

2008 Southern Regional Cooperative Soil Survey Conference  
Ad Hoc Committee on Subaqueous Soil Interpretations  
July 14-18, 2008

**FINAL REPORT**



About the cover: This is a soil core taken from an offshore seagrass flat near Cedar Key, FL. The core was taken by pushing a clear polycarbonate tube into the subaqueous soil, filling with water, capping, and then extracting by hand. Note the presence of an A horizon. The vertical streaks are edge effects of inserting the core tube into the soil. Note the dense bed of Manatee grass (*Syringodium filiforme*) in the background. Also note the patch of unvegetated soil, which is a common and often temporary occurrence in seagrass beds. For scale, the core tube is approximately 2.5 inches in diameter.

## **Committee Membership and Committee Charges**

### Co-Chairs

- L. Rex Ellis, Research Assistant Professor, University of Florida, Gainesville, FL
- Susan Casby-Horton, Soil Scientist/Geomorphologist (Retired), NRCS, Temple, TX

### Members

- Gerald Crenwelge, Soil Scientist, NRCS, Lubbock, TX
- Jerry Daigle, State Soil Scientist, NRCS, Alexandria, LA
- Wayne Gabriel, SDQS, NRCS, Temple, TX
- Wade Hurt, National Leader for Hydric Soils (Retired), NRCS, Gainesville, FL
- Eddie Seidensticker, Soil Conservationist, NRCS, Baytown, TX
- Joe Schuster, Co-Owner, Ecological Resource Consultants, Panama City Beach, FL
- Leslie Sturmer, Multi-county Aquaculture Extension Agent, University of Florida, Cedar Key, FL
- Bob Virnstein, Environmental Scientist VI, St. Johns River Water Management District, Palatka, FL
- Jon Wiedenfeld, Soil Scientist, NRCS, Rosenberg, TX

### Other Participants

The following individuals have participated via emails, phone calls, and teleconferences:

- Russell Castro, State Wildlife Biologist, NRCS, TX
- Justin Clary, RMS, NRCS, TX
- Kent Ferguson, State RMS, NRCS, TX
- Ed Griffin, Resource SS, CNTSC, NRCS, Fort Worth, TX
- Dan Keesee, State Wetlands Specialist, NRCS, TX
- George Peacock, Leader, Grazing Lands Team, CNTSC, NRCS, Fort Worth, TX
- Homer Sanchez, RMS, Grazing Lands Team, CNTSC, NRCS, Fort Worth, TX
- Levi Steptoe, SDQS, NRCS, Temple, TX

The following individuals participated via the breakout sessions on 7/16/2008 and 7/17/2008 of this workshop:

- Paul Benedict, Program Manager Soil Survey NRCS, Washington DC.
- Jerry Daigle, State Soil Scientist, NRCS, Alexandria, LA
- Ed Griffin, Resource SS, CNTSC, NRCS, Fort Worth, TX
- Charles Guillory, Assistant State Soil Scientist, NRCS, LA,
- Karl Hipple, National Leader, Soil Survey Interpretations, NRCS, Washington DC
- Darell Leach, Soil Scientist, NRCS, Gainesville, FL
- Deanna Peterson, State Soil Scientist, NRCS, Gainesville, FL
- Andrew Williams, Area Soil Scientist (A1), NRCS, FL
- Howard Yamatiaki, Soil Scientist, NRCS, FL

Additionally, 38 participants of the conference field trip (7/14/2008) were given a presentation on subaqueous soils. These individuals provided feedback after the presentation.

### Charges

1. Identify at least 3 subaqueous soils interpretations and the soil properties that are required to make these interpretations.
2. Develop a list of actual/potential customers who need these interpretations.
3. Define vision/process to develop Ecological Site Descriptions (ESD) for subaqueous soil map unit components.

### Background

In this section, we cover the background of subaqueous soil definitions and concepts and provide a summary of pedological research on these soils. This is included because it provides a context for understanding the committee charges and recommendations.

#### What is “Subaqueous Soil” and how does it fit into Soil Survey?

A brief review of various definitions of “subaqueous” shows that “underwater” is the central concept. The Natural Resource Conservation Service (NRCS) has interpreted this to mean that subaqueous soils are those that occur under permanent water. The current pertinent definition of subaqueous soils in the National Soil Survey Handbook (NSSH), Part 629.02(c), Glossary of Geologic and Landform Terms, is:

subaqueous soils - Soils that form in sediment found in shallow, permanently flooded environments. Excluded from the definition of these soils are any areas “permanently covered by water too deep (typically greater than 2.5 m) for the growth of rooted plants.

Based on this definition, subaqueous soils occur in aquatic areas historically mapped as the miscellaneous area “water” (including streams, lakes, ponds, and estuaries) by Soil Survey Division or in aquatic areas outside the extent of soil survey. Within these areas, however, can be vast expanses of intertidal land that is not under permanent water and therefore not subaqueous. This will be discussed in a later section.

#### Conceptually Bounding the Deep End of the Soil Continuum

The soil continuum extends beyond the water’s edge. Demas and Rabenhorst (1999) used the term “subaqueous soil” to describe the marine bottoms they studied. Their work led to a revised definition of soil in *Soil Taxonomy, Second Edition* (Soil Survey Staff, 1999), as follows:

*Soil* in this text is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter *or* the ability to support rooted plants in a natural environment. This definition is expanded from the previous version of *Soil Taxonomy* to include soils

in areas of Antarctica where pedogenesis occurs but where the climate is too harsh to support the higher plant forms.

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. 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. The horizontal boundaries of soil are areas where the soil grades to deep water, barren areas, rock, or ice. In some places the separation between soil and nonsoil is so gradual that clear distinctions cannot be made.

The definition of soil in the *Soil Taxonomy, First Edition* (Soil Survey Staff, 1975) allowed for the inclusion of subaqueous soils within the definition of soil provided the support for rooted plants was possible under normal conditions. The 1999 definition preserves this but suggests a natural cutoff is 2.5 m water depth because plants don't typically grow deeper water. This represents a conceptual restriction from the 1975 definition which offered no water depth guidance. Arguably the most important word in the definition is "or" because it allows for the substitution of pedogenesis for the support of rooted plants. In the line following that sentence, clarification is offered that the intent was to include Antarctic soils that have formed horizons via pedogenesis. However, the same argument applies to aquatic bottoms that cannot support vegetation yet have formed soil. This represents a conceptual expansion from the 1975 definition because it removes the requirement of rooted vegetative support.

Overall, the soil definition revision from 1975 to 1999 is inclusive because it includes aquatic portions of salt marsh ecosystems such as those in Louisiana and Georgia. These estuaries do not support submerged aquatic vegetation (SAV) due to limited light penetration of the water. As of 1999, the bottoms of these areas are candidates for inclusion within the definition of soil provided pedogenesis can be observed in the aquatic bottoms. In contrast, areas with very clear water such as the Florida Keys, can support SAV to depths well beyond 2.5 m (Zieman, 1982). These areas were within the definition of soil in 1975 and are still in 1999, although the 2.5 m guidance steers one away from considering them. Practicality also steers one away from considering them due to the relative difficulty of observing soil under 10 m water vs. 2 m of water. While these areas are technically soil due to their SAV support, should they be considered in a soil survey program?

Delineating the deep edge of soil is an important discussion for soil survey because it translates into a lateral expansion of land that will be mapped. When this committee initially considering this, the following questions arose:

- What is the lateral extent of soil?
- Is it to the edge of observable pedogenesis or SAV support, whichever is deeper?
- Is it to 2.5 m?
- Should the soil survey program be constrained by the definition of soil?
- Instead, should the soil survey program inventory all areas shallower than a defined depth (e.g. 2.5 m)?
- Should the soil survey program simply extend to a defined distance from the shore (e.g 5 miles)?
- Should the soil survey program only consider aquatic areas currently within the extent of soil survey?

### Delineating the Shallow End of Subaqueous Soils

According to the NSSH, subaqueous soils are aquatic bottoms that occur under permanent water. Therefore, intertidal zones would not be considered subaqueous or subaerial environments. Many SAV beds in marine areas (seagrass beds) are frequently exposed on low or very low tidal events. A similar situation occurs around the edges of lakes. In the case of lakes, the exposure can occur for days, months, or longer due to fluctuating groundwater supporting the lake. In either case, aquatic bottoms can often be out of water. Should these areas be designated as subaqueous, subaerial, or an intermediate term (e.g. intertidal)?

To deal with this issue and to highlight the continuous nature of soil across the terrestrial/aquatic border, Ellis and Hurt (2007) suggested that hydric soils be divided into subaqueous, aqueous, and non-aqueous based on percent of time exposed: hydric nonaqueous (<25%), hydric aqueous (25-75%), and hydric subaqueous (>25%). The percentages were chosen arbitrarily and it was suggested that research was needed to define the percent of flooding that would best fit these classes. This approach would allow for conceptual separation of intertidal areas from subtidal. It would also allow for separation of the drier from the wetter intertidal areas.

### Drowned Terrestrial Soils as Subaqueous Soils

Conceptually, subaqueous soils are on the aquatic end of the soil continuum and subaerial soils are on the terrestrial end. The concepts proposed by Demas and Rabenhorst (1999) indicated that soil genesis, including the four pedogenic processes of additions, losses, transformations, and transfers, are active in a subaqueous environment. However, soils under permanent water can be also linked to neighboring terrestrial soils, particularly through drowning of soil landscapes developed in terrestrial environments with permanent submergence accommodated by either subsidence or sea-level rise. These soils formed in a subaerial environment but now exist in a subaqueous environment. Much of the unpublished research in Florida shows this marked influence of terrestrial soils on subaqueous soils. Drowned spodic horizons have been observed along with chroma and particle-size distribution mirroring adjacent terrestrial soils.

### Subaqueous Soil Survey

Demas and Rabenhorst (1999) provided the first pilot subaqueous soil survey. Bradley and Stolt (2003), Osher and Flanagan (2007), and Ellis (2006) followed suit with similar pilot surveys focused on estuarine and shallow marine bottoms. In all cases, bathymetry were collected and converted to topographic maps which allowed for landscape visualization. Soils were sampled, described, and analyzed. Finally, soil surveys were created of the study areas. None of these studies addressed the joining of subaqueous surveys to existing soil surveys. Ellis and Hurt (2007) documented that joining would be quite complex with subtle transitions. These studies briefly mention interpretations, but do not explore the issue in depth. A small area of subaqueous soil has been mapped in Texas in conjunction with preparation of the Soil Survey for Padre Island National Seashore.

As NRCS moves toward the inclusion of subaqueous environments in Soil Survey, we are faced with having to move beyond these pilot research projects. In addition to the questions from the preceding

section, several other questions need consideration:

- How will we visualize subaqueous soil landscapes?
- At what scale will we map subaqueous soils?
- How stable are subaqueous landforms and how often will we need to re-survey an area?
- How will we develop soil/landscape relationships needed for subaqueous soil mapping?
- Who will use subaqueous soil maps and interpretations?
- What are the subaqueous soil interpretations needed by users and cooperators?

### Water Depth

In the context of aquatic habitats, subaqueous soils, and extending soil survey into aquatic areas, it seems that discussions of water depth are inevitable. These discussions almost always occur without an acknowledgement that water levels fluctuate. In fact, the term “permanent” is misleading because it suggests a static nature to aquatic systems which is not accurate. When discussing or reporting a water depth, when is this measurement made? Depending on the local hydrology, water levels of lakes or estuaries can fluctuate less than one ft (e.g. Blue Pond, FL) or more than 40 ft (e.g. Lake Brooklyn, FL). Do we measure water depth during high water events, average water events, or low water events? Should we instead report or discuss a suite of water levels (e.g. a frequent low, average, and frequent high)? Water fluctuations can vary tremendously throughout the United States, therefore this issue needs further consideration if we are to consider aquatic areas to be included within soil survey.

### Discussion of Committee Charges

The following charges are very important because they begin the justification for the NRCS to survey aquatic areas. From a research perspective, any area can be investigated provided important questions can be addressed in a meaningful way. However, for a federal agency such as the NRCS, ample justification is needed prior to such an effort.

#### Charge 2: Develop a list of actual/potential customers who need these interpretations

We first discuss Charge 2 because the importance and selection of interpretations is driven by the users of soil survey. Below is a list of potential customers and users of subaqueous soils information:

- Researchers (Universities, Federal Agencies)
- Aquaculture (e.g. shellfish)
- Engineers
- Surveyors
- Estuarine Managers
- Non-Profit Organizations
- Coastal-Zone Environmental Consultants
- State Agencies
- Federal Agencies (EPA, NOAA, USACE, USFWS, USGS)

While inclusion of several groups in this list is more obvious, the needs of customers with whom we are less familiar calls for more discussion. For instance, regarding aquaculture in Florida, oysters are

grown in gear off the aquatic bottom but clams are grown in mesh bags on top of the soil. Throughout their life cycle, the clams burrow into the soil, pushing the bag down with them. It is generally understood that sandy soils are preferred for clam growth (Grizzle et al., 2001). Silt, clay, and organic matter can negatively affect clam growth (Pratt and Campbell, 1956) due mainly to sulfide toxicity (Bergquist et al., 2003). As this research matures and the role of soils in aquaculture is better understood, subaqueous soil surveys could be used to plan new aquaculture lease areas and to understand areas currently in use. At present, Florida has 1,800 acres of state-owned land used for aquaculture.

Regarding estuarine management, water management districts in Florida are charged with managing estuarine habitats. Knowledge of the aquatic bottoms is crucial to their efforts because it allows them to have a context for understanding present conditions and provides input information for their predictions of future conditions. For example, there are approximately 40 fixed transects throughout the Indian River Lagoon, FL, where the water management districts have monitored seagrass distribution over the past 14 years. The goal of the program is to understand current trends in seagrass distribution and to restore seagrass amounts to a pre-determined level. Management decisions on planning restoration efforts would benefit from knowledge of subaqueous soil distribution.

Non-profit organizations in coastal and marine environments (e.g. Coastal Bend Bays and Estuaries Program and Galveston Bay Foundation in Texas) are customers with whom we have historically had minimal contact. These organizations often work closely with universities, researchers, and federal and state agencies and, as such, can often provide a network of potential customers and users of subaqueous soils information.

In summary, we can develop a list of local, regional, state, and federal agencies and organizations that could potentially use subaqueous soils information (mapping and interpretations). However, we do not currently have information on the specific interpretive needs of individuals and groups working in subaqueous environments.

### Charge 1: Identify Subaqueous Soil Interpretations and Required Soil Properties

The challenge of committee charges 1 and 3 is to determine the need and purpose of soil interpretations in a subaqueous environment, and specifically which soil properties (versus water quality, turbidity, water chemistry, etc.) affect the interpretation output and establish possible criteria limits. We can identify that (based on committee responses) the primary subaqueous interpretations of interest include:

- Potential for SAV Restoration
- Wildlife Management (related to specific vertebrates and invertebrates)
- Habitat for Migratory Waterfowl
- Habitat for Wading and Diving Shore Birds
- Habitat and Nursery Ground for Commercially Important Vertebrates (Fish)
- Habitat and Nursery Ground for Commercially Important Invertebrates (Shrimp, Crab, Clam)
- Management for Sustainable Oyster Production
- Habitat for Wading and Diving Shore Birds
- Effects of Boating Activities on SAV

Effects of Nutrient Loading on SAV  
Shoreline Erodibility  
Dredge Material Management

How do we isolate the soil properties that affect the interpretation output in these complex ecosystems? What additional soil properties or qualities (in comparison to subaerial soils) are important in subaqueous soil interpretations? How do we describe the dynamics of seasonal fluctuations in soil salinity, surface water salinity, water depth, frequency and duration of fresh water influx along coastal sites, etc., in relation to vegetation, habitat, wildlife management, etc.? What is the relationship among water depth, water salinity, and soil salinity and what are the seasonal fluctuations? As soil scientists, we are generally not qualified to make decisions or recommendations related to marine biology/ecology and need input from additional technical experts to assess what parts of the subaqueous environment (soils, water column quality and chemistry, tidal activity, wave action, water depth, etc.) influence vegetation dynamics and subaqueous ecosystems. Since water properties can be seasonally and spatially variable, we may need to design subaqueous soil interpretations that vary in relation to a range in water parameters.

Once we determine the soil properties, soil qualities, and any additional data elements required for subaqueous soil interpretations, we need to determine how to revise the NASIS database structure to accommodate this information. We also need to review map unit concepts and map unit names, including map unit phases, and propose new options for subaqueous soil environments.

At a minimum, the following properties and morphology are necessary to generate interpretations of subaqueous soils:

- Particle Size Distribution: presumably sand, silt, clay, by pipette along with sand sub-fractions.
- Carbon Content: organic and inorganic fractions either by weight loss after combustion or using a TC analyzer and acidification.
- Sulfides: various sulfide measurements can be made, such as moist incubation, total sulfur, acid volatile sulfides, etc. Each method provides specific information about sulfur.
- Bathymetry: important in determining water depth, soil landscapes and landforms, elevation, geography (which controls tidal amplitude), and potential exposure on high tide or water depth on low tide.
- Vegetative Cover: It should be noted whether the soils actively support or have the potential to support SAV. The SAV potential of subaqueous soils is difficult to assess.
- Bulk Density / n value: n value is determined by hand, while bulk density would be measured by coring and weighing the soil.
- Soil Color: field determination using a Munsell ® color book.
- Redox: IRIS tubes, platinum electrodes, and observations of soil colors

Potential for SAV restoration seems to be the primary subaqueous soil interpretation of interest. Suitability of an area for restoration is going to be (primarily) a function of the water depth, water quality, and soil properties. However, as soil scientists, do we determine the role of soil in SAV community restoration? Is the soil substrate the primary factor influencing restoration, or are water properties (turbidity, water quality, nutrient loading, etc.) more important?

Subaqueous soil interpretations related to aquaculture and habitat for commercially important vertebrates and invertebrates are also of primary interest. Planning of new lease areas or the understanding of current lease areas is needed for Florida shellfish aquaculture. At present, sandy soils low in organic matter (OM) and sulfides are preferred. Soil properties such as particle size distribution, OM content, and sulfide levels would, therefore, affect aquaculture interpretations.

Charge 3: Define vision/process to develop Ecological Site Descriptions for subaqueous soil map unit components

The development of ESDs for subaqueous soils (basically “underwater range sites”) is new territory for NRCS and must be coordinated with persons familiar with SAV, marine biology, and marine ecology. Several NRCS soil scientists and range scientists, representing the Texas State Office (Temple, TX) and Central National Technology Service Center (Fort Worth, TX) held a net conference on May 27, 2008, to discuss development of Ecological Site Descriptions for subaqueous soils. Participants included:

George Peacock, Leader, Grazing Lands Team, CNTSC, Fort Worth, TX  
Homer Sanchez, RMS, Grazing Lands Team, CNTSC, Fort Worth, TX  
Ed Griffin, Resource SS, CNTSC, Fort Worth, TX  
Kent Ferguson, State RMS, Temple, TX  
Justin Clary, RMS, Temple, TX  
Dan Keesee, State Wetlands Specialist, Temple, TX  
Russell Castro, State Wildlife Biologist, Temple, TX  
Levi Steptoe, SDQS, Temple, TX  
Wayne Gabriel, SDQS, Temple, TX  
Susan Casby-Horton, Soil Scientist-Geomorphologist (Retired), TX

The initial discussion included a review of the concept of subaqueous soils, charges for the Ad Hoc Subaqueous Soils Committee for the 2008 Southern Regional Cooperative Soil Survey Conference, and general questions related to the process/procedure for development of Ecological Site Descriptions (ESDs) for subaqueous soils. Participants discussed the definition of subaqueous soils and determined that key characteristics of subaqueous soils should include:

1. Permanently submerged soils – does not allow emergence, and tidal range only affects water depth
2. Presence of submerged aquatic vegetation (SAV)
3. Saline, brackish, or fresh water

Current pertinent definitions in the National Soil Survey Handbook (NSSH), Part 629.02(c), Glossary of Geologic and Landform Terms, generally support these key characteristics, as follows:

**subaqueous** – (adjective) Said of conditions and processes, features or deposits, that exist or operate in or under water. Compare – subaerial.

**subaqueous soils** - Soils that form in sediment found in shallow, permanently flooded environments. Excluded from the definition of these soils are any areas “permanently covered by water too deep (typically greater than 2.5 m) for the growth of rooted plants”.

**subaqueous landscapes** - Permanently submerged areas that are fundamentally the same as subaerial (terrestrial) systems in that they have a discernable topography composed of mappable, subaqueous landforms.

**subaerial** - (adjective) Said of conditions and processes, such as erosion, that exist or operate in the open air on or immediately adjacent to the land surface; or of features and materials, such as eolian deposits, that are formed or situated on the land surface. Compare – subaqueous.

The main differences between characteristics listed by net conference participants and the NSSH definitions are (1) specifically named presence of SAV and (2) specific mention of range in water salinity.

Participants then discussed Charge #3 for the Ad Hoc Subaqueous Soils Committee:

“Define vision/process to develop Ecological Site Descriptions for subaqueous soil map unit components.”

George and Homer expressed concern that we are in the information-gathering stage and not yet ready to propose a process/procedure for development of ESDs for subaqueous environments – we need technical and field input. Participants had several questions related to the logistics, management, and procedure for development of ESDs for subaqueous soils, including:

1. Should the ESD Site ID for subaqueous soils be specific to one MLRA (as now) or can the Site ID range across multiple MLRAs? Having Site IDs for subaqueous soils specific to only one MLRA could create an ESD maintenance issue. For example, could the same ESD be used across the Gulf Coast so that you would possibly have the same ESD from Texas to Mississippi? How variable is SAV across the Texas-Louisiana-Mississippi Gulf Coast?
2. Beyond the previous question, are soil temperature regime boundaries, currently determined based on terrestrial (subaerial) soils, also applicable to subaqueous soils? Do we need to consider soil temperature regimes for subaqueous soils separate from subaerial soils?
3. Following up on question #2, should we consider setting up new MLRAs or sub-MLRAs for subaqueous soils? Could this approach help with ESD development and management?
4. Current ESD guidelines include kinds, amounts, and proportions of vegetation by weight. Will we use this same approach for ESDs for subaqueous soils? Should other quantifiable approaches be used, e.g. percent cover?
5. How should we handle ESDs for soils in a fresh to brackish water environment?

### **Committee Recommendations**

Charge-specific recommendations are given in the sections below. In general, the committee recommends to the NCSS a national workshop to combine work in the southeast with that of MapCoast and other areas in the Mid-Atlantic and Northeastern U.S. This will coordinate the efforts of all regions conducting subaqueous pedological investigations. Also we recommend to the NCSS that a standing committee on subaqueous soils be established. This group can focus on the questions presented in this report along with other questions yet to be asked. The activities of a large federal agency command a thoughtful and lengthy consideration. During the breakout sessions, it was suggested that the activities of the committee be similar to the Hydric Soils committee (e.g. nationwide tours of sites that represent the range of lands to be considered). When considering members for this committee, we suggest representation from both marine and freshwater areas.

To begin, we suggest the following broad charges (not necessarily in order of importance):

- Revisit the USDA/NRCS definition of soil (Soil Survey Staff, 1999) to determine if it is adequate and compatible with the planned activities of extending soil survey into aquatic areas.
- Address the bounding of soil at deep water: what is conceptually correct, what is logistically possible, what is meaningful for the users, what is practical for the USDA.
- Address issues of map scale with respect to: users, meaningful interpretations, feasibility of mapping, natural variability, and compatibility with current Soil Survey data.
- Address standards (e.g. mapping and laboratory). Are the current field and laboratory methods adequate for subaqueous soils?

A national workshop on subaqueous soils could provide a more focused set of charges and direction for a national committee on subaqueous soils. With regard to the charges of this Ad-hoc committee, we offer the following recommendations.

### Charge 2 Recommendation

1. Recommend development of a questionnaire for a broad group of actual and potential customers, as well as partners and NCSS cooperators. This questionnaire would solicit information on needs and potential uses of subaqueous soil mapping, subaqueous soil interpretations, and ESD information on subaqueous soils. Recommend that this questionnaire be distributed and responses collated prior to the regional workshop discussed below.
2. Following questionnaire distribution and collation, recommend a one-day user conference, possibly in each coastal state within the Southern Region, similar to the MapCoast Subaqueous Soil and Sediment User Conference held in Rhode Island on April 30, 2004. The afternoon portion of this user conference featured a participant workshop where, using breakout groups, the participants generated a large list of data and products needed. The break out groups focused on four main questions:
  - What kind of information do you currently use?
  - What kind of information do you need?
  - What products do you use?
  - What kind of products do you need?

Information gathered through questionnaire responses and the user conference could be summarized and used as input for determining the need and purpose for specific subaqueous soil interpretations.

### Charge 1 and 3 Recommendations

Following decisions on the need and purpose for specific soil interpretations, the associated soil (and additional resource) properties and criteria table would be addressed by an interdisciplinary team of soil scientists, range scientists, marine biologists, and marine ecologists. NRCS should first define the boundaries of the subaqueous soil environment in relation to soils within a tidal zone for purposes of subaqueous soil mapping and interpretations. Following input from the needs questionnaire mentioned above, we suggest an approach to development of interpretations and ESDs in subaqueous

environments similar to the ongoing approach to ESD development for riparian areas. This recommendation would include the following:

1. Recommend a regional workshop that reviews customer and partner needs, potential use of subaqueous soil interpretations and ESDs, and results in a “buy-in” from affected and interested parties. Recommend that the workshop be designed similar to the “Addressing Riparian Ecology in ESD Development Workshop” held in Albuquerque, NM, on August 14-16, 2007. The workshop agenda included in-house presentations (objectives, goals, technical topics on vegetation, soils, and geomorphology), field trip time, and development of agreed-to action items resulting from workshop efforts. The workshop objectives would focus on how to address subaqueous environment ecology in interpretations and ESD development. The workshop would concentrate on State and Transition concepts and theory development and not be a training effort. Only individuals with a thorough knowledge of ecological sites and subaqueous ecosystems would be invited to participate. The State and Transition theory of vegetation dynamics is the current scientific basis for the description of the vegetation dynamics in the ESDs. The workshop would be designed to allow the research and scientific community to communicate with NRCS on how subaqueous environment ecology can be addressed when developing State and Transition models for ESDs and other soil interpretations related to wildlife management, habitat, SAV restoration, etc. Discussions and decisions would allow NRCS to better refine vegetative concepts related to subaqueous soils and will support management recommendations to producers. Participants would include representatives from NRCS (State level), NRCS National Technology Support Centers (NTSC), and non-NRCS sources (state agencies, non-profit agencies, universities).
2. ESD development for subaqueous soils is new ground for range scientists who have historically worked on terrestrial/subaerial and intertidal (marsh) rangeland, so the technical input from biologists, ecologists, etc. working in a subaqueous environment is critical. Recommend contact with marine biologists and ecologists for participation in this workshop and prior to any interpretation or ESD development for subaqueous soils.
3. Prior to the regional workshop, NTSC personnel would coordinate development of a draft subaqueous soil ESD with proposed ESD structural changes. The Grazing Lands Team (including Homer and George) would coordinate with NRCS representatives from states working on subaqueous soils to develop this draft ESD within a 6- to 9-month time frame.
4. Recommend pursuing funding for this regional workshop through outside sources (other federal agencies, partners, NCSS cooperators, or customers?). Funding should accommodate 25 to 35 workshop participants and the workshop location should be along the coast to accommodate a field visit. In email discussions in March 2008, Pete Biggam (National Park Service) also indicated an interest in pursuing development of interpretations for subaqueous soils.

## **Conclusions**

Based on feedback and comments in from the field trip, the breakout sessions, and at other times throughout the conference, this committee is very optimistic about the attention currently being given to subaqueous soils. It appears that the majority of the attendees of this conference are supportive of efforts to study these areas as “soil” instead of sediments. The enthusiasm we perceived from this conference will hopefully provide a necessary base for soils research and survey activities in aquatic areas. Following this conference, the committee is encouraged about the future of subaqueous pedology. However, we recognize the conceptual and practical challenges of expanding a terrestrial discipline and agency into aquatic environments. It follows then that there are many uncertainties that must be addressed at the national level. We are optimistic these challenges will be overcome and look forward to the future of subaqueous soil science.

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