# Introduction to Subaqueous Soils: History and Background

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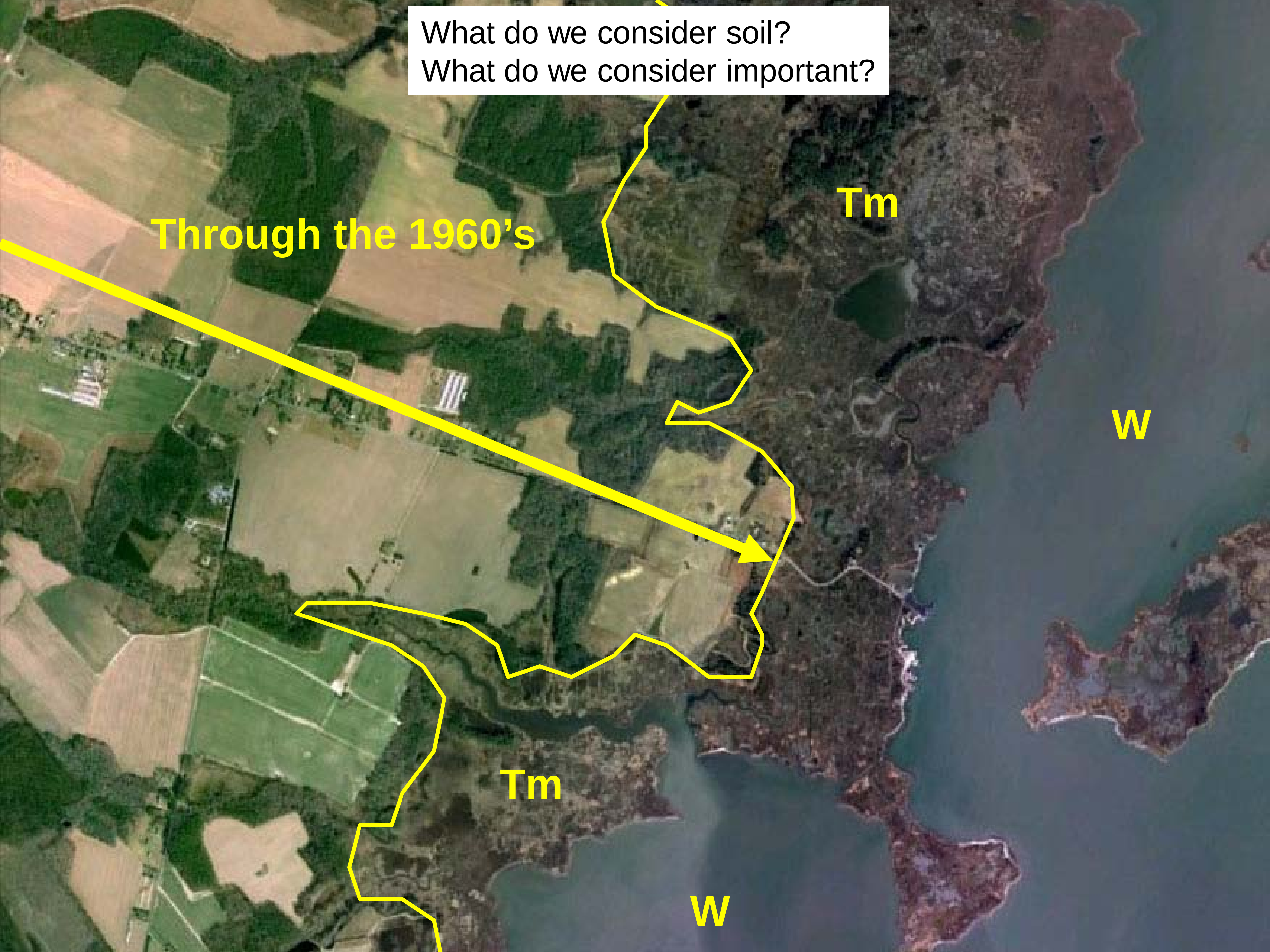
What do we consider soil?
What do we consider important?
Through the 1960's
Tm
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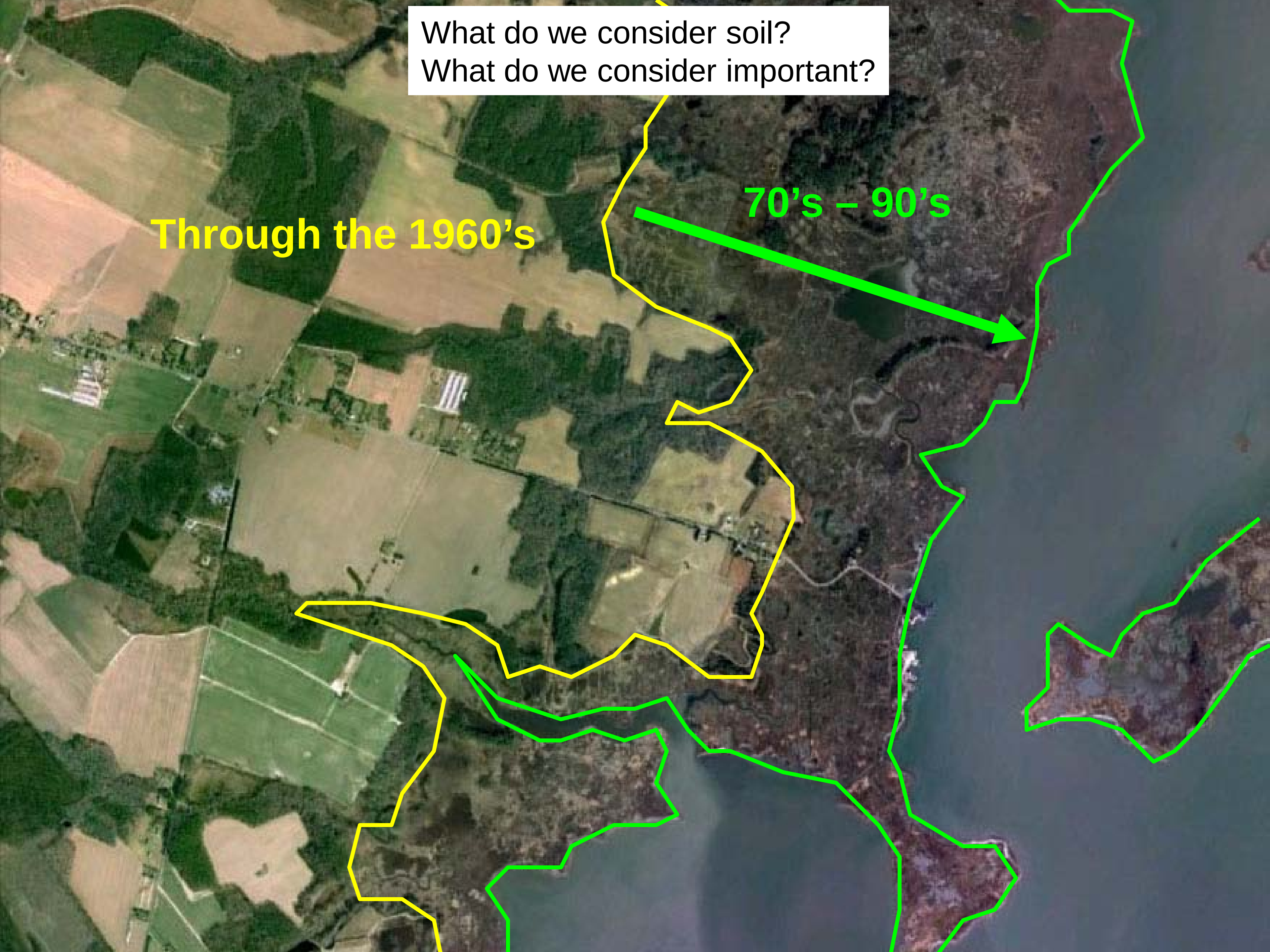
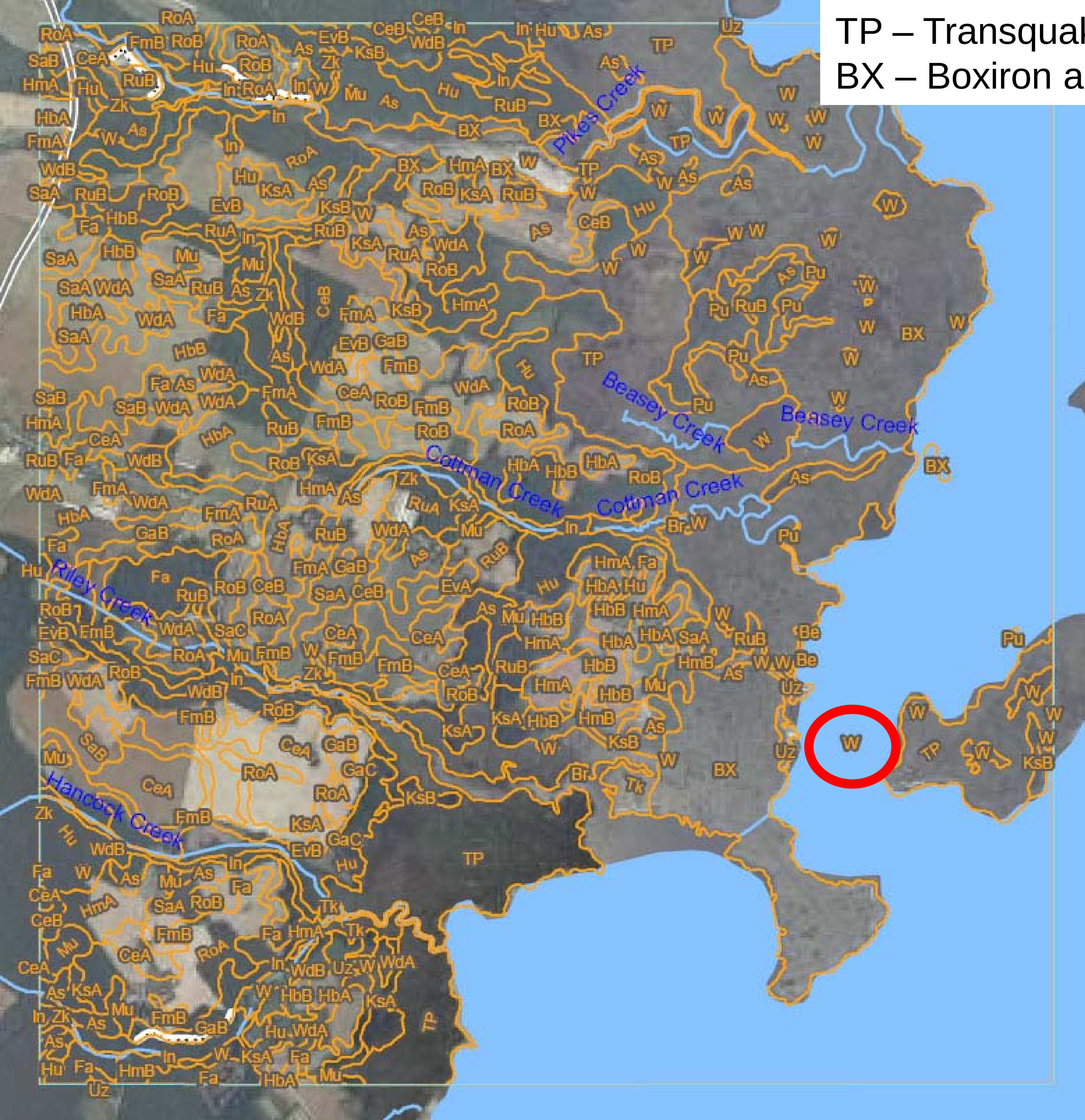
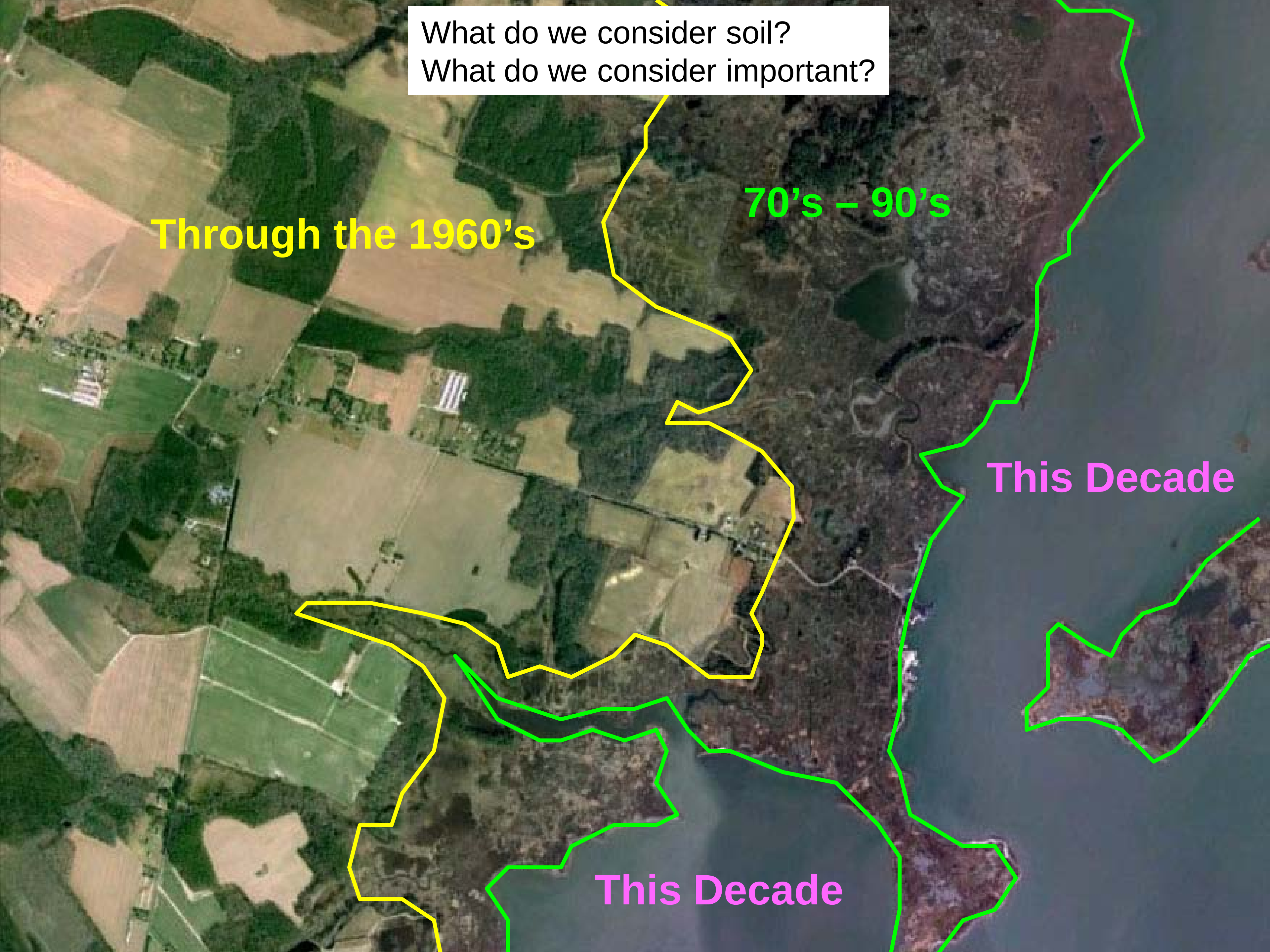
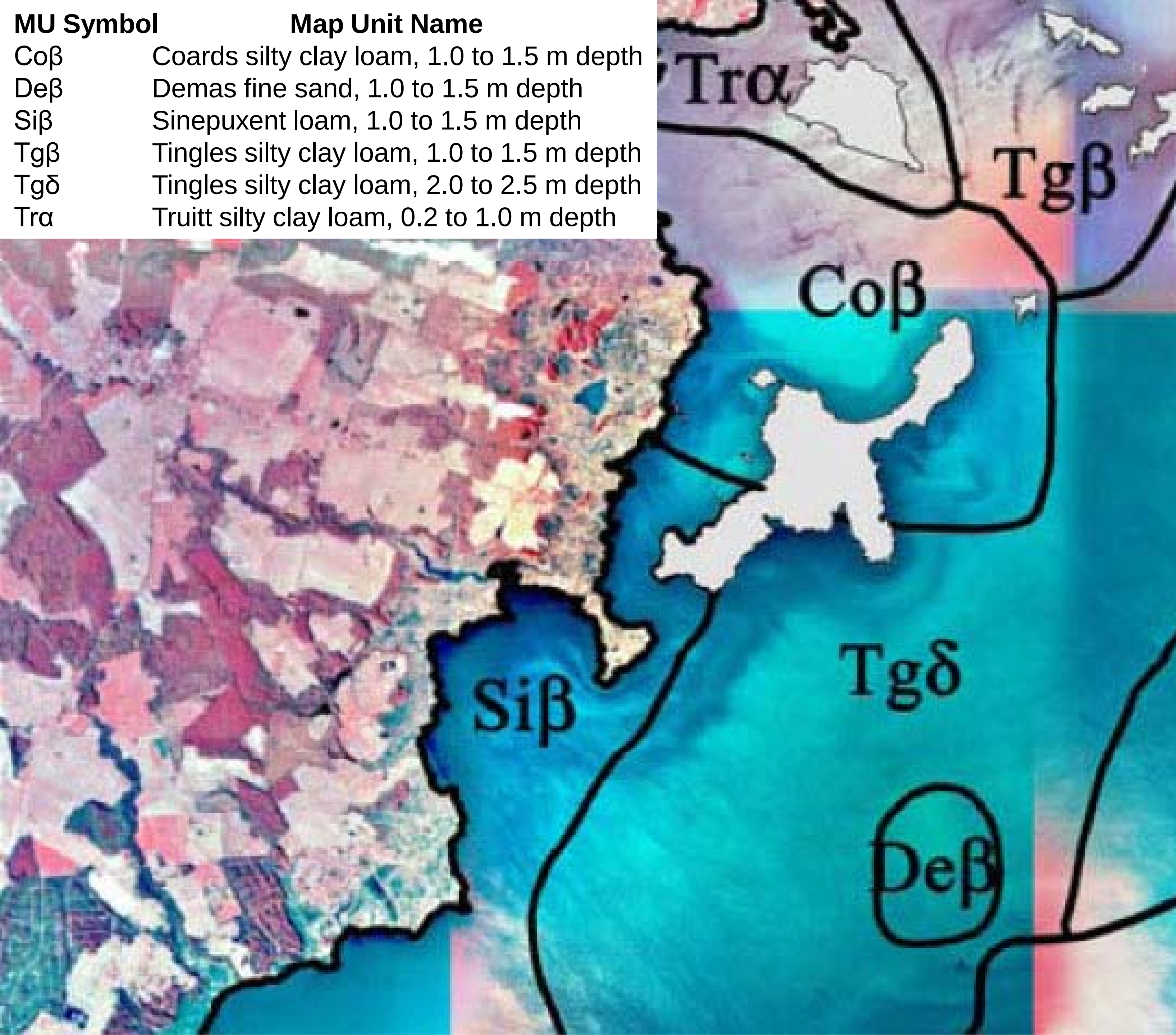

What do we consider soil?
What do we consider important?
Through the 1960's
70's – 90's

TP – Transquaking and Mispillion Soils
BX – Boxiron and Broadkill Soils




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

| MU Symbol | Map Unit Name |
|---|---|
| Coβ | Coards silty clay loam, 1.0 to 1.5 m depth |
| Deβ | Demas fine sand, 1.0 to 1.5 m depth |
| Siβ | Sinepuxent loam, 1.0 to 1.5 m depth |
| Tgβ | Tingles silty clay loam, 1.0 to 1.5 m depth |
| Tgδ | Tingles silty clay loam, 2.0 to 2.5 m depth |
| Trα | Truitt silty clay loam, 0.2 to 1.0 m depth |



# How did we get here today?

# von Post, 1862

## (according to Hansen, 1959)

- First nomenclature for subaqueous soils
- Introduced the terms “gyttja” and “dy” to describe limnic sediments.
- Gyttja soil
  - a “coprogenic formation consisting of a mixture of fragments from plants, numerous frustules from diatoms, grains of quartz and mica, siliceous spicules from Spongilla, and exoskeletons from insects and crustaceans”
  - “organic rich”
- Dy soil
  - consisted of the same constituents as gyttja, but in addition had “brown humus particles”
  - “organic poor”
- Although his concept of “soils” differed from the current one, he was, nevertheless, the first to use this terminology

# Kubiëna (1953)

- Proposed a comprehensive soil classification system for Europe that included all soils "including the neglected sub-aqueous soils."
- Separated the "sub-aqueous" soils into two main categories:
  - True subaqueous soils always covered with water that do not form peat
  - Peat forming soils - mostly Histosols in emergent wetlands, bogs, or forests (not subaqueous by current understanding)
- Terms developed by Kubiena
  - Not currently used in *Soil Taxonomy* or the World Reference Base
  - Therefore it is a difficult system to use in describing subaqueous soils.

# Kubiëna's Classification of Subaqueous Soils

| Subaqueous Soil Types | Interpretation |
|---|---|
| **Protopedon**<br>Chalk deficient Protopedon<br>Dystrophic lake iron Protopedon<br>Lake Marl Protopedon<br>Sea Chalk Protopedon | **Sediments without organic material accumulation** |
| **Dy** | **Muds low in organic matter and nutrients** |
| **Gyttja**<br>Limnic Gyttja<br>1. Eutrophic Gyttja<br>2. Chalk Gyttja<br>3. Oligotrophic Gyttja<br>4. Dygttja<br>Marine Gyttja<br>1. Schlickwatt Gyttja<br>2. Sandwatt Gyttja<br>3. Cyanophyceae Gyttja | **Organic rich muds, high in nutrients**<br>Lake (fresh water) sediments<br><br><br><br><br>Marine (saline water) sediments |
| **Sapropel**<br>Limnic Sapropel<br>Marine Sapropel<br>1. Mudwatt Sapropel<br>2. Diatomwatt Sapropel | **Dark colored sediments rich in organic matter**<br>Lake (fresh water) sediments<br>Marine (saline water) sediments |

# Kubiëna (1953)

- Kubiena also introduced horizonation of the sub-aqueous soil profiles.
  - (A)C - soils that do not have a distinct humus layer (an A horizon)
  - AC - those that do have a distinct humus layer
  - AG - those with a humus layer underlain by a gleyed horizon
- Although Kubiena was the first to develop a classification system for  subaqueous soils, there is no evidence that this classification system is currently in use anywhere.

# Muckenhausen (1965)

- Proposed a soil classification system for FRG (West Germany)
  - based on Kubiena’s (1953) work.
- He described Subhydric soils and included four types.

| Class | Types |
| --- | --- |
| Subhydric soils | I Protopedon |
| | II Gyttja |
| | III Sapropel |
| | IV Dy |

# Ponnamperuma (1972)

- Use the term "soil" to describe the uppermost layers of unconsolidated sediments of rivers, lakes, and oceans, because:
  - 1) they were formed from soil materials
  - 2) pedogenic processes were occurring
  - 3) they contained OM and organisms
  - 4) subaqueous soil bacteria were similar to those found in subaerial soils
  - 5) soil horizons were present
  - 6) there were variations in texture, mineralogy, and OM content

# 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


- NRCS – Soil Survey Project Leader
- Pioneer in Subaqueous Soils
- USDA - Secretary's Honor Award for Scientific Research
- SSSA - Emil Truog Award for outstanding contribution to Soil Science through the Ph.D. thesis (1999)
  - *presented by the SSSA*
- Early concept paper "Submerged soils: a new frontier in soil survey." Soil Survey Horizons (1993)

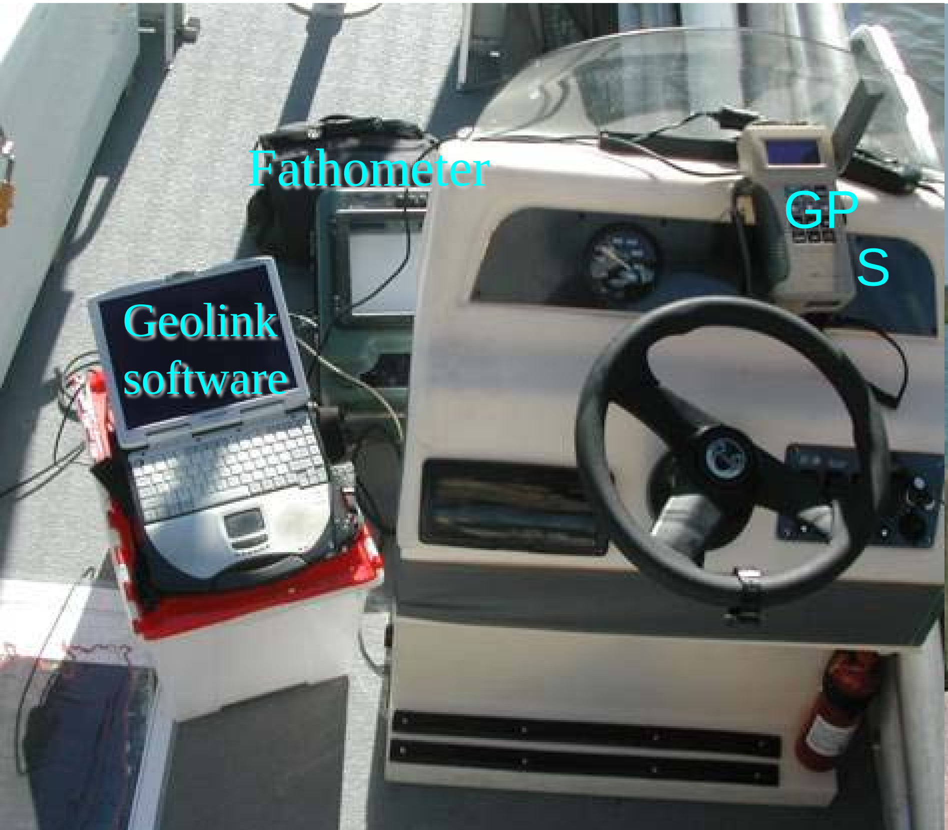
## The Challenge of Subaqueous Soil Investigations

- How does one view or evaluate topography or landscapes here? – the “bathymetry problem”
- How does one observe, describe or sample soils here?

# Demas and Colleagues addressing the bathymetry problem

- Had access to reasonably good quality CIR photography
- However, under ideal conditions, could only see about 1 meter below the water surface.


- Demas (starting in 1996) joined a research grade fathometer with a real time GPS while at the same time recording tide levels to permit correction.
- Were able to develop a high quality bathymetric DEM for shallow water estuaries.  When joined to areal photography, permitted the identification of subaqueous landforms in a manner analogous to the subaerial landforms



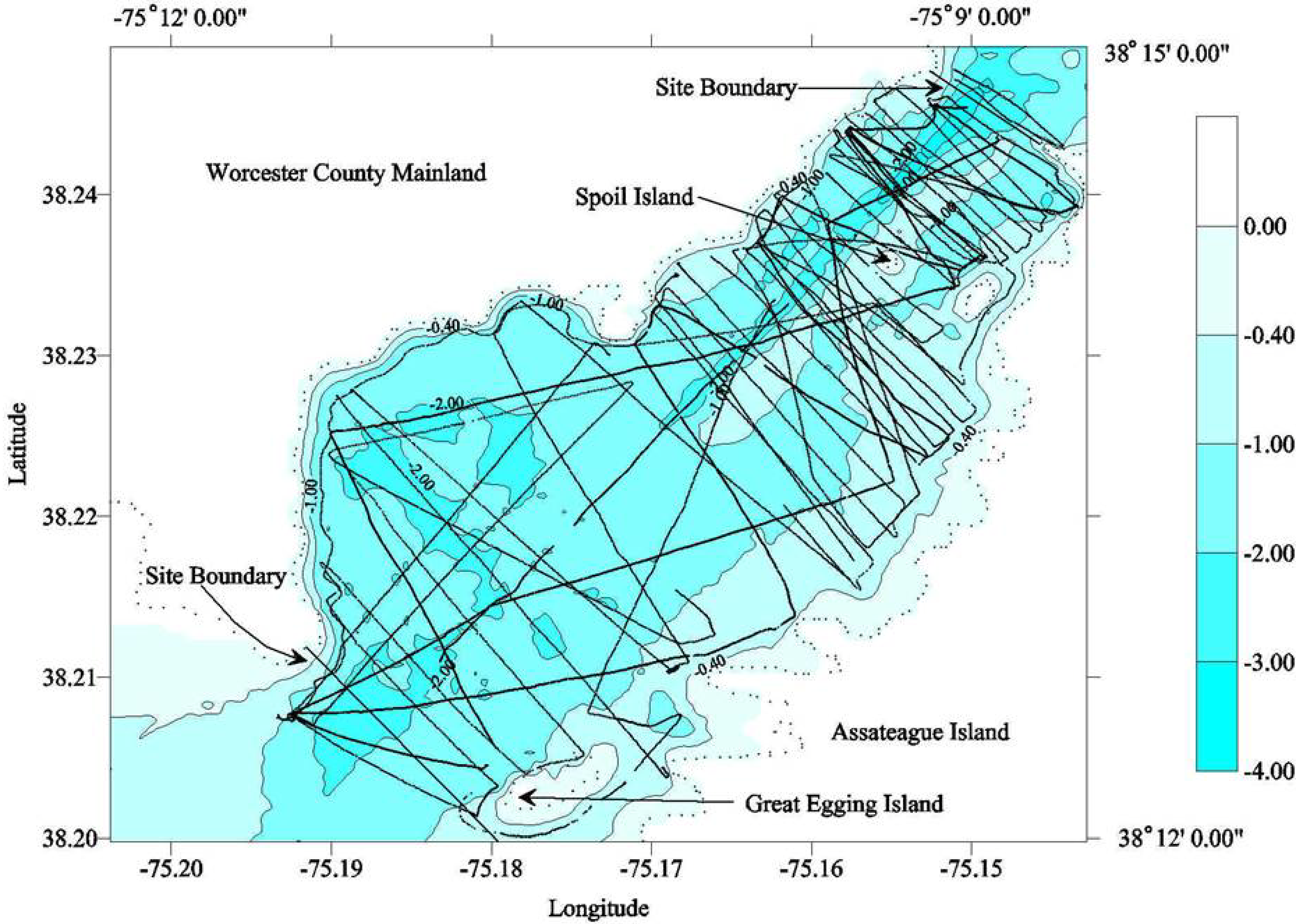
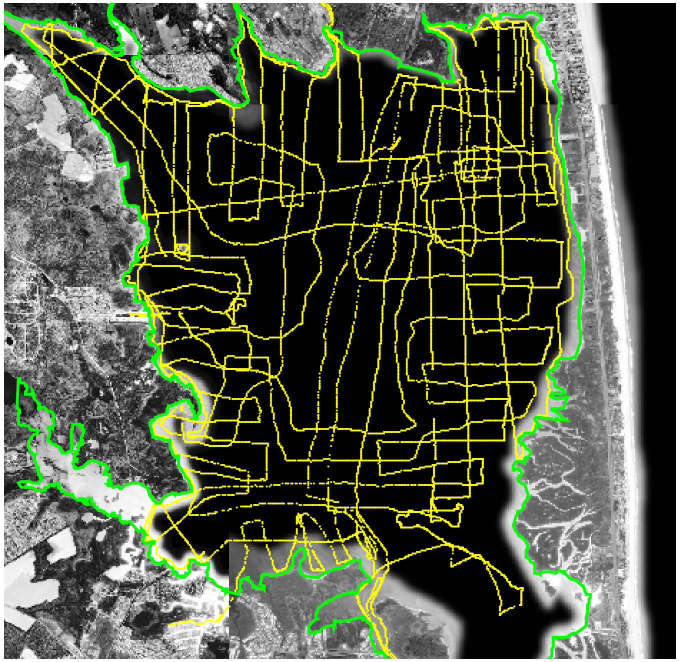




Figure 3-2. Location map of bathymetric runs in Sinepuxent Bay (depth in meters below MSL). Distance between successive readings was approximately 10 m.

… to develop a high quality bathymetric DEM for shallow water estuaries.



Availability of bathymetry permits analysis of the landscape and recognition of landforms.

## Identification of Subaqueous Landforms

Based upon:

1) proximity to other landforms

2) shape of a landform

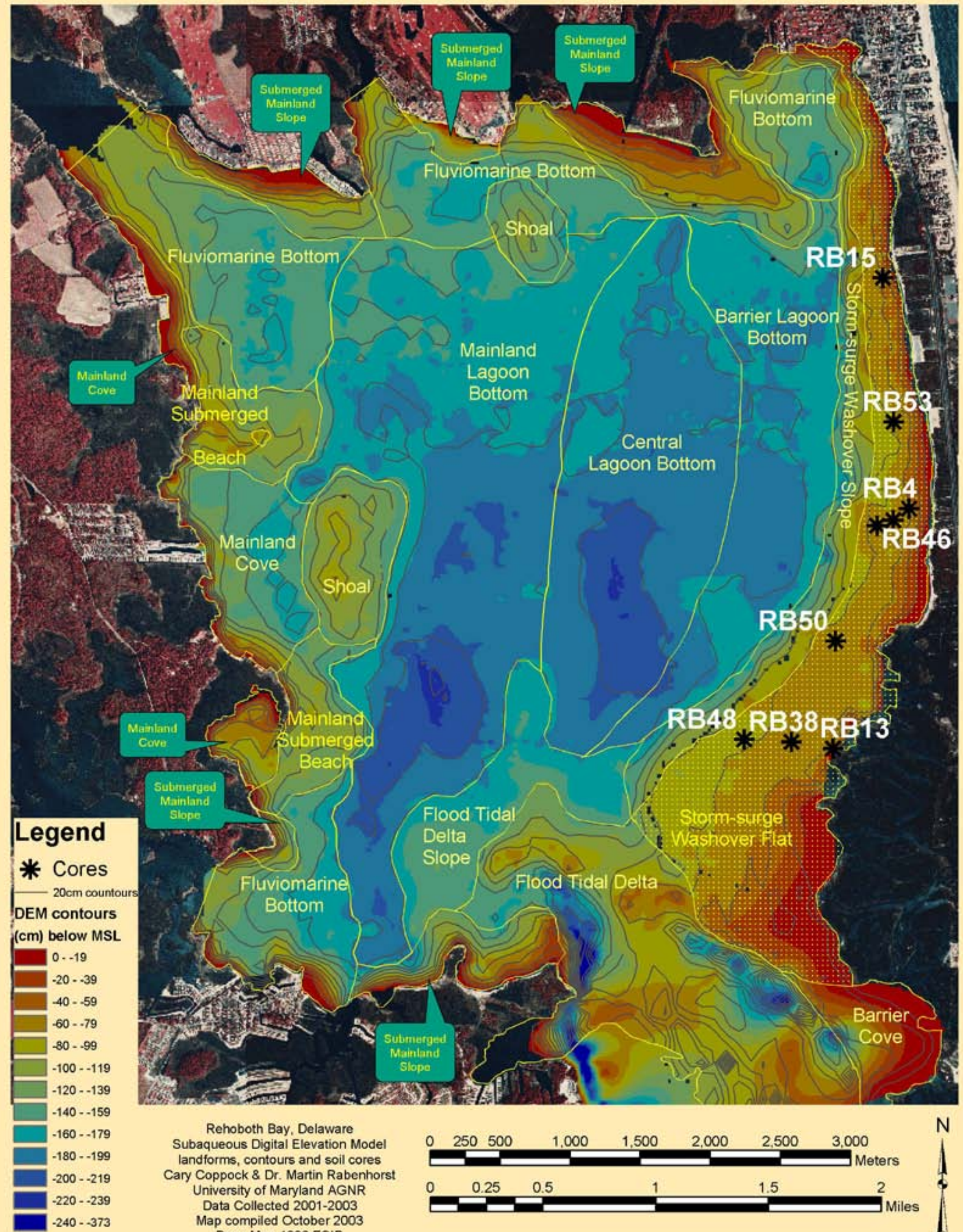
3) water depth

4) slope of subaqueous surface

Glossary of Terms for Subaqueous Soils, Landscapes, Landforms, and Parent Materials of Estuaries and Lagoons

http://nesoil.com/sas/glossary.htm

**Rehoboth Bay Landform Map with Bathymetry:**



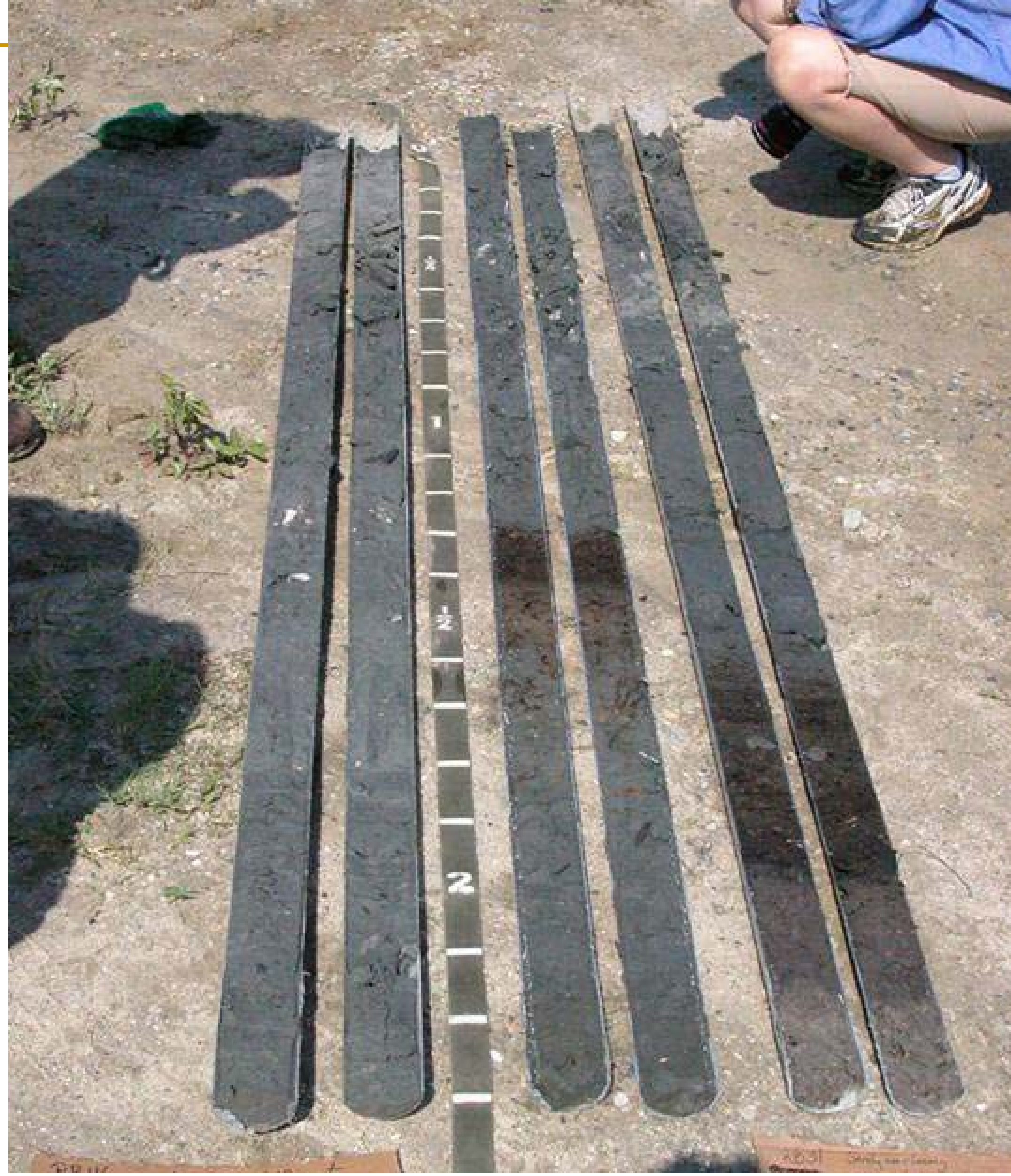

From C. Coppock MS Thesis Work

# Other early developments

- Collection and examination of cores (vibracoring, Macaulay auger, bucket auger)
- Recognition of soil horizons formed as a result of the generalized processes of additions, losses, transfers, and transformations.
- These soils could therefore be classified according to Soil Taxonomy

# Evidence for Pedogenesis and Horizon Differentiation

- Nature and distribution of Organic C
- Sulfide distribution
- Physical properties
- Soil color and other morphological properties



Obvious evidence of soil horizons in soils sampled in Indian River Bay, DE

# A proposal was submitted to modify the definition of soil, which resulted in….

- *Soil* .... is a natural body .... that occurs on the land surface, ... and is characterized by [either]
  - 1. ..... horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter *or*
  - 2. the ability to support rooted plants in a natural environment.....
- The upper limit of soil is the boundary between soil and air [or] shallow water, ...... [not]… too deep (typically more than 2.5 m) for the growth of rooted plants.
- The Green Light!

from *Soil Taxonomy 1999*

# Other Early Developments

## Application of Soil Taxonomy

- Typic Sulfaquents (co-lo; fi-si; s)
- Haplic Sulfaquents (co-lo)
- Typic Psammaquents
- Sulfic Fluvaquents (co-lo; fi-lo)
- Typic Endoaquents (co-lo)
- Terric Sulfihemist (fi-si)
- Terric Sulfisaprists (co-lo)
- Typic Halaquept (co-lo)

11 different taxonomic families recognized

# Other Early Contributions

- Proposal and establishment of official soil series for subaqueous soils
  - Trappe,
  - Whittington
  - Tizzard
  - Southpoint
  - Sinepuxent
  - Fenwick

(later renamed Demas)

LOCATION SOUTHPOINT MD

Tentative Series
GPD
11/2002

## SOUTHPOINT SERIES

MLRA(s): 153C, 153D
MLRA Office Responsible: Raleigh, North Carolina
Depth Class: Very deep
Drainage Class: Very poorly drained (permanently submersed)
Permeability: Moderately slow or slow
Index Surface Runoff: Negligible
Parent Material: Silty terrestrial tidal marsh sediments underlain by paleo-terrestrial organic deposits
Slope: 0 to 3 percent
Mean Annual Air Temperature: 56 degrees F.
Mean Annual Water Temperature: 57 degrees F.

**TAXONOMIC CLASS:** Fine-silty, mixed, subactive, nonacid, mesic Thapto-histic Sulfaquents

**TYPICAL PEDON:** Southpoint sand on a smooth 0.5 percent slope in a deep mainland cove under 4.2 feet of permanent estuarine water. (Colors are for moist soil.)

**Ag**--0 to 2 inches; black (N 2.5/0) sand; single grain; loose; 5 percent, by volume black (10YR 2/1) organic fragments; moderately alkaline; strongly saline; abrupt smooth boundary. (1 to 5 inches thick)

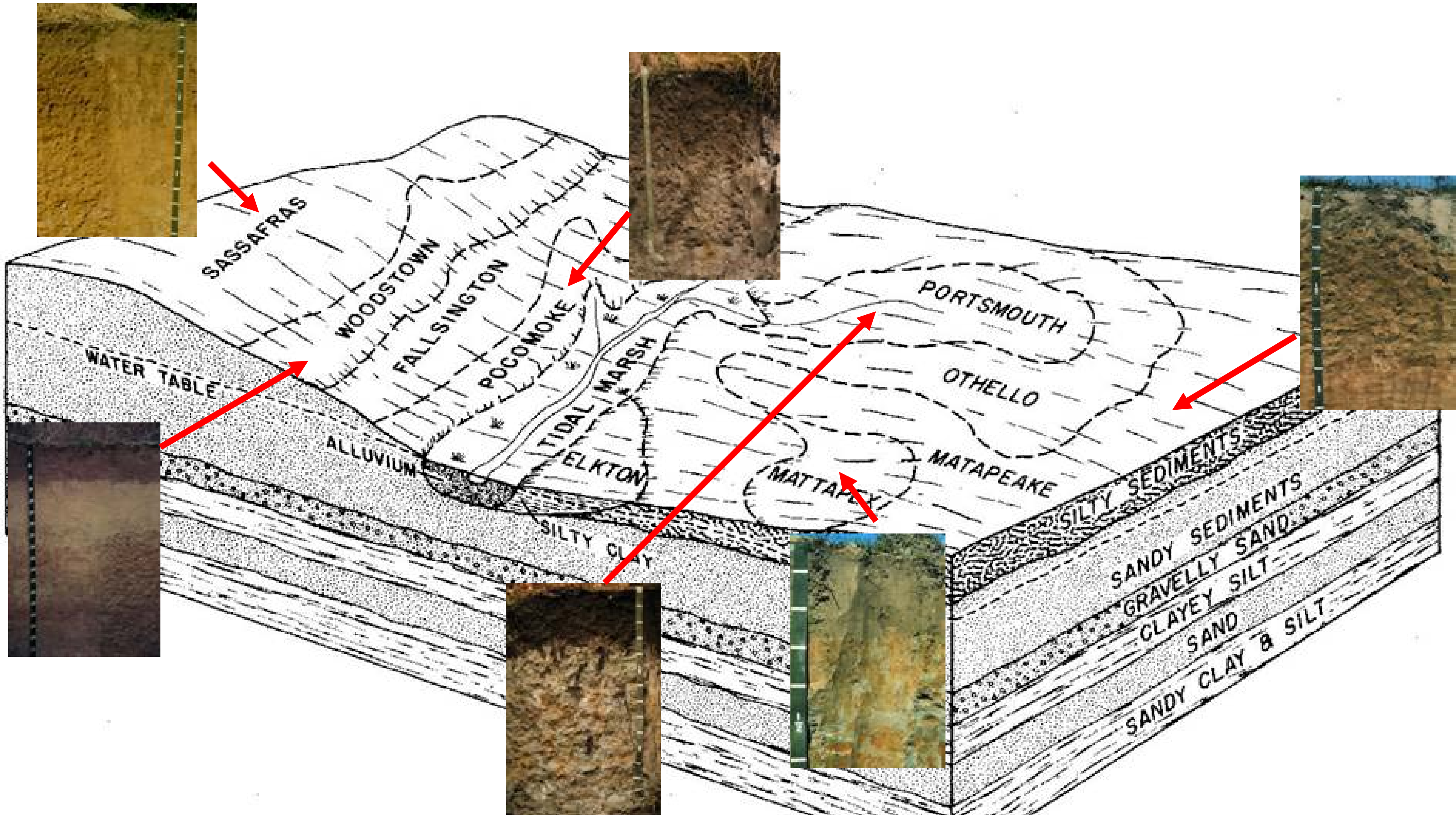
**Cg1**--2 to 4 inches; very dark gray (5Y 3/1) loam; single grain; loose; moderately alkaline; strongly saline; abrupt smooth boundary. (0 to 9 inches thick)

# Other Early Developments

- Thus far, mainly descriptive
- What about larger pedological concepts?

# Other Early Developments

- Observed that similar subaqueous soils occurred or formed on similar subaqueous landforms.  Suggested that a “soil-landscape” paradigm could be applicable in the subaqueous environment, as in the subaerial environment.

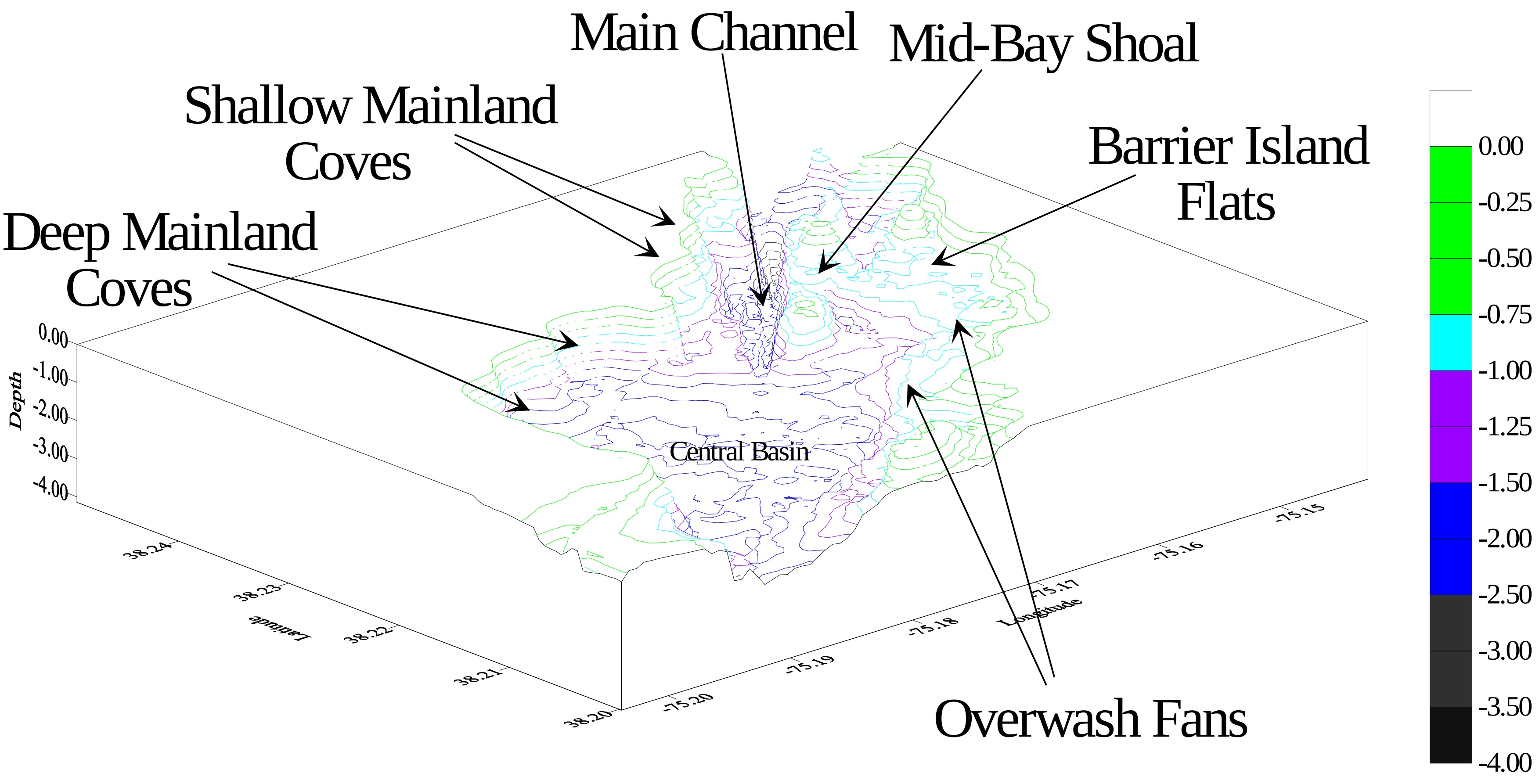



Conceptual Soil-Landscape Models Outer Mid-Atlantic Coastal Plain

# Other Early Contributions

Specific soil-landscape relationships began to be documented for the coastal lagoons of the Mid-Atlantic USA.

# Conceptualization of subaqueous landforms in Sinepuxent Bay

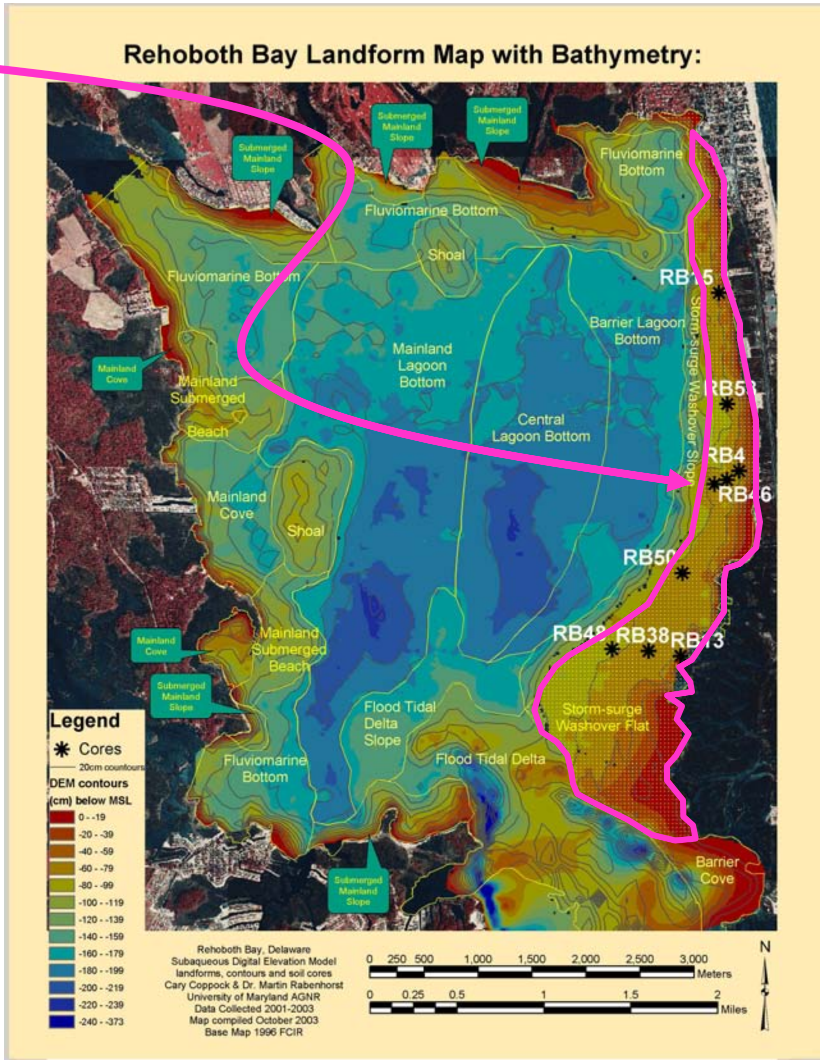


# Identification of particular soils with specific landforms

# Further development and Application of Soil Landscape Models

**Storm-surge Washover Fan Flat**

- Located adjacent to:
  - Barrier island
  - SSW fan slope
- Characterized by:
  - Water Depth < 1m
  - Slope: <0.1%
- Soils:
  - Mixed sandy mesic Haplic Sulfaquents
    - Dominantly sands in upper meter
    - pH drop with incubation (sulfidic mat)
    - n-value <0.7  (good bearing capacity)
    - No buried marsh surfaces within 2m



# The Sedimentary (ruling) Paradigm
**Folger (1972)**

$$Se = f\,(G, H, B)$$

Estuarine sediments (Se)

Source geology (G)

Hydrologic condition (H)

Bathymetry (B)

# Other Early Contributions

- Established a framework for understanding the genesis of subaqueous soils.

**Jenny's State Factor Equation**

$$S = f\,(C, O, R, P, T)$$

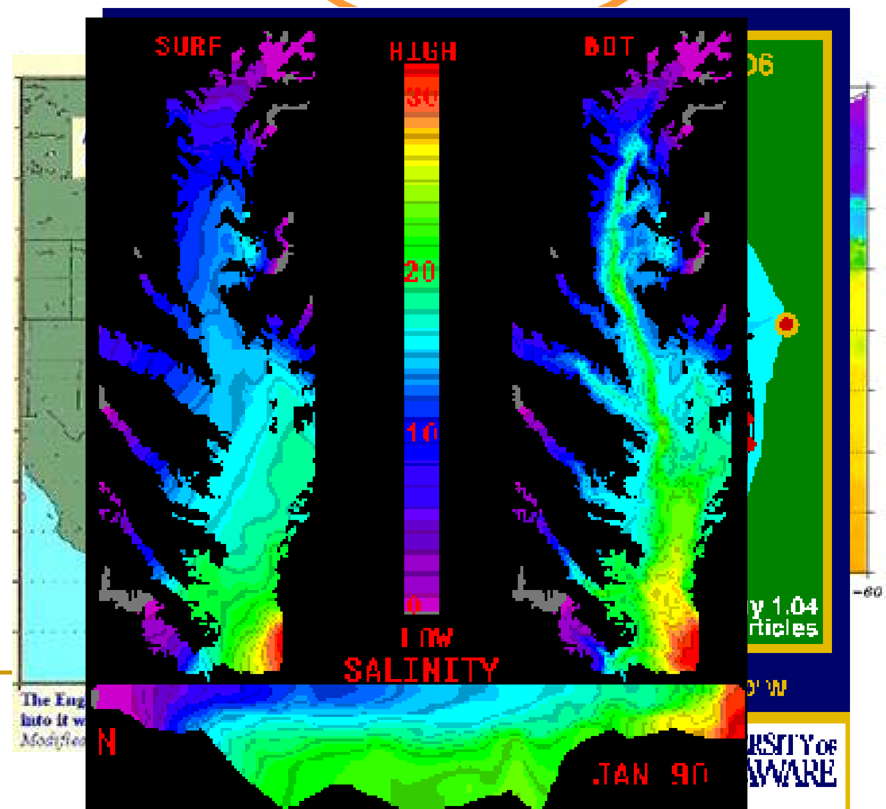
**Folger's Equation**

$$Se = f\,(G, H, B)$$

# State Factor Equation for Subaqueous Soils

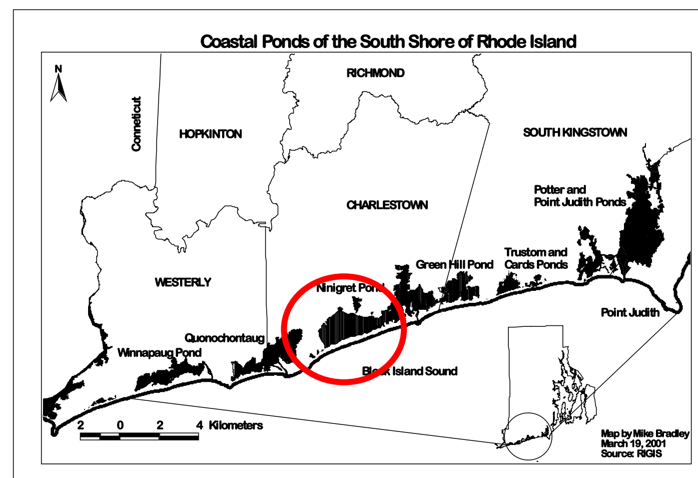
$$S = f\,(C, O, R, P, T) \qquad Se = f\,(G, H, B)$$

- $Ss = f\,(C, O, B, F, P, T, W, E)$
  - 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



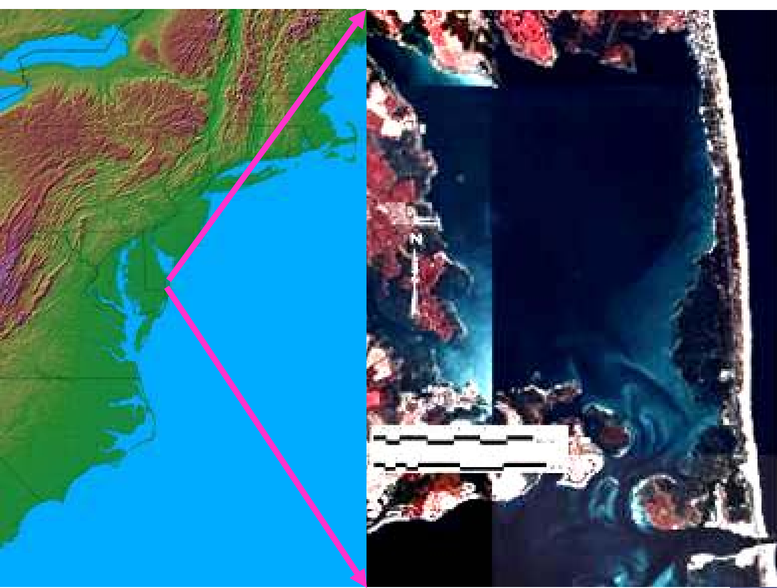
# Other Early Developments and Studies

- Mike Bradley and Mark Stolt
  - Ninigret Pond - coastal lagoon in RI
- Their bathymetric map - essentially the same as one created from 40 year old NOAA data
  - Suggests many subaqueous landforms change very little with time
  - Most of the change in the landscape was occurring in the tidal delta areas near the inlet to the lagoon.
- Work led to more formal descriptions of the soil-landscape relationships for the coastal lagoons in Southern New England
- Began work on terms for consistent use in naming subaqueous landforms (http://nesoil.com/sas/glossary.htm).
- Bradley also attempted to begin to develop some ecological interpretations for SAS in particular, interpretations for eelgrass (*Zostera marina*)  restoration.



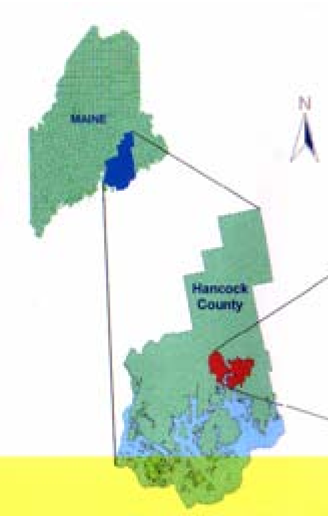
# Other Early Developments and Studies

- Cary Coppock
  - Graduate student UMD
  - Began work in Rehoboth Bay, Delaware which was significantly larger (3,300 ha) than subaqueous areas previously studied.
  - Refinement of soil landscape models for coastal lagoons
- Good collaboration with NRCS



# Other Early Developments and Studies

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





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

# Other Early Developments and Studies

- Under the guidance of Dr. Mary Collins at the University of Florida, Larry T. Ellis completed his doctoral research studying the interactions of sea grasses in SAS
- Kelly Fischler and Tom Saunders both conducted SAS research in Florida.
- Collaborating with Wade Hurt – NRCS and UFL

# Other Developments and Studies

- Danielle Balduff completed a study of SAS in Chincoteague Bay in Maryland which is an 18,000 ha coastal lagoon located behind the Assateague barrier island.
- Will describe more about that project later in the week.


- There have been many addition individuals working on subaqueous soils in a variety of locations – mostly along the coast
- New work beginning in fresh systems

# Summary of current or completed subaqueous soils projects (Stolt and Rabenhorst, 2010)

| Investigators | Affiliation | Location | Project Focus | Publications |
|---|---|---|---|---|
| Demas | UMD/NRCS | Sinepuxent Bay, MD | soil survey, methods, pedogenesis | Dissertation, Demas, 1993; Demas et al, 1996; Demas and Rabenhorst, 1998; 1999; 2001 |
| Bradley | URI | Ninigret Pond, RI | soil survey, eelgrass, methods | Thesis, Bradley and Stolt 2002; 2003; 2006 |
| Flannagan | UME | Taunton Bay, ME | soil survey | Thesis; Osher and Flannagan, 2007 |
| Jespersen | UME | Taunton Bay, ME | carbon accounting | Thesis; Jespersen and Osher, 2007 |
| Angell | UMA | Freshmeadow Pond, MA | soil survey | Report |
| Ellis | UFL | Cedar Key, FL | soil survey | Dissertation |
| Fischler | UFL | Indian River Inlet, FL | submerged aquatic vegetation | Thesis |
| Casby-Horton/ Brezina | NRCS | Padre Island, TX | soil survey, ecological site descriptions | ---- |
| Payne | URI | Greenwich Bay, RI | water quality, methods | Thesis |
| Coppock | UMD | Rehoboth Bay, DE | soil survey | Thesis in progress |
| Balduff | UMD | Chincoteague Bay, MD | soil survey, methods | Dissertation |
| Keirstead/ Hundly | NRCS | Little Bay, NH | soil survey | --- |
| Surabian/Parizek/McVey | NRCS | Little Narragansett Bay, CT, RI | soil survey, mooring interpretations | Report; Surabian, 2007 |
| MapCoast | MapCoast | Rhode Island estuaries | Soil survey, methods | Web available data |
| Salisbury | URI | Quonochontaug Pond, RI | shellfish and dredging interpretations | Thesis is progress |
| Pruett | URI | Point Judith Pond, RI | eelgrass and carbon accounting | Thesis in progress |
| Wong | NCSU/NRCS | Jamaica Bay, NY | soil survey and eelgrass | Thesis |

# Conclusions

- Over the last 15 years, the concept of subaqueous soils has become accepted within the soils community and is gradually being recognized in the broader estuarine community
- There are a number of places where SAS inventories have been completed and others where they are currently underway
- There are limited teams conducting research on SAS and much of current thrust is on SAS interpretations
- There is a great deal of additional work to be done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