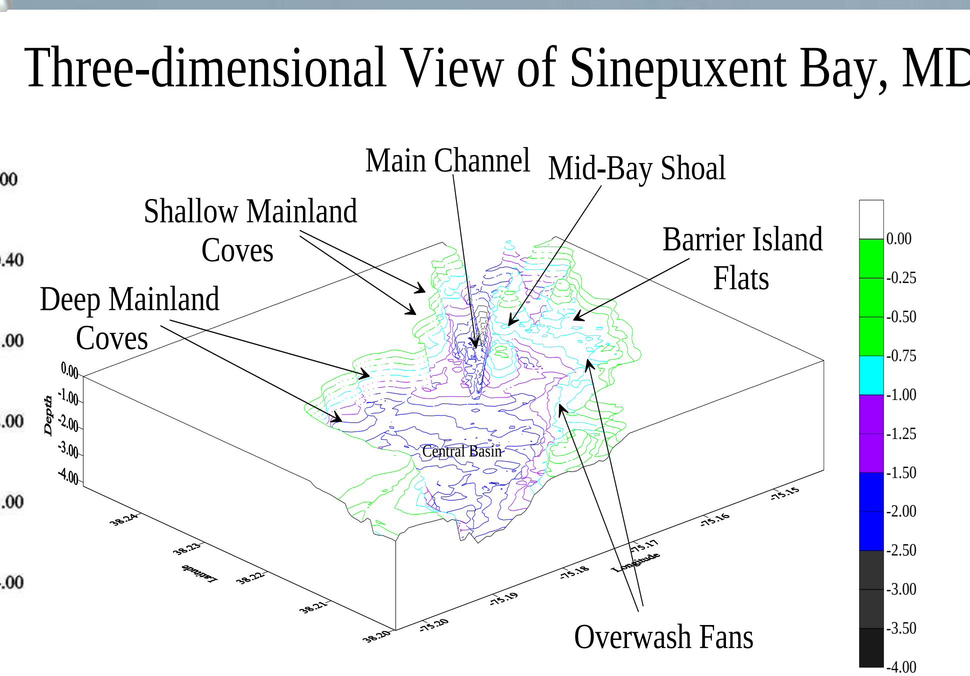
Criterion	1975	1999
Upper Limit	*Its upper limit is air or shallow water.*	*The upper limit of soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not begun to decompose.*
Margins	*At its margins it grades to deep water or to barren areas of rock or ice.*	*The horizontal boundaries of soil are areas where the soil grades to deep water, barren areas, rock, or ice.*
"Not Soil"	*Areas are not considered to have soil if the surface is permanently covered by water deep enough that only floating [i.e. non-emergent] plants are present*	*Areas are not considered to have soil if the surface is permanently covered* ***by water too deep (typically more than 2.5 m) for the growth of rooted plants.***

George Demas – Contributions

- Developed an approach for viewing the underwater land surface –obtaining high quality bathymetry
  - Joined research grade fathometer, real time GPS, tide measurement corrections







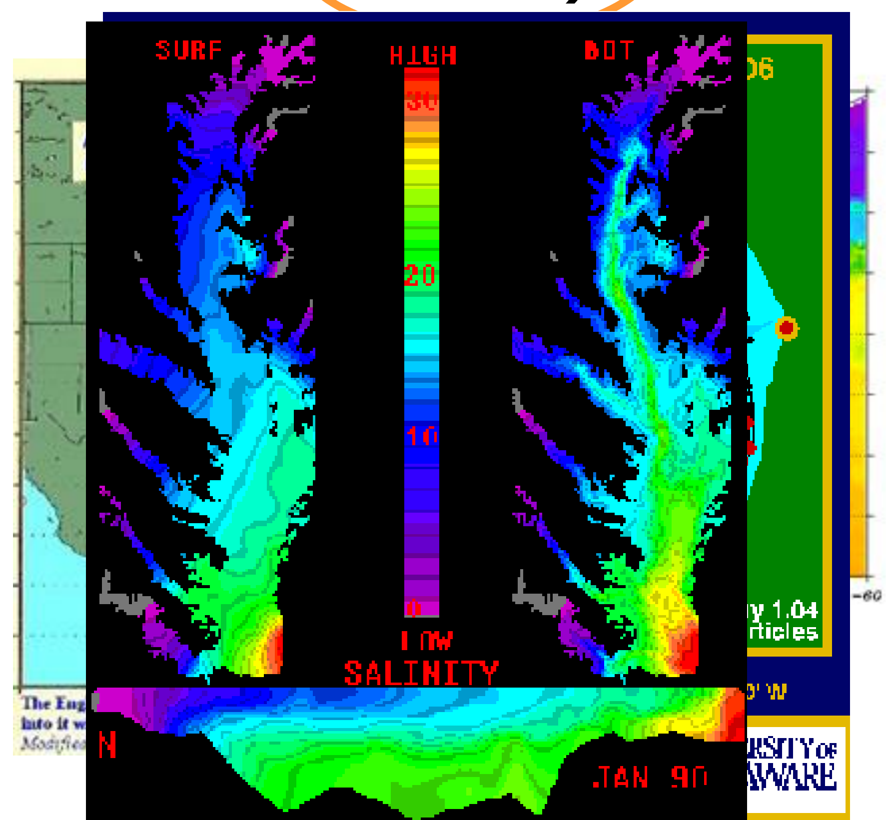
George Demas Contributions

- Recognized that **horizons** in subaqueous soils formed as a result of pedogenic processes
- Soil genesis models
  - Factors of subaqueous soil formation (modification of Jenny’s state factor model)
  - Simonson’s generalized model

State Factor Equation for Subaqueous Soils

$$S = f\,(C, O, R, P, T) \qquad Se = f\,(G, H, B)$$

- $Ss = f\,(C, O, B, F, P, T, W, E)$
  - where Ss is subaqueous soil
  - C is climatic temperature regime
  - O is organisms
  - B is bathymetry
  - F is flow regime
  - P is parent material
  - T is time
  - W is water column attributes
  - E is catastrophic events



Demas, G. P., and M. C. Rabenhorst. 2001. *Factors of Subaqueous Soil Formation: a System of Quantitative Pedology for Submersed Environments*. Geoderma. 102:189-204.

George Demas – Contributions

- Evaluated the hypothesis that the soil–landscape paradigm could be applied in subaqueous systems;
- Demonstrated its validity in mid-Atlantic coastal lagoons:
  - those soils formed on the storm surge washover fan flats bear a great deal of similarity to each other, while
  - those soils forming on lagoon bottom landforms also share a great many similarities, but
  - that the soils of these two landforms are highly contrasting

George Demas Contributions

- Sought to apply *Soil Taxonomy* to subaqueous soils
  - Essentially, all fit within various classes of Aquents
  - Proposed six soil series to accommodate mapping of SAS in Sinepuxent Bay:
    - Trappe
    - Whittington
    - Tizzard
    - Southpoint
    - Sinepuxent, and
  - Fenwick
    - as a tribute, was later renamed Demas

The new millennium
(the first decade, 2000 – 2010)

M. H. Stolt and his students – Southern New England

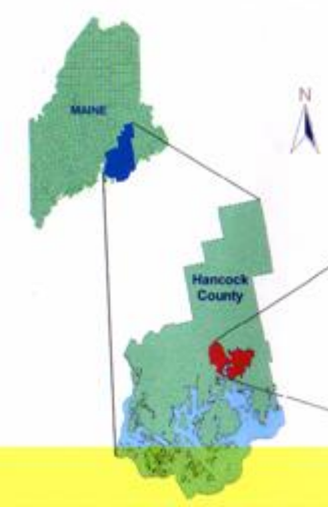
- Mike Bradley (2000)
  - coastal ponds, eelgrass interps, soil-landscape relationships
  - compared old (1950s) NOAA bathymetry with current (2000); minimal changes in landforms
  - characterization for establishing new series in SNE
- Maggie Payne (2007)
  - Embayments instead of lagoons, Greenwich Bay, Wickford Harbor, Little Narragansett Bay (LNB); soil-landscape relationships
  - water-quality-soil relationships, sulfides
  - characterization for establishing new series in SNE
- Jonathan Bakken (2010)
  - Freshwater ponds
  - P and invasive species
  - carbon in freshwater subaqueous soils, established 5 new series
- Alex Salisbury (2010)
  - shellfish productivity
  - dredging interpretations
  - soil temperature
- Chrissy Pruett (2010)
  - metals, carbon pools and sequestration
  - eelgrass restoration






Other Early Developments and Studies

- Students of **Dr. Laurie Osher** (UME) began studying SAS in Taunton Bay, Maine.
  - Graduate student **Chris Flannagan** (2005) focused on developing soil landscape relationships in Taunton Bay, ME
  - Graduate student **Jen Jesperson's** (2006-7) work was focused on the carbon sequestration and storage in subaqueous soils



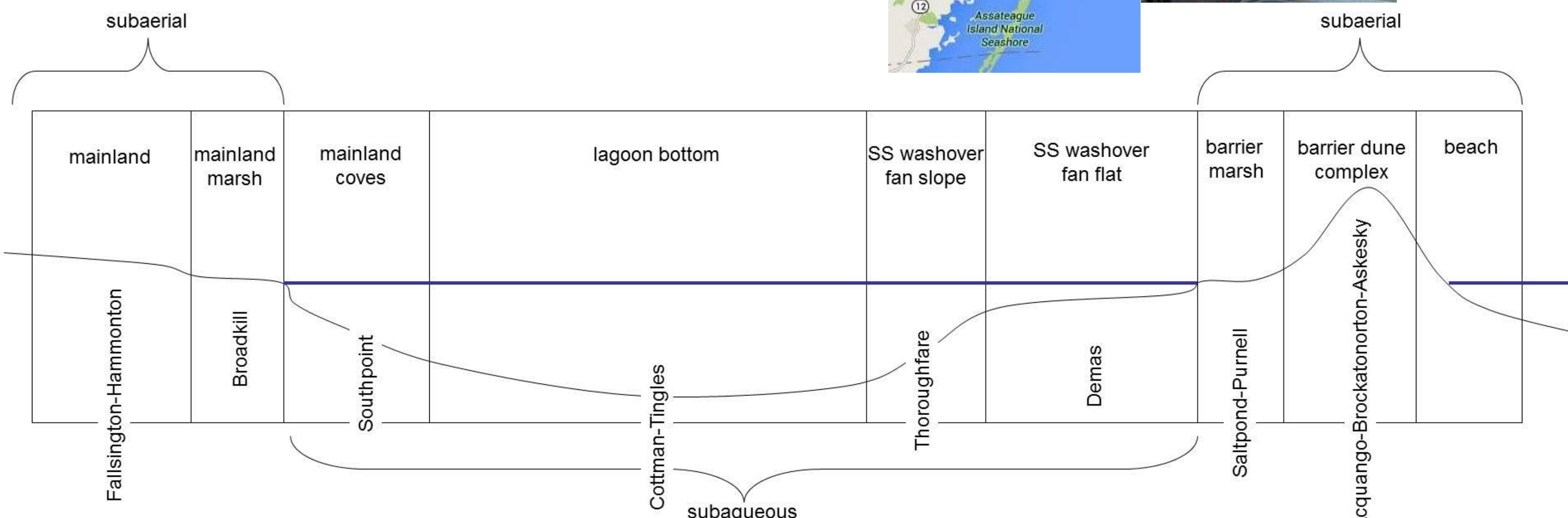
Other Early Developments and Studies

- Students of **Dr. Mary Collins** at the University of Florida
  - **Larry T. (Rex) Ellis** (2006)
    - Dissertation - interactions of sea grasses with SAS, Cedar Key
  - **Kelly Fischler** (2006)
    - SAS and seagrass in a recently constructed habitat in the Indian River Lagoon
  - **Tom Saunders**
  - Collaborating with **Wade Hurt** – NRCS and UFL

- Student of Pat Drohan (Penn State)
  - Emilie Erich (2009-2010) Freshwater subaqueous soils

Other work in DE and MD (now available on WSS)

- Cary Coppock (2003)
  - Rehoboth Bay (8000 Acres)
- Danielle Balduff (2007)
  - Chincoteague Bay (40,000 Acres)



Other NRCS Efforts

- RI and CT; Jim Turrene, Maggie Payne, Rob Tunstead; Debbie Surabian, Donald Parizek, Shawn McVey
  - Mooring interpretations (2005-2007)
  - MapCoast Partnership (2004 – present) this lead to mapping all of the RI coastal ponds, Narrow River, eventually other parts of Narragansett Bay

Other NRCS Efforts

- DE and MD; Phil King
  - Indian River Bay, Little Assawoman Bay

Other NRCS Efforts

- Yiyi Wong and Rich Shaw
  - Jamaica Bay, NY

Locating Potential Restoration Sites for Zostera marina L. (eelgrass) Using a Subaqueous Soil Survey of Jamaica Bay, NY

Other important developments

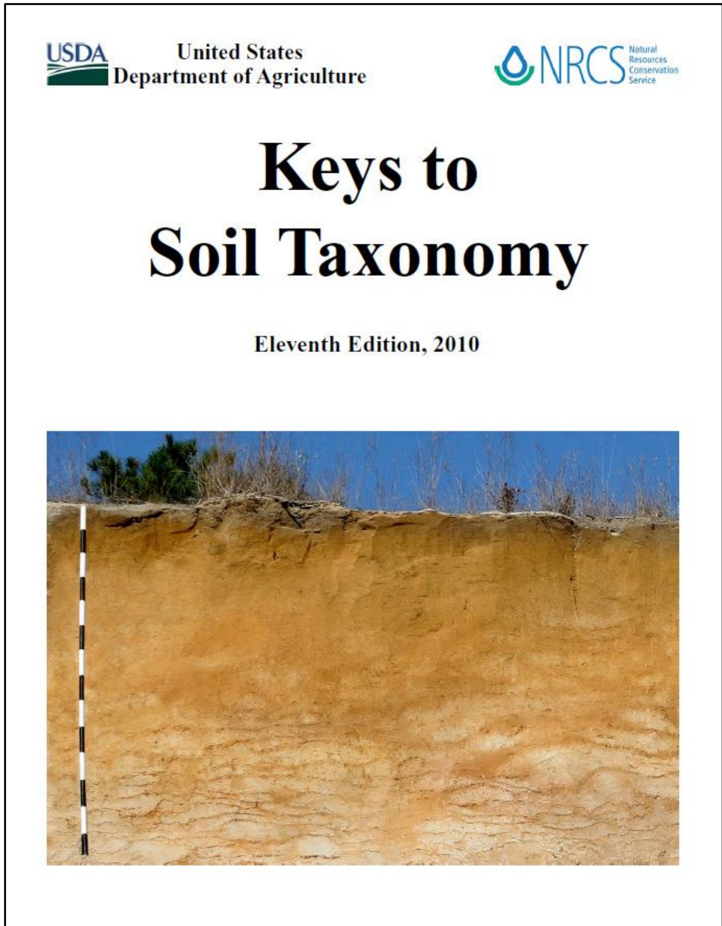
- Glossary of subaqueous landforms (2005)

- Incorporated into the ***Glossary of Landform and Geologic Terms*** - NRCS

Other important developments

- Modifications to Soils Taxonomy
  - Wass suborders of Entisols and Histosols
  - 11th Ed KST (2010)

From the Forward:
"One of the most significant changes in the eleventh edition is the addition of the suborders Wassents and Wassists for subaqueous Entisols and Histosols."



NATIONAL WORKSHOP ON SUBAQUEOUS SOILS

July 14-18, 2003

Georgetown and Rehoboth Bay, DE

Goals   Classroom Topics   Field Sessions   Registration Info

Weekly Schedule

WORKSHOP LEADERS:

Martin C. Rabenhorst - Professor of Pedology, University of Maryland
Philip King - Soil Scientist, Georgetown, Delaware
Mark Stolt - Associate Professor of Soil Science, University of Rhode Island
Laurie Osher - Assistant Professor of Soil and Water Quality, University of Maine

Download Brochure (PDF)   *What to Bring*   *Location*   ***Download Registration Form (MS Word)***

Workshop Sponsors

UNIVERSITY OF MARYLAND   University of Rhode Island   THE UNIVERSITY OF MAINE   NRCS Natural Resources Conservation Service

1st National Workshop - Topics Covered

- THEORY
  - Introduction to subaqueous soils (Rabenhorst)
  - Processes of subaqueous soil formation (Rabenhorst)
  - Overview of subaqueous soil horizonation and description (Stolt)
  - Introduction to subaqueous soil survey (King)
  - Coastal Processes - Geology and Geomorphology (Kelvin Ramsey, DE Geol. Surv.)
  - Subaqueous Landforms (Stolt)
  - Subaqueous Terrain Analysis (Osher)
  - Subaqueous Soil-Landscape Models (Stolt)
- METHODOLOGY
  - Bathymetric data collection (Rabenhorst)
  - Post processing of bathymetric data (Rabenhorst)
  - Tide models and normalization of data (Osher)
  - Using ***Arcview*** and ***Surfer*** to create basemaps from bathymetric data (John Inkster, Geo-ink-Graphics)
  - Handling and laboratory analysis of subaqueous soil samples (Rabenhorst/Stolt)
- INTERPRETATIONS
  - Benthic/Estuarine Ecology (Ben Anderson, DE DNREC)
  - Subaqueous Soil Taxonomy and Interpretations (Stolt/King)
- CASE STUDIES
  - A case study in Rehoboth Bay, DE – (Coppock)
  - A case study in Sinapuxent Bay, MD (Rabenhorst/King)
  - A case study in Ninigret Pond, RI (Stolt/Bradley)
  - A case study in a Maine estuary (Flannagan/Osher)


UNC

2nd National Workshop on Subaqueous Soils
August 8-13, 2010   Kingston, RI

2nd National Workshop on Subaqueous Soils

August 8 to 13, 2010, Kingston, RI
Schedule Matrix

Click HERE to Download the Field Booklet

	Sunday August 8th	Monday, August 9th	Tuesday, August 10th	Wednesday, August 11th	Thursday, August 12th	Friday, August 13th
Morning	Travel Day	Lecture Session 1	Field Session 2 Group 1: Pedon Descriptions Group 2: Freshwater SAS Group 3: Bathy and Landscapes Group 4: Vibracoring	Field Session 3 Group 1: Freshwater SAS Group 2: Bathy and Landscapes Group 3: Vibracoring Group 4: Pedon Descriptions	Field Session 3 Group 1: Bathy and Landscapes Group 2: Vibracoring Group 3: Pedon Descriptions Group 4: Freshwater SAS	Travel Day
Afternoon		Field Session 1 Group 1: Vibracoring Group 2: Pedon Descriptions Group 3: Freshwater SAS Group 4: Bathy and Landscapes	Lecture Session 2	Lecture Session 3	Lecture Session 4	
Evening				Technical Field Tour/Social		

Group Session Information:

Pedon Descriptions - Group Leaders Mark Stolt and Martin Rabenhorst
At this session participants will review describing subaqueous soil pedons and collecting samples for laboratory analysis. Vibracore samples collected in the other session will be cut open and described using the methodology developed. Pedons will be sampled using field meters, bulk density sampling, and other methods to assist with classification. Each pedon will be entered in a pedon description form and classified to the series (if possible) level.

University of Rhode Island
UNIVERSITY OF MARYLAND
SOCIETY OF SOIL SCIENTISTS SNE
PENNSTATE
NRCS Natural Resources Conservation Service

2nd National Workshop on Subaqueous Soils

August 8 to 13, 2010
URI Coastal Institute, Narragansett , RI | **View Photos of the Workshop HERE**
Workshop Agenda and Topics – Click HERE for field schedule matrix | Click HERE to Download the Field Booklet.
Sunday, August 8, 2010
Travel day – folks should check into to lodging Sunday night to get early start Monday morning.
Monday, August 9, 2010
8:00 to 8:30 AM: Registration – Hazard Room, URI C
8:30 to 9:00 AM: Welcome to RI and overview of th
Scientist).
9:00 to 9:45 AM: Introduction to Subaqueous Soils:
9:45 to 10:30: The Coastal Zone Soil Survey of Rhod
Sediment (Jim Turenne).
10:30 to 10:45 AM: Break
10:45 to 11:30 AM: Overview of the geology of New
Geologist)
11:30 to 12:00 PM: Boating safety basics – rules of
12:00 to 1:00 PM: Lunch and travel to 1st field sessi
1:00 to 5:00 PM: Field Session 1.
Tuesday, August 10, 2010
8:00 to 12:00 PM: Field session 2 – meet at Coastal
12:00 to 1:00 PM: Lunch and Return to Classroom.
1:00 to 1:30 PM: Properties and Characterization o
1:30 to 2:00 PM: Developments in soil taxonomy, la
2:00 to 3:00 PM: Benthic geologic mapping and geo

3:00 to 3:15 PM: Break
3:15 to 3:45 PM: Geomorphology of submerged lands (Phil Schoeneberger)
3:45 to 4:15 PM: NASIS data elements, new amendments, data collection/entering (Debbie Surabian).
4:15 to 5:00 PM Case Study: Freshwater research, mapping, and needs - Jonathan Bakken | Pennsylvania Freshwater Study - Patrick Drohan.
5:00 to 6:00 PM: NASIS discussions - optional, set up for intere

Wednesday, August 11, 2010

8:00 to 12:00 PM: Field session 3 meet at Coastal Institute at 8
12:00 to 1:00 PM: Lunch and Return to Classroom.
1:00 to 1:30 PM: Shellfish and Aquaculture (Dale Leavitt, Roge
1:30 to 2:30 PM: Subaqueous Soil Interpretations (Mark Stolt).
2:30 to 4:30 PM: Travel to Ft. Getty – Save the Bay's Eelgrass re
Furguson) Save the Bay
4:30 to 5:00 PM: Open discussions with group at pavilion.
5:00 to 8:00 PM: Dinner Social.

Thursday, August 12, 2010

8:00 to 12:00 PM: Field session 4 meet at Coastal Institute at 8
12:00 to 1:00 PM: Lunch and Return to Classroom.
1:00 to 2:00 PM: Bathymetric data, GIS analysis and landscape
Bradley
2:00 to 2:30 PM: Benthic ecology and Biology of shallow subtic
2:30 to 3:00 PM: NOAA Restoration efforts in the Coastal Zone
3:00 to 3:15 PM: Break
3:15 to 4:00 PM: Case Study: Mapping Chincoteague Bay in Ma
4:00 to 4:30 PM: Coastal Marine Classification Systems and the
4:30 to 5:00 PM Open - discuss expanding work, Q/A, method

Friday August 13

End: Travel Day Back Home

Fluidity Class Field Test (highly fluid)

The new millennium

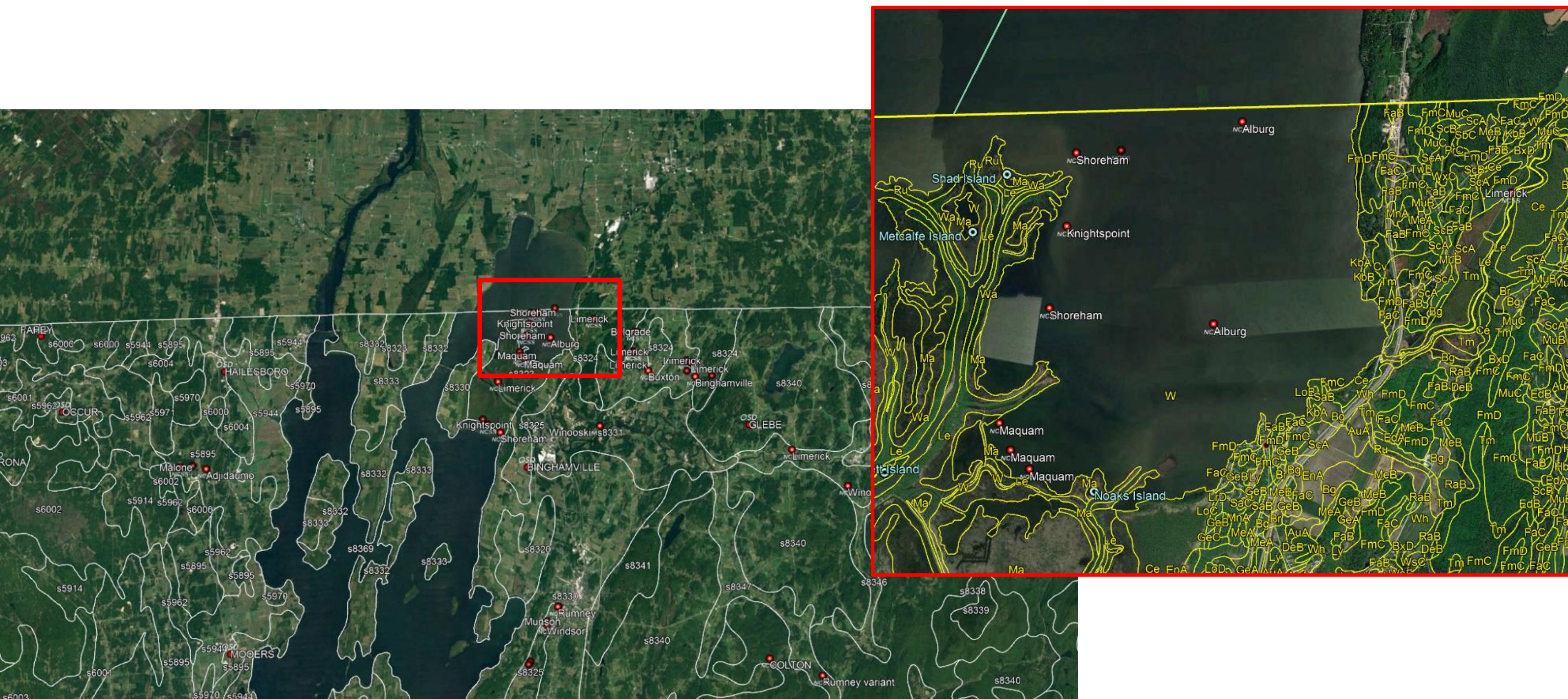
(the second decade, 2011 – present)

M. H. Stolt and his students – Southern New England

- Brett Still (2016)
  - shellfish aquaculture
  - coastal acidification,
  - coastal pond multiple use policy based on soil interps, regulations
- Chelsea Duball (2017)
  - soil changes/ benthic infauna and water quality
  - relative to 3 to 20 years of shellfish aquaculture
- Andy Paolucci (2017)
  - ESD’s
  - effects of dredging--mostly on benthic infauna;
  - part of the work done by Bianca Peixoto in her senior thesis

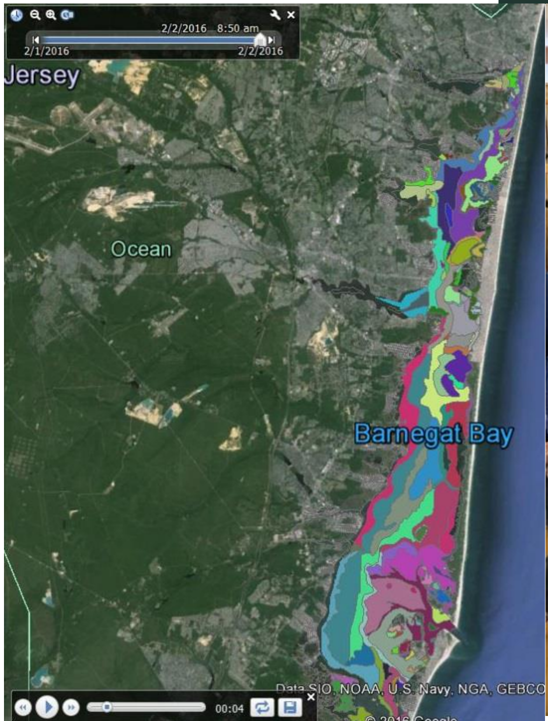
Other NRCS Efforts

- Tom Villars and Vermont NRCS
  - *Mapping the Subaqueous Soils of Lake Champlain's Missisquoi Bay Using Ground-Penetrating Radar, Digital Soil Mapping and Field Measurements*
  - Zamir Libohova, James Doolittle, Reed Sims, Thomas Villars, and Larry T. West (2014)



Other NRCS Efforts

- URI and CT NRCS mapped Thimble Islands, CT (2014-15).
    - Long Island Sound; (much of the work was done by Brett Still and Andy Paolucci at URI)
- NJ; Rob Tunstead
    - – Barnegat Bay



Other important developments

- Incorporation of SAS section in Ver. 3.0, Field Book for Describing and Sampling Soils
  - *Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.*

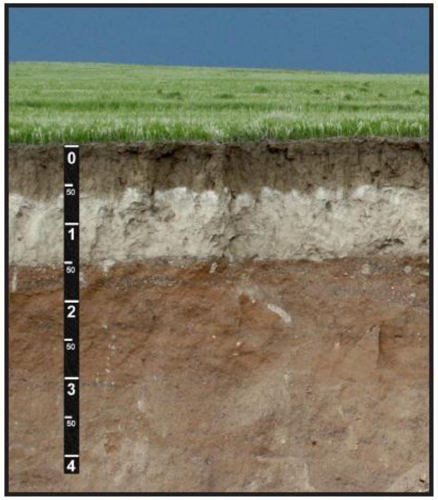
SUBAQUEOUS SOILS (SAS) DESCRIPTION

S. McVey, P.J. Schoeneberger, J. Turenne, M. Payne, and D.A. Wysocki, NRCS, and M. Stolt, URI

DISCUSSION: Permanently submerged mineral or organic substrates covered by relatively shallow water display recognizable soil morphology and meet Simonson's soil formation (1959) model in that chemical and physical additions, losses, transformations, and translocations created the morphology. Such soils are informally known as "subaqueous soils." Kubiena (1953) proposed a comprehensive classification that included subaqueous soils. More recently, Demas (1993, 1998) and Demas et al. (1996) reintroduced subaqueous soil concepts in the U.S. Recent reviews (Stolt and Rabenhorst, 2012; Soil Survey Staff, 2012d) provide comprehensive treatment of subaqueous soil settings and processes. Payne (2010) presents operational methods for subaqueous soil inventory. The 11th edition of *Keys to Soil Taxonomy* (Soil Survey Staff, 2010) presently recognizes subaqueous soils as suborders of Entisols and Histosols (Wassents and Wassists) that meet the criterion of "a positive water potential at the soil surface for more than 21 hours of each day in all years."

The description of subaqueous soils is similar to that of terrestrial soils but differs in several important ways. Many subaqueous soil parameters (color, texture, RMF, etc.) fit traditional descriptive conventions outlined in this Field Book. The unique setting and morphology of subaqueous soil coupled with its recent scientific import warrant a separate section that presents all descriptors in one place. This section includes description forms and subaqueous soil description examples. (***NOTE:*** The most prevalent subaqueous settings are coastal marine or brackish estuarine. The descriptive

Field Book for Describing and Sampling Soils



Version 3.0

National Soil Survey Center
Natural Resources Conservation Service
U.S. Department of Agriculture

September 2012

Other important developments

- Chapter 10 in Soil Survey Manual (2017) on Subaqueous Soil Survey
  - *Stolt, Mark, James Turenne and Maggie Payne. 2017. Subaqueous Soil Survey. In C. Ditzler, K. Scheffe, and H.C. Monger (eds.) Soil survey manual, USDA Handbook 18, Government Printing Office, Washington, D.C., pp. 505–523.*
- And incorporated throughout
  - e.g. Chapter 8 - Interpretations

CHAPTER 10

Subaqueous Soil Survey

By Mark Stolt, University of Rhode Island, and James Turenne and Maggie Payne, USDA-NRCS.

Introduction

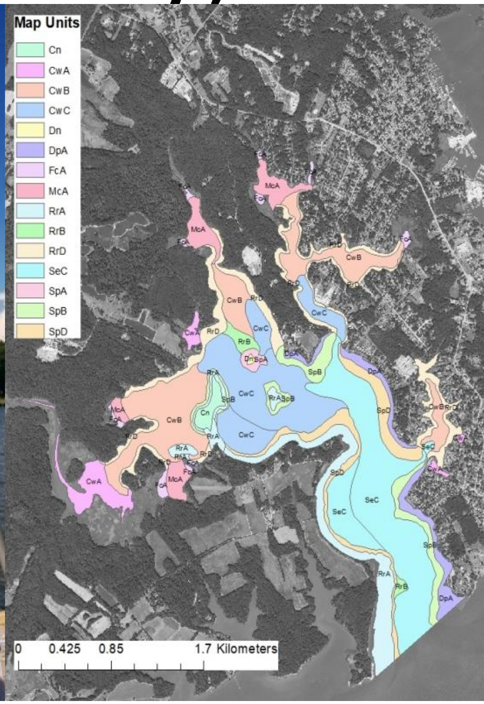
Subaqueous soils differ from subaerial, or terrestrial, soils by having perennial water on the soil surface. These soils occur in shallow freshwater and marine environments, such as ponds, lakes, and the subtidal areas of estuaries and tidal embayments. The Soil Survey Staff (2014) defines "shallow" as approximately 2.5 m. At depths greater than 2.5 m, sunlight is typically attenuated and submerged aquatic vegetation (SAV) is typically absent. In especially clear waters, however, this depth may be much greater. Thus, for interpretive purposes, mapping is typically done to depths of 5 meters of water. Areas with extreme tidal ranges are also included as subaqueous soils even though they may be exposed for an hour or two during a neap tide or similar event. Subaqueous soils occur on a range of subtidal and limnic landforms, such as flood-tidal deltas, washover fans, and lake beds (Schoeneberger and Wysocki, 2012; USDA-NRCS, 2016). These soils are currently classified in the Histosol and Entisol orders of Soil Taxonomy (Soil Survey Staff, 2014).

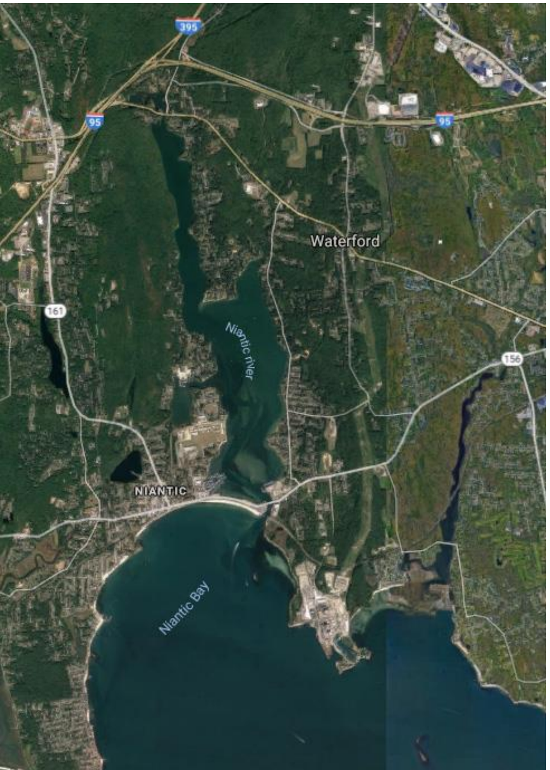
Occurrence

Subaqueous soils occur worldwide, except in the driest inland areas where water does not pond permanently to form lakes or ponds. In coastal areas, these may be the most extensive soils on the landscape. For example, Rhode Island has approximately 700,000 acres of subaerial soils. If the area of subaqueous environments having water depths of less than 5 m are included, the total area of soils would almost double.

Current Activities (future history)

- Chesapeake Bay (Maryland)
  - Doctoral student Barret Wessel
  - Developing and testing soil landscape models
    - Rhode River
    - West River
  - Evaluation of subaqueous landscape stability in CB subestuaries
  - Integration with aquaculture activities





- Niantic Bay and River (Connecticut)
  - Thomas Privott (MS student)
  - understanding aeric soils and ground discharge in coastal lagoons and rivers

Current Activities (future history)

2018 Coastal Zone Soil Survey (CZSS) Work Planning Workshop

Savannah, GA – January 8th – 12th, 2018

Monday, January 8th, 2018 – Travel Day

Tuesday, January 9th, 2018

8:00 am – 8:30 am	Registration / Coffee Reception
8:30 am – 8:45 am	Welcome and Opening Remarks
	** Dr. David Lindbo*
8:45 am – 9:00 am	Work Planning Workshop – Why are we here?
	What it takes to get started and why / what are the expectations for this week / we can all agree to continue to work cooperatively in some prioritized fashion –
	** Jim Turenne*
9:00 am – 9:30 am	Introduction of Participants - All
9:30 am – 10:00 am	Subaqueous Soil Survey History – Past, Current, and the Future
	** Dr. Martin Rabenhorst*
10:00 am – 11:00 am	Coastal Zone Soil Survey (CZSS) Introduction
	Jim Turenne, Maggie Payne, (models of excellence) and Rob Tunstead (data deficiencies)