Sub-aqueous Vegetation Sediment Classification System and Mapping Study for the Barnegat Bay

Executive Summary

January 6, 2005

The Sub-aqueous Vegetation (SAV)Sediment Classification System and Mapping Study for the Barnegat Bay (SCMS), prepared by The Ocean County Soil Conservation District in Cooperation with the USDA - Natural Resources Conservation Service is a study to determine if a relationship exists between bottom sediment and SAV. It is hoped that any such possible correlation may help explain the causes of the lost of SAV beds that has occurred during the past forty years and suggest actions to restore SAV prior levels.

The study area, just west of Island Beach State Park, did show that certain sediment characteristics consistently support SAV. Similar to an upland drainage catena from ridge top to valley bottom on a downward sloping toposequence, decreasing aeration negatively impacts SAV production. Aerated soils have little or no organic accumulation on the surface. Less aerated soils have thick black mineral surfaces and the wetland equivalent is a muck soil with a thick organic surface. The water column is similar to the gaseous atmosphere over upland areas. The water column is the mechanism to deliver oxygen to the ecosystem and the soil surface.

When the upper 4 inches of sediment, on a weight basis, is comprised of than 60% medium or 60% fine sand or more than 70% when coarse sand is added to either fraction separately, SAV is consistently healthy. The geometry of the particle to particle porosity of these relatively uniformly sized sand grains supports the free flowing exchange of water carrying oxygen from the overlying water column and the removal of metabolic wastes, mainly hydrogen sulfide. This sand mixture is usually found on convex ridges and the upper side slopes in water that is 2.5 to 6.5 feet deep. The sediment usually has an organic layer of less than ¾ inch thick and is underlain with a thin black surface and dark gray subsurface. Other than the fact the soil is under water, the upper two inches of soil look very similar to an upland soil in the forest with a thin accumulation of organic matter at the on the mineral surface. In this setting, the combination of tide and landform propels currents sufficiently to limit settling of finer particles or organic debris which can clog the pores between the sand grains and prevent the release of hydrogen sulfide produced in or below the root zone from being released or exchanged to the water column above the soil. Where the toxic hdrogen sulfide accumulates in the root zone it strickens the SAV or eventually kills the plants.

Unlike sandy textured upland soils, when fine particle and/organic matter are added the soil increases the efficiency of gas and water cycling through building soil structure and the resulting large diameter aggregate-to-aggregate porosity. However, in the sodium saturated dispersed condition of the estuarine sediment, only partitcle-to-particle is possible and the accumulation of fines and organic debris act instead to clog pores and reduce gaseous exchange.

Map units based on landscape were delineated using NOAA bathymetric data, color infrared photography and water depths and sample characteristics observed in the field.

In conclusion, landform and the resulting coarser non-transportable mineral sediments are relatively permanent properties of the ecosystem. Transportable fine particles and increased organic accumulation on and in the sediment surface is detrimental to SAV. Management of the watershed to reduce erosion of fine particles and reduction of nutrients that stimulate algae growth will change properties of the water column and influence future sedimentation. In addition, restoration of drained, filled and otherwise degraded upland wetlands and estuarine tidal wetlands would further improve the trapping of sediment and removal of nutrients from both surface and groundwater flowing into the Bay. The implementation of both prevention and water treatment alternatives offer the best opportunity to restore production of SAV in Barnegat Bay.

Sub-aqueous Vegetation Sediment Classification System and Mapping Study for the Barnegat Bay (SCMS)

Prepared by

The Ocean County Soil Conservation District in Cooperation with the USDA - Natural Resources Conservation Service

December 5, 2004

Background:

On June 23, 2003, an agreement was entered into between the US Department of Agriculture-Natural Resources Conservation Service (NRCS), and the Ocean County Soil Conservation District (OCSCD) to establish a simple classification system for the identification of sub-aqueous soils within the Barnegat Bay. The work plan identified several steps expected for the process:

- identify a sampling grid that included areas with both an existing SAV growth and a lack of SAV growth;
- GPS the sampling locations;
- describe the soil oxidation levels and vegetation characteristics;
- develop a substratum legend based on the data collected;
- create a GIS data layer of the results; and
- prepare a final report that summarizes the data collection methods, findings, and use of the legend and any insight that might be provided by a soil scientist.

The agreement was the result of several failed attempts by the Barnegat Bay Estuary Program (BBEP) to transplant eelgrass in shallow water areas, and the recognition that better ways to predict SAV survival are needed. In January 2002, the BBEP Science and Technical Advisory committee agreed to use SAV as one environmental indicator to monitor implementation progress of the Watershed's Management Plan. In April 2002, the committee listed four data gaps in developing the overall monitoring program. Development of scientifically-based management information about the properties of sub-aqueous sediments in order to augment the re-establishment of submerged vegetation was one of these identified data gaps. The NRCS/OCSCD project was created to help understand the relationship between SAV and sediment characteristics, in order to improve future sea grass restoration efforts.

The original basis for the work plan was an idea that the soil oxidation levels could be determined through visual analysis alone, based on layer thickness and color that ranged from gray to brown to black, and that this color would be an accurate predictor of the suitability of the site for SAV. After examining the sediments in several areas, the project team hoped to capture areas extensive enough to make the prediction model acceptable for the layperson's use.

Between the original planning and initial field work, however, several things occurred that changed the way the project was carried out. First, the team decided to coordinate their data collection efforts with an on-going effort by the Rutgers University Center for Remote Sensing and Spatial Analysis (CRSSA) and the Jacques Cousteau National Estuarine Research Reserve. The CRSSA project was collecting aerial digital color imagery to determine the location of sea grass beds, and conducting boat-based surveys to determine species type. NRCS/OCSCD also reviewed the GIS data layers created from similar periodic surveys conducted since 1968. From these data, several transects of the bay were laid out. The NRCS/OCSCD team would use GPS to find the exact locations of the CRSSA boat-based data collection points and collect the sediment samples there.

Several collection methods were tried over a total of four field days. A 13’ Boston whaler was found to be too unstable to remain on the precise GPS point while using the sampling equipment. Eventually, a flat 20’ pontoon type boat was used with far greater success. A safety note of caution however, this type of boat did not seem well suited to wind and waves. Three different sampling devices were tried: a typical clam digger, a post-hole digger with custom 8’ handles, and a commercially available hand corer (Wildco model 2424). While the clam digger did collect enough sediment for a sample, the post-hole digger was the easiest and most efficient method. The commercial device failed to collect any sediment. With the combination of the right boat with the post-hole digger, over 20 samples were collected on the final day of sampling.

Another significant change from the initial work plan was the realization, after the first field day, that the use of sediment oxidation levels was not a completely reliable indicator of SAV survival or health. The samples did not have enough consistent variability between where eelgrass was growing and where it wasn’t. The planned “plant health index” was also not going to work. Determination of color, size, and vigor was just too subjective to be useful for the layperson.

What was realized was that there were several dynamic forces constantly at work in the bay. Regardless of water depth, there were areas that displayed various combinations of five characteristics:

- high vs. low energy,
- high vs. low turbidity,
- convex vs. concave bottom slope,
- impact areas of waves and high current vs. calm still water areas, and
- sands dominated by medium or fine particle sizes vs. mixed sand textures.

These characteristics were collected for 38 sites and located using a Garmin 760 GPS unit. Using GIS technology, a sediment map of approximately 4261 acres and a topo map identifying nearly 11,000 additional acres deeper than six feet, where the combination of conditions are probably unsuited for SAV growth under current conditions. Results indicate that the presence or absence of eelgrass is closely related to particle analysis, organic matter and the release of hydrogen sulfide, and only somewhat related to water depth and proximity to high energy water. Eelgrass survives well in areas of uniformly sized sediments, low to moderate levels of organic matter and no accumulation of hydrogen sulfide within the upper few centimeters. In addition, the combination of turbidity and water depth must allow sufficient sunlight can reach the plant. These factors can be estimated based on the topography of the bay bottom in combination with known current and wave action information. However, the existing topography map of the bay is not extensive enough to make accurate estimates of where new eelgrass beds should be planted. Better topographic data would enhance the predictive ability of SAV survival and help determine locations that should be targeted for protection in the future.

Similar projects in other states, i.e. Maryland, have been carried out as a soil survey. Officially, the soil survey does not consider the unconsolidated bottom sediments to be root restrictive soil material. Therefore, the soil survey is required to examine and describe profiles to a depth of two meters or more. Soil series have been established by making observations to a depth of two meters as required. It was decided in this project that all pertinent data could be collected within the upper six inches, since the establishment of SAV was the only intended purpose of this study. The cost of sampling to a depth of two meters was prohibitive and unnecessary. A review of the established series to see if those could be used included the series names of Purnell, Southpoint, Sinepuxent, Trappe, Tizzard, Whittington and Demas. One very interesting difference between these soils and the sediments in this study was that the mineral soils did not identify an organic layer at the surface in any mineral soil series. In addition, the Trappe series indicated a brown surface that was in our original classification schema but was seldom found. It is what might be termed a mudflat soil in shallow water. The SCMS did find isolated examples of the aerated surface but at a much deeper depth. Further, this series consists of loam and sandy loam textures to a depth of seven inches and supporting SAV vegetation. In the SCMS study, any textures this fine would not be brown and would not support SAV. Whether or not the warmer temperature further south and the accelerated oxidization can explain the lack of organic matter at the surface, it may be that excessive nitrogen inputs have changed the bottom surface of Barnegat Bay.

Setting

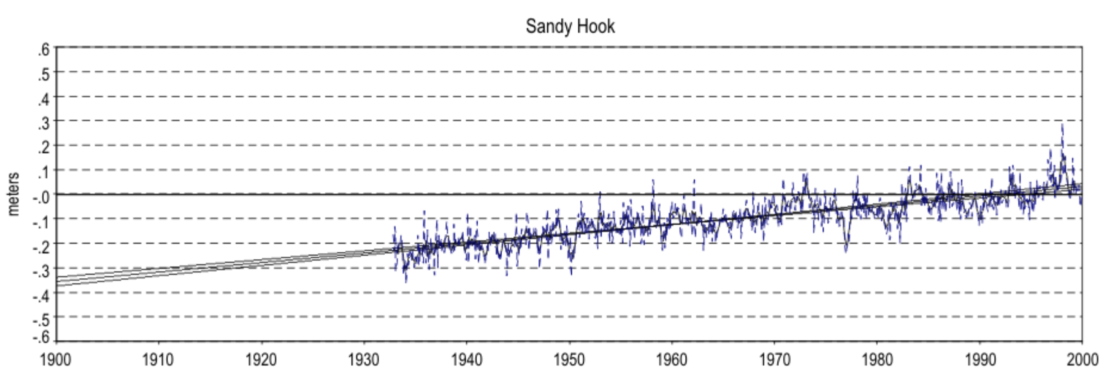
Barnegat Bay is an estuary protected by the micro tidal transgressive barrier islands of Island Beach and Long Beach. These islands have wave-dominated shorelines and are expected to have tidal range of less than six feet. Transgressive islands are characterized by a deficiency of sand and a high potential for shoreline erosion. (1) Transgressive means that as sea levels rise, the island migrates to the west by processes of dune over wash and blowing sand. In the case of Barnegat Bay, the east to west migration is characterized by washover fans and tidal delta. Washover fans are built during infrequent storm related events moving dune sand to the bay. Tidal deltas are the result of sand carried underwater by tidal currents through the inlet. The sand is carried both west and east. However, there is a net movement to the west and toward uplands.(2) The barrier islands themselves consist of a clean mixture of sands, as most silts and clays are carried out to sea by the water's energy. In Ocean County, there is a steady movement of sand from north to south along the ocean shore carried by littoral drift as the eastern nose of Monmouth County is being tectonically depressed more rapidly than Ocean County's shore.

Soil conditions in the uplands of the Barnegat Bay watershed are comprised of deeply weathered feldspathic gravels. During the weathering of feldspathic rock, clay is released that is carried by downward moving water into the subsoil. Thus, this gravel is the almost exclusive source of silts and clays within the watershed. Originally deposited as fluvial sediment, 15 to 30 feet thick, within the bottom channel of the Hudson River approximately six million years ago, those gravels have subsequently been reworked to lower positions in the watershed by successive transgressions of the ocean and by erosion events generally thought to have occurred during glacial advance when this portion of the coastal plain was a frozen tundra.

Under the gravel layer are coarse sandy sediments of the Cohansey Formation. These geologic materials have limited capacity to yield clay regardless of the length of time they weather.

All the soils are highly permeable under conditions of native forest where small amounts of surface runoff might be expected in the most severe of hurricanes. Therefore, the stream pattern arises from groundwater discharge with no response to individual rainfall events. It would have shown some increase in the winter and spring, as plant consumptive use dropped off, and then a lowering of baseflow in the summer, as rains attempt to recharge the soil storage with little or no water passing completely through the soil profile and into the groundwater. The slope and cross section had adjusted to the baseflow and vegetation conditions of the climate, so that upon colonial settlement the streams were entirely sediment free. This was true until more recently, because large tracts of land were never cleared for farming, being that the soils are generally not well suited to growing crops. With urban development, runoff patterns started changing and streams have had to adjust both slope and cross-section to carry a flashier runoff pattern. This means direct surface runoff from parking and lawns, and less groundwater recharge. This causes streams to down cut and widen. When this happens more quickly, it is easily noticed when bridge abutments are undercut or stream banks erode, undercutting trees and leaving their roots exposed. When the rate of down-cutting is slower than the rate of revegetation, the loss of soil is much harder to detect.

The sea level rise is due to a combination of melting polar ice and tectonic depression of the continent plate. In the following graph appearing on the National Oceanic and Atmospheric Administration website, tides have risen almost two feet in the past 70 years.



The change in depth causes one of the most basic rules of sedimentation to dominate, which that as water depth increases, velocity of the water decreases. As velocity decreases, only smaller and smaller particles can be carried in suspension. The result is termed an “upward fining sequence.” This refers to the decrease in average particle diameter from the lower to the upper depth within the layer with the smallest mineral particles are on the mineral surface. This sequence forms stratographic layers that can be tracked over large areas of a consistent geomorphic surface. The impact of changes in sedimentation is a key factor. Stephen Leatherman summed it up by saying, “The distribution of bottom communities depends largely on the type of substrate available.” (2) The approach in this study is to discover if mapable areas of substrate (i.e. sediment) exist, and to discover the key relationships between the sediment that might cause it to be suitable to SAV growth. Sediment, like soil, reflects an accumulation of processes over time. Properties such as water temperature, salinity, oxygen content are highly subject to change. Soil shows an average of conditions over periods long enough to build an ecosystem. Preliminary reconnaissance of the bay showed that soil conditions varied greatly and seemed to vary consistently with vegetation condition. A simple color chart was developed to attempt to group soil conditions into meaningful interpretive grouping for the purpose of distinguishing the soil suitability for growing SAV. Color is generally related to aeration of the profile and the oxidation-reduction of iron and organic matter. Less aerated soil tends to accumulate organic matter when all other factors are held consistent. Texture is one of the most permanent properties that sediment or soil has. For the purposes of this paper, the terms “soil” and “sediment” will be used interchangeably.

Procedure

The first step in studying sediments is to determine if sampling processes could satisfy the scientific requirement that the results can be duplicated independently. To test this, sediment samples would be taken at the same location as an ongoing study by Rutgers University. Using a different GPS unit on a different day, we will navigate to the same point, collect a sediment sample and compare the particle sand separates as to their relative percentage. The posthole digger with the 8 foot handles seemed to secure the most representative sample. It could remove a sample of uniform diameter usually to a depth of approximately 6 inches.

Test the simple schema of soil horizons developed in the preliminary excursions and determine if they can be consistently identified.

Test mapping process

Develop a simple Classification card to which soil conditions can be matched on the basis of color and layer thickness.

Results

Three preliminary field trips were made before entering into this Agreement and three day-long sampling trips were made during the summer of 2003.

The first requirement was to verify that on separate field trips with different groups of people, particle size results could be duplicated. Using a Garmin 76 GPS unit without the external antennae, we navigated to within about 15 to 25 feet of the point. Some samples were taken by actually walking the GPS unit to the point. However, most of those in deeper water were taken from the deck. The boat was put into position and the sample taken as quickly as possible, as we never successfully anchored. We had difficulty maintaining our position over the point and finally sampled as best we could. We were producing a general map over a large area with very few observations. Changes in landscape relief were generally slow even though there were a few exceptions. Vegetation was either observed as we during the final few feet of the approach, roughly a 5 square meter area or was recorded from the sample brought to the surface. The deeper sites it was impossible to see the bottom so the determination was made completely from the sample.

Both the Rutgers method, measured to the nearest tenth gram and my own method, measured to the nearest gram, of particle analysis used a dry sieve technique. Four other points were also duplicate sampled but they were so fine that the particles had trouble passing through the sieves due to the high amount of organic matter. The fact that organic matter was very high is significant in that it is highly correlated with a high percentage of fines.

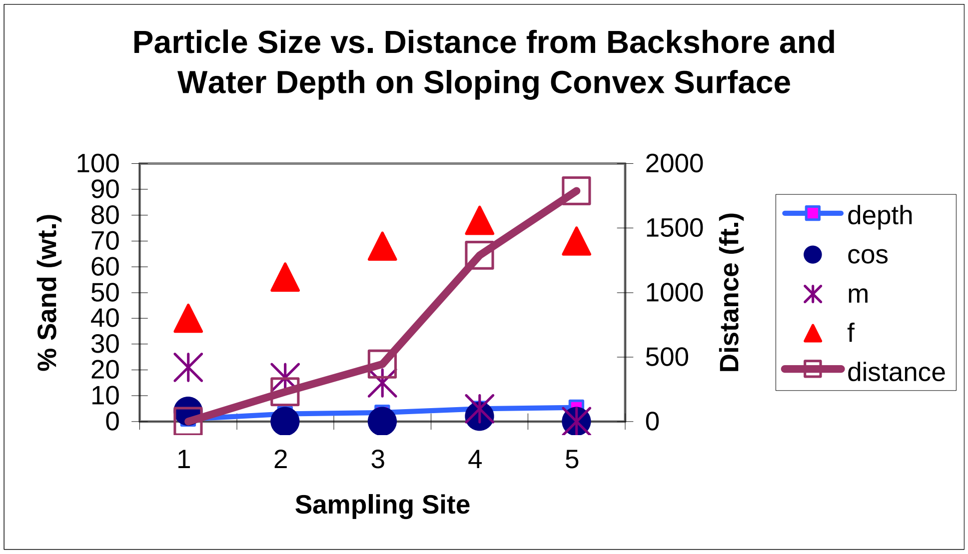
Same Site Comparison of Rutgers Sampling and SCMS Particle Analysis

Samples ID	Very coarse sand	Coarse sand	Medium sand	Fine sand
CS73	0	24	61	6
SAV302	1.5	20.2	61.4	6.8
CS82	0	18	66	8
SAV310	0.7	19.5	63.5	8.7
CS97	0	6	78	10
SAV321	0.4	5.6	76.8	13.4

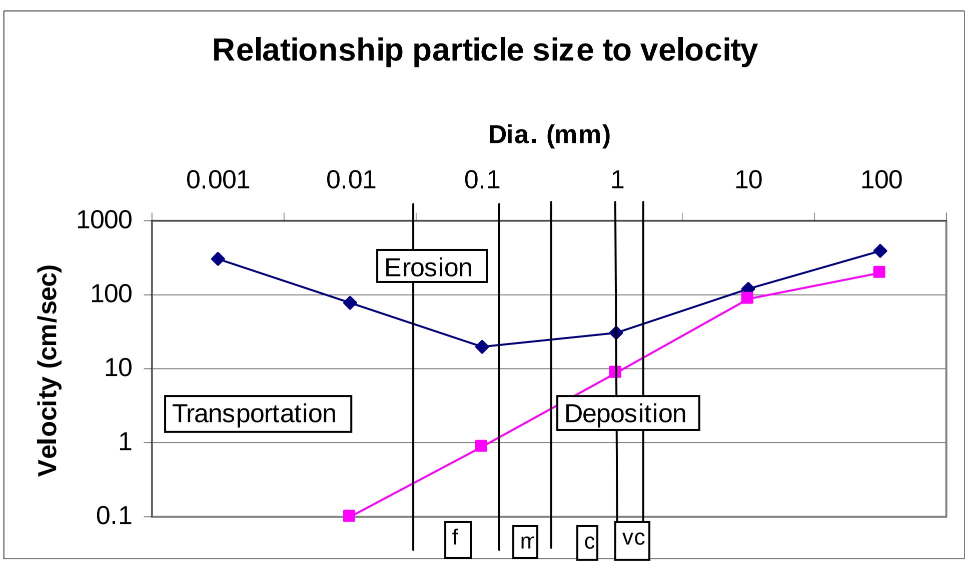
Any direct measurement of organic matter is difficult because the sampling method tends to mix the A horizon with C1 horizon.

Facts about particle size and data samples collected along the Rutgers Transect beginning with #25 and ending with #53:

The back bay is filled by the overwash of the barrier island. The heavier, larger grains are the first dropped just behind the island. With greater distance and water depth smaller and smaller grains are deposited. Notice that as the distance behind the island is beyond 1500 feet, the amount of fine sand begins dropping, even though the percentage is above 60% fine sand at a distance of 2000 feet. A mixture of both medium and fine sands and some coarse sand exists close behind the island in the shallow depths.

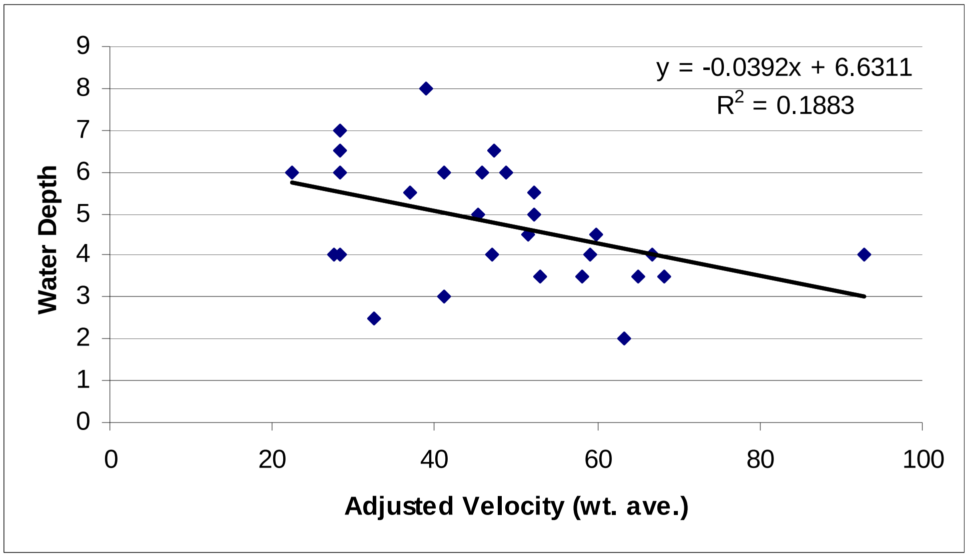


When velocity slows, particles become finer.



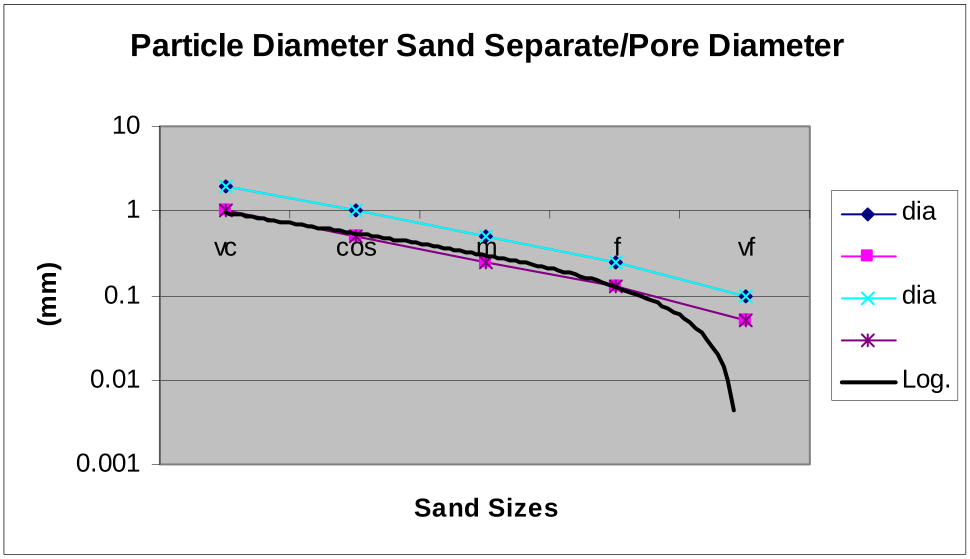
(3)

The deeper the water, the slower the velocity, as shown by a plot of the sites sampled. The x axis shows the weighted average velocity of all sand particles sampled in the study. This is calculated from the percentage of particle diameter multiplied by the velocity from the above chart. This chart is in agreement that deeper water does collect particle of smaller diameter and the average.



These particles show that velocities in the Bay are too slow to transport coarse or very coarse sands in the back bay environment. In addition, very fine sands and finer articles are very slow to settle. Areas where fines do accumulate are concave and have slow velocities regardless of depth, or are in water so deep that only fines are transported, regardless of landform. Particles with diameters less than 0.1 mm are very cohesive once settled and are not easily re-suspended. The preliminary data clearly showed that SAV grow in sandy areas. Thus, the primary focus should be on the medium and fine sand fractions.

The following graph shows the logarithmic change in pore diameter as particle diameters decrease in a theoretical single size population of single diameter sand grains. Note the exceptionally large change from fine to very fine sand. For the purposes of gas release, or ease of plugging the pore opening with organic matter, all particle sizes below fine sand have been grouped together for the purposes of this study.



After the first trip, it was apparent that the Classification card could quickly identify large areas that were not suited to SAV. The card was subsequently simplified from six to four categories. Any sediment that was soft and black is unsuited. These sediments are dominated by a high percentage of fines and organic matter. Near the bottom, they are low energy (i.e. low velocity), high turbidity due to slower settling finer particles in more still waters. Fines are trapped in a slow moving water column and then settle. The density of these sediments is low because the settling velocity is slow and there is no wave or current to compact the grains. In addition, striking the bottom with the sampling tool or removing the sample would often produce bubbles of gas. It is my belief that this gas is hydrogen sulfide that was trapped just below the surface. These soils are fully dispersed due to sodium saturation preventing the formation of soil aggregates or peds. There is only particle to particle porosity, Instead of organic matter gluing mineral particles together into soil aggregates as it does in upland soils, under sodium saturation, it clogs the pores. In conversation with Dr. Stephanie Murphy, Director of the Rutgers Soil Testing Lab, attempts to sieve the sands, both the Rutgers Soil Testing Lab and I had difficulty passing the very fine sand fraction through the sieve. There seems to be an adherence to the screen mesh causing it to clog.

The Classification card serves as a broad method to quickly eliminate totally unsuited areas and have a second quantitative method to evaluate areas that are marginal and require a closer analysis. The first broad brush evaluation was to use the card with the six categories. The second revised classification method was not developed at the time of sampling.

While the card can eliminate some areas, there were many other areas that could or could not support SAV without any clear explanation as to why. While, working with the sand fraction numbers to determine if results could be reproduced independently, I noticed that sample sites supporting SAV had particularly high percentages of either medium or fine sand. With the relatively limited number of samples, I determined that when either medium, or fine sands accounted for more than 60% of the total weight, or the medium or fine sands plus coarse sand accounted for more than 70% of the total weight, the site supported SAV. I believe this is the most significant finding of this study. Clean sands allow aerated water to pass through the upper few inches. This will oxidize moderate amounts of accumulating organic matter as well as provide pore space to ventilate the hydrogen sulfide gas produced just below the surface. This forms the central connection between particle size, organic matter and hydrogen sulfide.

Mapping

The process of mapping attempted to incorporate everything learned from the sampling. Areas too shallow, generally less than two feet, have too much energy, are turbid because of waves stirring the sediments, causing high sediment density from the pounding. Areas too deep, generally deeper than six and a half feet, are limited because they collect finer particles and organic matter, as well as having too little light.

Map Unit Description

Hec High energy – currents

These areas predominate where currents velocities are actively carrying sand. The depth can be highly variable, in that the flow of sand is a function of water entering the inlet. The shifting sand over washes existing underwater surfaces. This map unit is generally near the inlet, as the transgressive process attempts to fill the bay by pushing sand through the inlet by current. These areas are very active, and potential for revegetation is very low. . Classification Card, Category 4 sediments are most common with some Category 2 as well

Hew High energy – waves

These areas are characterized by water zero to two feet deep behind the barrier island. The wind creates waves that pound the shallow waters on the backslope. The soil is dense. Particles are often of mixed size. A certain amount probably results from the waves smashing into the bottom and stirring up the sediment. Classification card Category 4 sediments are most common with some Category 2 as well

Mecv Medium energy – convex

These areas generally have water depths between two and six feet. They are often broad submerged over wash tongues that have positive grade and, therefore, keep the water flow diverging. Fines cannot settle because the velocity from even tides fluctuation is too fast. They are dominated by medium and fine sands. They have the highest potential to be vegetated, especially 300 to 1500 feet behind the island, depending on water depth. They usually consist of Category 3 and Category 4 sediment.

Mepl Medium energy – planar

These areas are in the midslope position, down from the Mecv unit. These areas will likely have a higher percentage of Category 3 and less Category 4 sediments. The depth is generally deeper but the water flows steadily,

Lepl Low energy – planar
These areas represent the toe slope position or lower 1/3 of the slope surface. Water flow is slowed by a flattening of the land slope and smaller tidal gradient. This area is dominated by Category 2 sediments. The areas are usually deeper than 6 feet.

Lecc Low energy – concave
Flow from upland areas converges and concave topography slows the exit of water. The areas are usually deeper than six feet. In places, there appears to be a back swamp landform formed behind an overwash berm.   Informal conversation with Stewart Farrell, professor of Estuarine Geology at Stockton State College, determined that the recent deposits in the bay are relatively shallow and that coarser particle, including some gravel within the soil may be the result of dredging operations.

Recommendations

<u>Additional Study</u>

It is my intention to include all ideas about the project since this will mostly likely be my single comment on this study. While collecting the samples, various observations were made but not all were measured and recorded. The process of soil or sediment mapping of what cannot be totally seen from the surface is also the process of collecting indicators of what may be below the surface. The best indicators are features that are easily measured and are strictly correlated to the property of primary interest. While reading after the sample collecting phase, I realized that one of those features observed and not recorded was probably very important as an indicator.

Ripples resulting from water currents flowing over the sandy bottom are such a feature. From the literature, I have learned that when water flows over non-cohesive sand, regularly spaced ripples develop that are oriented perpendicular to the direction of flow. The smallest ripples form in the finest sands. When sand diameters are >0.6 mm, which defines the medium, fine sand, and very fine sands that were determined to be critical, ripple crests range from 4 to 60 cm apart, and the height of the crests range from 0.3 to 0.6 cm above the trough. In general, coarser sands produce ripple crests that are farther apart and higher. At very low velocities, ripples do not form because particles are not being transported. As velocity increases, small ripples form with straight parallel crests and troughs. These are identified as straight-crested small ripples. As the speed increases still further, the crest begins to wander, producing a wavy or undulating form. Although the crests are out of phase, the ridges can be traced some distance. These are called undulatory small ripples. With increasing velocity, the ridge or crest of the ripples become discontinuous and cannot be followed for any distance. These are called Lingoid small ripples.(4) The point of this discussion is to describe real differences in particles sizes and flow velocities that have been identified by sedimentary geologists. What needs investigating is the possibility that a link exists between the configuration of the ripples and the potential to establish or maintain SAV. This would be much faster and cheaper and can be determined *in situ*. Sites already sampled for particle size need to be revisited for ripple distribution measurements.

Another area of study is what is known as pit and mound structures related to gas escaping upward from the sediment. At the point of emergence the gas bubble produces a mound with a pit within the center point much like a very small volcano. In the literature, they are identified as being up to 1 cm in diameter. This may give a clue as to the entrapment of gas formed by decomposing organic matter. To observe these structures would probably involve donning goggles and looking at the undisturbed sediment in place on the bottom. In fact, we made no attempt to make any observations of the sediment in place. If the presence or absence of this feature provides valuable information as to the entrapment of hydrogen sulfide, this feature may be an especially important indicator. (5) Gas release curves under different pressures might help explain what the influence of particle size is on gas entrapment.

The loss of eelgrass may self-correct if the transgressive process were allowed to occur and push fresh sand westward. However, even that will not last unless sedimentation within the watershed is under control. Fines from upland erosion are a source of finer particles that did not exist to such an extent with strictly geologic erosion. Before colonial settlement, runoff from the excessively drained soils of the slowly growing forested Pinelands was negligible. Whatever small amounts of sediment that were produced passed through large tidal marshs that were capable offiltering and effectively trapping the water and settling most very fine sands, silts and clays within the vegetation. The growth of water-borne algae was not artificially stimulated by elevated levels of nitrates. Thus, depth of the water within the Barnegat Bay is not, by itself, a limitation for SAV.

Anaerobic conditions in the sediment column are not by itself limiting to SAV since they produce their own oxygen. Likewise, the presence of some organic matter on the sediment surface is not, by itself, limiting. In the finer sediments, the separation of the water column from the sediment column becomes indistinguishable. Walking on the bottom into concave areas compresses the organic matter and squeezes the gas from the mixture. Until the tiny bubbles are consolidated into large enough pockets or pushed out from within the mat, the gas remains in the organic layer.

Applying what has been learned from this study, it seems that when excessive finer sediments and algae block sunlight, and hydrogen sulfide is trapped by a combination of a mix of particles and organic matter that can trap the deadly gas in the root zone, the deepest areas are the first to suffer. Although it is not known what proportion of the problem is attributable to each cause, solutions to the loss of SAV must address the issues of sedimentation and excessive algae growth. Sedimentation refers specifically to the finest particles. This can be reduced by limiting erosive flows across the land and through along stream channel banks and bottoms.

Reestablishing lost wetlands and tidal marshes along the upland margin would restore nature’s sediment and nitrogen filter. The problem is compounded by use of inorganic fertilizers. A large quantity of nitrogen can be concentrated in one small bag. Limiting fertilizer to organic forms would reduce the fertilizer’s potency. However, to more fully control nitrogen, an upland landscaping culture needs to develop that relies more on native vegetation that does not require chemical inputs, especially nitrogen and phosphorus. Use fertilizers for the establishment of plants only, not for their maintenance. Improve nutrient uptake where high intensity uses require fertilizer by using soil testing and the addition of limestone and organic matter additions to take advantage of the pH dependent cation exchange capacity of the organic fraction. Collect plant materials such as grass clippings and transport them outside the watershed boundary for use as fertilizer where it is needed. Beyond trucking, nitrogen can only be effectively eliminated by holding the material in wetlands and treating the recently mineralized nitrogen by exposing it to denitrifying bacterial wetland processes that produce nitrogen gas which is harmlessly released to the atomsphere. Composting organic materials does not remove nitrogen from the watershed. It only serves to create a larger and larger reservoir them will one day mineralize to inorganic forms. Perhaps collecting a user tax on nitrogen imported into the watershed could be escrowed. It could be reclaimed as financial incentive by those individuals trucking the material outside the watershed boundary. The problem is similar to Lancaster County, PA. There similarly are not enough farms to use the nitrogen where eventual crop harvesting would constitute the nitrogen removal.

When studying the topography of some areas near the main channel, the relief is surprisingly similar to an upland floodplain. A raised berm along the underwater channel with a concave area behind it, which cuts through the berm farther downstream, is similar to the oxbow feature of an upland floodplain. One such feature was located at the northern end of the study area. It is thought this is probably a feature of dredging operations. Coarser sand which actually included a few gravels was found. The creation of a raised berm that blocks or slows the water from flowing across the main slope and returning to the main channel is determinital to SAV. The flow distance is increased, which reduces average bottom slope and thus flow velocity and particle size. If future dredging operations were changed to create the underwater spoil areas that were oriented perpendicular to the channel new convex ridges could be created in presently concave valleys. It is possible that new areas for eelgrass might develop, but at least it would cause fewer negative impacts on those areas already supporting the SAV. Although it sounds extreme, recontouring the bottom might help in some places.

Particle size is one of the most permanent properties of a soil. Shutting down the supply of fine particles will affect new deposits associated with the rising sea level but it is unlikely to have any affect on the current layers of sediment at the surface. Organic matter on the other hand responds to management in uplands soils and I believe it might do the same in the Bay. It may be possible to increase the oxidation of organic matter by exposing it to the oxygen in the water column when oxygen is in surplus, by lightly disking so as to re-suspend thin layers of organic matter in the water column. Such an activity might work best on a falling tide and during a time of year when plant growth is minimal.

The mapping process attempted to separate concave, planar and convex surface. Concave areas at any depth have sufficiently slow settling velocities to trap finer particles and particulate organic matter. Map unit design attempted to separate areas on depth and the type and source of the energy supply as those factors affect the characterisitcs of the sediment.

Slightly higher velocities of convex and planar surfaces prevent deposition of finer particles. The rise in sea-level cannot be changed. Therefore, it must be accommodated. The adverse impacts of an upward fining sequence can best be negated by controlling sedimentation, a factor on which we do have some margin of control.

Perhaps rapid surface discharges in direct respond to rainfall events move nitrates to the bay and into open water.(6) In the spring, the algae growth would be stimulated by the nitrogen and immediately start an accelerated growth rate. This also is a source of turbidity which further exacerbates the effects of sedimentation and rising sea-level. The channelization, deepening, widening, and straightening of streams through tidal marshes speeds the movement of sediment directly to open water.

Large boats and powerful engines increase velocity of water, probably lifting finer sediments from deeper depths. Fine sediments, (<0.1 mm) refers to very fine sand, silts and clays according to USDA classification. The energy needed to reset small grains increases with decreasing grain size. However, once in motion, and back in suspension, travel is mainly a function of settling velocity. It requires greater energy to set clay particles in motion than sand particles into suspension. But the sand grains settle rapidly, while clay particles remain in suspension because of their smaller settling velocities. When the horizontal velocity of the water is less than the settling velocity, there is considered to be a cessation of movement. There may be some separation into finely divided layers with the finest particles on top caused by secondary mixing of sediments. This would tend to place the most flow-restrictive layer on the surface and prevent exchange of gas between the sediment and water. No precise surface thin layer inch by inch sampling was done to test this possibility

Another source of information about inland bays is the Hydrographic Survey produced by NOAA. The information is not presently digitized, but is the source of the depths shown on the topography maps which were digitized for this study. They apparently are interested in the anchoring capability of the sediment as an aid to sailors, telling them where it is safe to anchor. They use a three-category system, too soft to hold an anchor, too hard for the anchor to sink into the bottom sediment and finally sediments that are suitable to hold the anchor securely. There may be some correlation between SAV and those map units that might save time and expense where these maps are available to eliminate some areas as unsuitable. The too soft areas I would expect might be the concave valley. Too hard could be the wave compacted sands. But it might also include areas suitable for SAV as we were never successful at anchoring our boat. I am not familiar with the NOAA test to determine their categories nor did we have the official equipment to make the test. However, it is a possibility for future studies either here or in other areas already assigned designated by NOAA categories.

Data
The actual data in included in the append section of this report

Summary:

Until very recently, bottom sediments would have hardly been considered a subject for a soil scientist. A portion of this study was to generate an overall point of view of a soil scientist that would probably be different than those that had been offered by other disciplines. Certainly, explaining why SAV grows in one location and not in another is a complex topic and will require the combined knowledge of a group of associated scientific approaches.

In conclusion, it seems that landscape position is critical to the growth of SAV. When conditions are less than ideal, the slow but steady movement of water is critical. The flowing water reduces the settling of mineral fines and organic debris. Keeping the sediment pore space open means hydrogen sulfide produced by decaying organic matter can escape the sediment before reaching toxic levels. Since texture and landform are usually considered a permanent feature of land, the mineral portion of the sediment itself is not associated with a reduction in SAV.

Slowing water velocity is a result of a deepening of the bay that is associated with sea-level rise and lack of clean sandy overwash sediments to fill the Bay. The lack of the washover events comes from efforts to stabilize the barrier island and the lack of major storms. Less upland groundwater recharge means base flows from streams and groundwater discharge that could steadily and consistently flush the Bay, even during summer and early fall, are reduced. This is the result of an increase in flashy surface water runoff from urban development, causing a reduction of return flow through the ground system. Flashiness is characterized by excessive flows during and immediately after rainfall events followed by reduced base flow of streams and groundwater discharge into the bay. Prior to modern development, flow rates would have probably varied only modestly on a seasonal basis.

The production of and accumulation of excess organic matter in the bay is also affected by slowing flow patterns caused by the deepening water. However, I would estimate that the greatest portion of the change can be attributed to the introduction of large amounts of surface-applied nitrogen in the form of lawn fertilizers and pet wastes. It is it quite possible that groundwater withdrawals serve to concentrate nitrogen even before the water discharges to the bay. Most of the water withdrawn for consumption is pumped directly to the ocean bypassing the stream network and the Bay.

Because the nitrogen is soluble, it can move to areas where the water is so still that sediment would never be transported. Once there, it stimulates the excessive growth of algae increasing turbidity. Upon death of the plants, they fall to the bottom and fill the pore space, which slows gas exchange with the water column and thus prevents the growth of SAV because hydrogen sulfide gas accumulates in the root zone of the SAV plants. Reducing the accumulation of organic debris is an essential step in restoring SAV in the bay. Organic matter levels respond to management in upland soils and I believe would also respond in the submerged soil. When organic additions are less than the oxygen equivalent in the water, oxidation rates would exceed inputs and begin oxidizing bottom accumulations of organic matter. The process is slow, however this problem was created over a long period and it is reasonable to think it will take nearly as long to correct.

A second possible contributing cause of slowing flow could be the sand that flows into the inlet from the ocean side of the barrier island and westward into the bay, reducing the cross-sectional area of the inlet, which would reduce the flow. This underwater obstruction would seem to cause more pooling of the water in the bay. The formation of these sand bars is associated with the westward migration of the barrier island system as sea levels rise. There would not seem to be very much that can be done about it. Again, depth itself is not a factor in reducing SAV, but depth without flow or reduced flow means more mineral particulate fines and organic debris are going to increase the turbidity of the water. It becomes more critical than ever that base flows remain high and natural filters remain in place to sustain the highest clarity of water.

Because there is a general dieback and there seems to an abundance of seed source of the SAV, it is hard to imagine that SAV is not already growing in all areas that are suitable. Thus, new plantings may not be worth the expense and effort, and may not be successful in the long term. However, changing the characteristics of the overlying water column may change the amount of organic matter and that will change the aeration state of the sediment and the growth and health of the SAV. From a practical standpoint, mapping sediment may not be useful tool other than to track gradual changes in the long term accumulation or depletion of organic sediment. I believe this study has taken a selected area and characterized sediment and made a generalized map of those conditions. In ten or twenty years, it would be interesting to revisit the area and see if there are measurable changes in both SAV and in the sediment.

Comments from the author,

I thankful to all those who participated in the study including all of the support staff, and especially Pete McClain, Dave Friedman, Bill Slack, Ruben Burgos, and Janice Reid. Without the combined efforts of everyone involved, this report would not be possible.

I am a soil scientist, which means I have education, training and the experience to understand the ecology and factors affecting soil formation. This project was extremely interesting because it forced me to apply my discipline in a setting where many of the same rules and theories apply with a surprisingly similar outcome to upland soils. However, a study of sediment, by definition, involves a study of the processes and environments of sedimentation. I am not a sedimentation geologist. Therefore, I may not have recognized nor provided as full or complete a description of some of the bay's processes as is needed. I recommend that such a person be included in any similar studies conducted in the future.

References;

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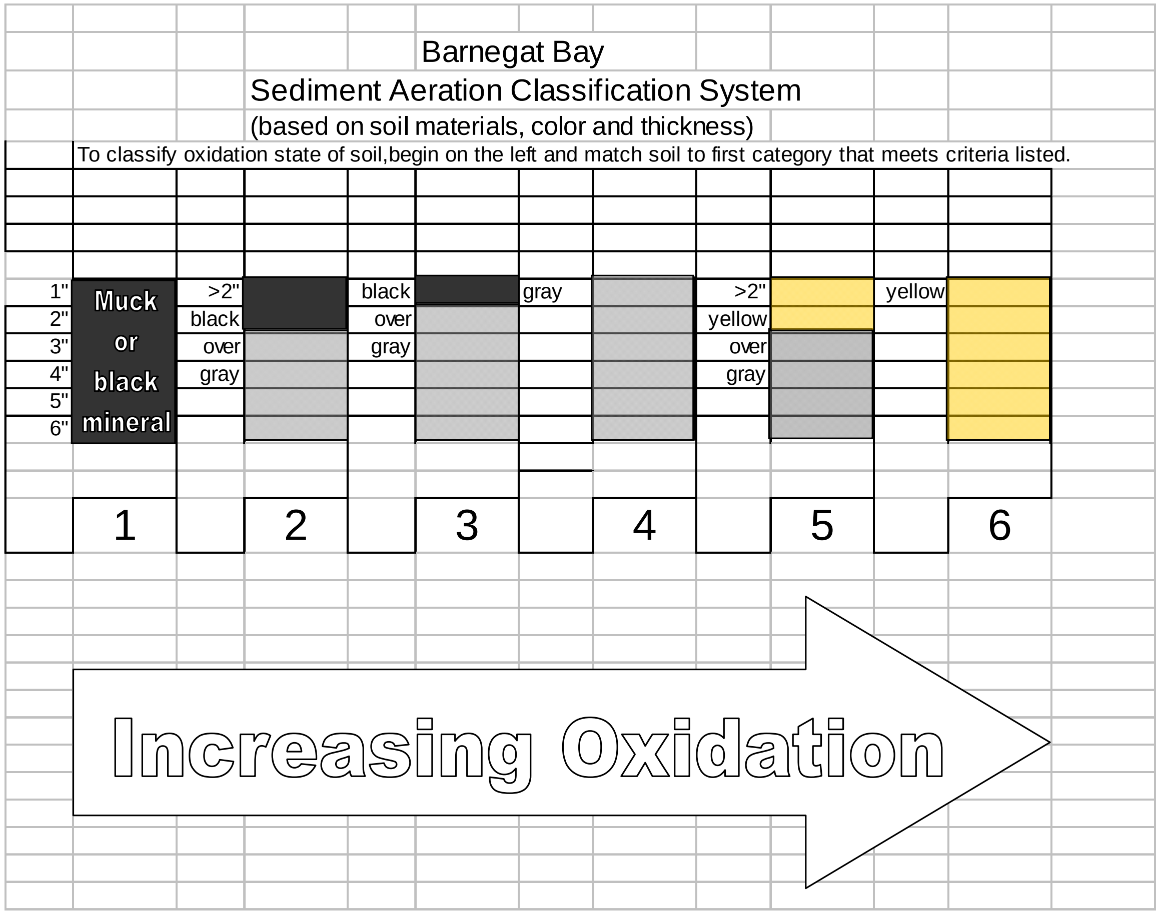
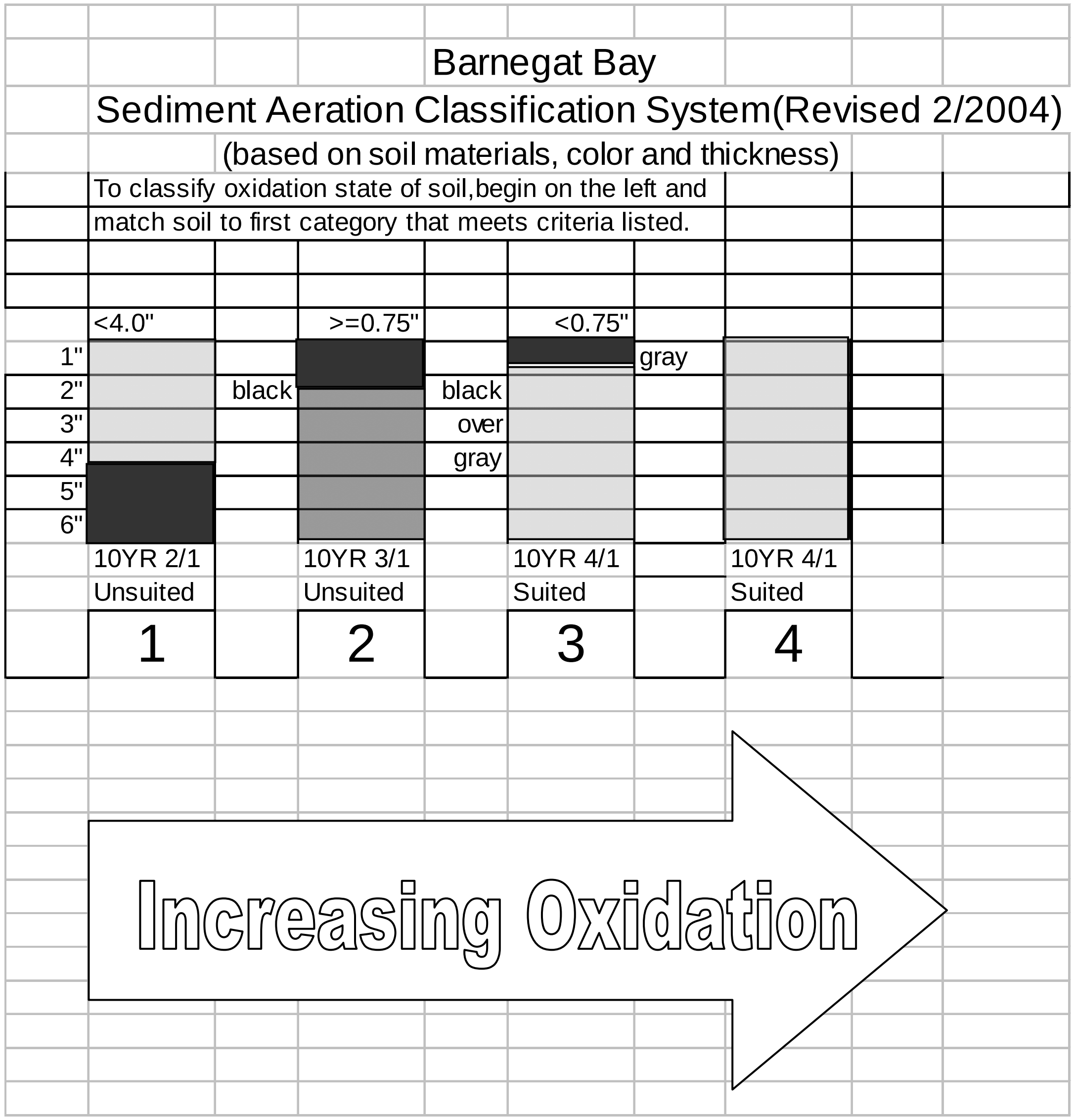
4. Reineck, H.E. and Singh, I.B., Depositional Sedimentary Environments, 2nd Edition, Sringer-Verlag, New York, 1980, page (36-38)
5. Reineck, H.E. and Singh, I.B., Depositional Sedimentary Environments, 2nd Edition, H.E. Reineck and I.B. Singh, Sringer-Verlag, New York, 1980, page (57)
6. An informal telephone discussion with Professor Fred Short of New Hampshire.

Appendix A

2.0 Version of Classification Chart



2.0 Version of Classification Chart



Sediment Category 1 - Low Energy/High Turbidity/Low Density

Sediment Category 2 - Low Energy/High Turbidity/Low Density

- a. Low velocity currents in concave landform
- b. Accumulation of organic matter, on or in soil surface
- c. Surface is soft, spongy, squishy, high squeezable
- d. Gas (H_2S?) released upon pressure applied
- e. Subsurface layer has nearly as much OM as the surface

Sediment Category 3 - Medium Energy/Medium Turbidity/Medium Density

- A. Appearance
  - a. No, or only limited, accumulation of OM on or in the soil surface
  - b. A layer with much less OM is immediately beneath, usually within 2 cm
  - c. Uniform and moderate flows narrow the differential between the largest and smallest particles. (probably not a field determination)
- B. Restoration Potential
  - a. High - on convex surface water will flow downhill
  - b. Low - in concave depression and lower planar tends to collect finer particles and detritus.
  - c. Medium – upper planar has continuation of the flow from convex but slower

Sediment Category 4 - High energy/High turbidity

- A. Current
  - a. Swift moving currents, causing saltation of sand grains and clean sand deposits
  - b. Little or no accumulation of organic matter
  - c. Constant reworking of sediment along the bottom
  - d. No potential for restoration
- B. Wave
  - a. Pounding waves along shore cause sand to densely pack
  - b. Little or no accumulation of organic matter
  - c. Constant water movement major limitation
  - d. No potential for restoration

Appendix B.

sample #	Class group	0 - 1"	1 - 2"	2 - 3"	3 - 4"	4 - 5"	5 - 6"	Note:
513	1	3/4" dark yellowish brown	dark grayish brown	dark grayish brown	dark grayish brown	dark grayish brown	dark grayish brown	like mudflat, yellow sulfur?
105	1	dark brown	very dark gray	very dark gray	very dark gray	very dark gray	very dark gray	a few organisms
506	1	dark gray	muck	dark gray	dark brown	dark gray	dark gray	
510	2	black	black	very dark gray	very dark gray	very dark gray	very dark gray	iron staining, sulfur? Perhaps buried surface
509	2	3/4' black	dark gray	dark gray	dark gray	dark gray	dark gray	clams
514	2	3/4' black	dark gray	dark gray	dark gray	dark gray	dark gray	no grass
195	2	gray	gray	black	black	black	black	bloodworms; aerated surface?
68	2	black	black	dark gray	dark gray	dark gray	dark gray	worms, old root mat to 4"
87	2	black	black	black	black	black	black	
100	2	.75 black	very dark gray	very dark gray	very dark gray	very dark gray	very dark gray	bloodworms
83	2	black	black	black	black	black	black	
63	2	.25 black	very dark gray	dark gray	dark gray	dark gray	dark gray	w/o grass no dark surface; veg. Seems to hold dark surface
101	2	black	black	dark gray	dark gray	dark gray	dark gray	
29	2	black	dark gray	dark gray	dark gray	dark gray	dark gray	
23	2	black	black	black	black	black	black	1" silt over fine sand
524	2	muck	muck	muck	muck	muck	muck	
515	2	black	very dark gray	very dark gray	very dark gray	very dark gray	very dark gray	tubworms
519	2	black	very dark gray	very dark gray	very dark gray	very dark gray	very dark gray	surface vfs over fs 3" root mat, a few bubbles of gas, almost looks like oxidized iron on surface of sand pile, only 1mm thick
511	2	black	black	very dark gray	very dark gray	very dark gray	very dark gray	at 3" was a 1" thick clam line, flat & tub worms
96	2	black	black	black	black	black	black	N 2/0 fine

512a	2	black	very dark gray	very dark gray	very dark gray	very dark gray	very dark gray	
64	3	3/4" black	very dark gray	dark gray	dark gray	dark gray	dark gray	no root mat
517	3	1mm black/dark gray	dark grayish brown	dark grayish brown	dark grayish brown	dark grayish brown	dark grayish brown	
93	3	.5 black	dark gray	dark gray	dark gray	dark gray	dark gray	surface consolidated; 3" root mat
518	3	.5 black	dark gray	dark gray	dark gray	dark gray	dark gray	
16	3	.5 black	dark gray	dark gray	dark gray	dark gray	dark gray	
82	3	.3 black	dark gray	dark gray	dark gray	dark gray	dark gray	
73	3	1mm black/dark gray	very dark gray	very dark gray	very dark gray	very dark gray	very dark gray	
521	3	.5 black	dark gray	dark gray	dark gray	dark gray	dark gray	
97	3	.5 black	dark gray	black	dark gray	dark gray	dark gray	
189	4	dark gray	dark gray	dark gray	dark gray	dark gray	dark gray	
173	4	dark gray	dark gray	dark gray	dark gray	dark gray	dark gray	
174	4	dark gray	dark gray	dark gray	dark gray	dark gray	dark gray	
20	4	dark brown	dark brown	dark gray	dark gray	dark gray	dark gray	
24	4	dark gray	dark gray	dark gray	dark gray	dark gray	dark gray	4" of recent sand
27	4	dark gray	dark gray	dark gray	dark gray	dark gray	dark gray	
108	4	dark gray	dark gray	dark gray	dark gray	dark gray	dark gray	
175	4	dark brown	dark gray	dark gray	dark gray	dark gray	dark gray	
194	4	dark gray	dark gray	dark gray	dark gray	dark gray	dark gray	

Appendix D.Sites sampled by both Rutgers and SCMS

LabNo	*MY ID*	*Rutgers ID ?*	*Sample ID*	*MASand*	*MASilt*	*MAClay*	*MATexture*	*OM*	*VCS*	*CS*	*MS*	*FS*	*VFS*	**Predict veg.**	**Rutgers Veg. Classification**	**Observed veg.**
				%	**%**	**%**		**%**	**%**	**%**	**%**	**%**	**%**			
3059	49	27	SAV-27	100.0	0.0	0.0	Sand	0.1	0.4	7.7	64.8	26.7	0.5	Y		
3060	64	28	SAV-28	99.4	0.6	0.0	Sand	0.4	0.2	6.5	69.5	21.3	2.4	Y	A44	lot of grass
3061	65	29	SAV-29	97.4	1.0	1.6	Sand	0.6	0.2	3.4	52.9	38.9	4.6	N	A44	
3062	67	30	SAV-30	97.7	0.6	1.6	Sand	0.5	0.2	1.5	37.4	54.8	6.1	N		
3063	101	33	SAV-33	49.0	42.0	9.0	Loam	5.6	0.1	0.6	2.7	56.8	39.8	N		
mysample	101*		101						0.0	3.0	31.0	15.0		N	No deter L95	N
3064	104	36	SAV-36	88.4	8.6	3.0	Sand	1.1	0.5	4.5	35.3	42.1	17.6	N	A44	
3065	105	37	SAV-37	92.4	4.6	3.0	Sand	0.6	0.6	18.5	38.6	30.2	12.1	N	A44	N
mysample	105		105						1.0	3.0	33.0	59.0		N		
3066	107	39	SAV-39	95.4	3.6	1.0	Sand	0.6	0.2	10.5	60.7	22.2	6.4	Y	A44	
3067	110	40	SAV-40	92.0	5.0	3.0	Sand	0.8	0.0	0.8	25.2	70.5	3.5	Y		
3068	130	41	SAV-41	95.0	4.0	1.0	Sand	0.4	0.1	2.0	59.8	36.6	1.5	N		
3069	133	42	SAV-42	98.0	2.0	0.0	Sand	0.3	0.2	9.4	70.4	19.3	0.7	Y		
3070	134	43	SAV-43	99.4	0.0	0.6	Sand	0.3	2.0	29.6	63.5	4.3	0.7	Y	L95	
3071	71	301	SAV-301	98.0	1.0	1.0	Sand	0.3	1.8	37.2	58.2	2.3	0.5	Y		
3072	73	302	SAV-302	92.0	5.0	3.0	Sand	0.8	1.5	20.2	61.4	6.8	10.1	Y	L95	Y
mysample	73		73						0.0	24.0	61.0	6.0		Y		
3073	75	306	SAV-306	92.4	7.0	0.6	Sand	0.7	1.8	21.2	56.4	12.4	8.2	Y	A44	
3074	78	307	SAV-307	94.0	5.0	1.0	Sand	0.5	0.5	12.7	65.0	13.7	8.1	Y		
3075	82	310	SAV-310	95.0	3.0	2.0	Sand	0.7	0.7	19.5	63.5	8.7	7.7	Y	A44	Y
mysample	82		82						0.0	18.0	66.0	8.0		Y		
3076	83	311	SAV-311	75.4	18.6	6.0	Sandy Loam	2.7	0.9	9.5	44.2	27.9	17.4	N	L85	N
3077	86	314	SAV-314	94.7	2.6	2.6	Sand	0.7	0.4	11.7	68.9	13.2	5.7	Y		
3078	87	315	SAV-315	80.4	17.0	2.6	Loamy Sand	1.1	0.3	0.1	0.2	51.0	48.4	N	L85	N
mysample	87*		87						0.0	3.0	31.0	15.0		N		
3079	91	318	SAV-318	94.4	3.0	2.6	Sand	0.7	0.7	30.3	51.5	14.8	2.7	Y		

3080	92	319	SAV-319	92.6	6.7	0.6	Sand	0.6	1.8	21.2	58.8	9.8	8.4	Y		
3081	96	320	SAV-320	44.3	43.7	12.0	Loam	7.0	0.9	3.5	20.1	33.3	42.2	N	Np grass 6.5'	N
mysample	96*		96						0.0	3.0	31.0	15.0		N		
3082	97	321	SAV-321	96.4	3.0	0.6	Sand	0.6	0.4	5.6	76.8	13.4	3.8	Y	Eel grass 3.5'	Y
mysample	97		97						0.0	6.0	78.0	10.0		Y		
3083	98	322	SAV-322	71.0	24.4	4.6	Sandy Loam	2.4	0.8	0.9	9.0	58.2	31.1	N		
3084	100	323	SAV-323	90.0	7.4	2.6	Sand	0.9	2.8	23.4	48.6	13.5	11.8	Y		sick plants
3251			400	85.5	11.4	3.2	Loamy Sand	1.2	0.2	0.4	0.5	62.1	36.8	Y		
3252			401	87.5	8.4	4.2	Sand	0.7	0.0	1.0	17.1	61.6	20.2	Y		
3253			402	91.8	4.0	4.2	Sand	0.6	0.3	0.0	0.1	79.1	20.5	Y		
3254			403	94.8	1.0	4.2	Sand	0.4	0.0	0.3	10.5	81.1	8.1	Y		
3255			404	84.5	12.4	3.2	Loamy Sand	1.0	0.0	0.0	0.5	53.8	45.7	N		
3256			405	78.5	18.4	3.2	Loamy Sand	1.3	0.1	0.0	0.2	34.2	65.5	N		
3257			406	93.8	4.4	1.8	Sand	0.5	0.1	0.2	0.3	69.9	29.5	Y		
3258			407	96.8	0.0	3.2	Sand	0.3	0.1	0.2	7.6	87.7	4.5	Y		
3259			408	75.1	22.0	2.9	Loamy Sand	1.3	0.1	0.2	0.1	28.9	70.7	N		
3260			409	97.1	0.0	2.9	Sand	0.5	0.1	0.2	6.1	85.1	8.5	Y		
3261			500	95.1	2.4	2.5	Sand	0.5	0.0	0.1	3.0	84.8	12.1	Y		
3262			501	82.5	10.0	7.5	Loamy Sand	2.4	0.1	0.1	0.2	68.3	31.3	Y		
3263			502	94.1	3.4	2.5	Sand	0.6	0.3	0.4	0.9	77.9	20.5	Y		
3264			503	94.1	3.0	2.9	Sand	0.6	0.1	0.2	0.4	77.6	21.7	Y		
3265			504	90.5	6.6	2.9	Sand	1.0	0.2	0.1	0.3	74.7	24.7	Y		
3266			505	84.8	11.6	3.5	Loamy Sand	0.9	0.1	0.3	0.2	52.7	46.7	N		
3267			506	87.8	9.4	2.9	Sand	0.9	0.1	0.1	2.3	79.7	17.8	Y		
3268			507	93.1	4.4	2.5	Sand	0.6	0.2	0.4	5.6	84.0	9.7	Y		
3884			110	83	14	2	Loamy sand	0.8	0.1	0.0	0.3	74.5	25.1	Y		
3885			200	91	9	0	Sand	0.7	0.3	0.4	5.9	82.9	10.5	Y		
3886			201	87	10	3	Loamy sand	1.0	0.1	1.2	29.9	55.3	13.5	N		
3887			202	94	4	2	Sand	0.8	0.2	0.5	4.5	81.1	13.7	Y		
3888			203	73	21	6	Sandy loam	2.2	0.0	1.2	6.9	62.4	29.6	Y		
3889			204	94	5	1	Sand	0.8	0.3	5.7	42.5	42.0	9.5	N		

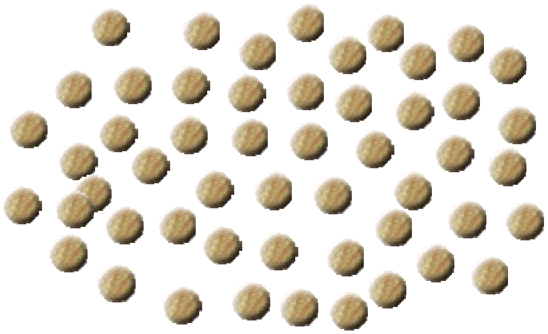
3890	205	87	9	3	Sand	1.2	0.2	5.9	42.1	41.5	10.3	N
3891	206	91	7	2	Sand	1.2	0.2	2.3	42.0	47.6	8.0	N
3892	207	94	3	3	Sand	0.7	0.3	1.0	36.1	57.1	5.5	N
3893	208	97	1	2	Sand	0.5	0.2	1.2	53.2	42.2	3.1	N
3894	209	87	11	2	Sand	1.7	0.0	1.4	29.4	54.2	14.9	N
3895	210	85	7	8	Loamy sand	1.0	0.0	0.9	19.6	69.3	10.2	Y
3896	211	77	11	12	Sandy Loam	1.3	0.2	1.5	10.9	69.2	18.2	Y
3897	212	80	12	8	Loamy sand	0.9	0.1	1.2	7.7	61.7	29.3	Y
3898	213	79	10	11	Sandy Loam	1.0	0.2	0.4	11.4	72.1	15.9	Y
3899	214	90	5	5	Sand	0.6	0.1	2.9	38.0	48.0	11.0	N
3900	215	76	14	9	Sandy Loam	1.1	0.2	4.5	34.0	40.3	21.0	N
3901	216	94	2	5	Sand	0.6	0.1	2.9	39.7	52.3	4.9	N
3902	217	96	2	3	Sand	0.6	0.1	11.3	12.2	78.0	8.4	Y
3903	218	76	13	11	Sandy Loam	1.7	0.1	0.1	0.7	62.1	36.9	Y
3904	219	69	14	17	Sandy Loam	2.4	0.5	4.2	30.0	51.5	13.9	N
3905	220	53	28	19	Sandy Loam	2.8	0.1	1.3	11.5	45.5	41.6	N
3906	221	87	6	7	Loamy sand	0.9	0.0	0.7	12.7	73.5	13.1	Y
3907	222	74	13	13	Sandy Loam	1.2	0.1	2.0	10.4	61.8	25.7	Y
4525	115-Site 1	97	1	2	Sand	0.2	0.2	6.1	28.3	64.1	1.4	Y
4526	A1	85	9	6	Loamy sand	1.2	0.4	0.4	0.8	74.1	24.3	Y
4527	A2	93	4	3	Sand	0.5						N
4528	A3	77	16	7	Loamy sand	2.5	2.3	1.2	2.3	76.0	18.2	Y
4529	A4	85	11	4	Loamy sand	0.8	0.1	0.1	1.6	84.6	13.5	Y
4530	A5	96	2	2	Sand	0.3	0.3	0.5	4.8	88.7	5.7	Y
4531	A6	69	19	12	Sandy Loam	1.2	2.4	3.3	4.3	72.8	17.2	Y
4532	A7	97	2	2	Sand	0.2	0.1	0.2	2.5	93.0	4.2	Y
4533	B1	83	14	3	Loamy sand	1.4	0.7	0.7	0.1	85.4	13.1	Y
4534	B2	87	10	3	Sand	1.0	0.1	0.4	0.2	83.9	15.4	Y
4535	B5	79	14	7	Loamy sand	1.5	0.4	0.6	0.4	74.6	23.9	Y
4536	B6	91	6	3	Sand	0.7	81.0	0.1	0.5	16.0	2.5	N
4537	B7	95	2	3	Sand	0.4	0.2	0.2	3.1	89.3	7.3	Y
4538	B10	62	30	8	Sandy Loam	3.0	0.7	0.1	0.3	16.2	82.7	N
4539	C1	25	69	7	Silt Loam	1.5	0.7	0.2	0.7	72.2	26.2	Y

4540	C2	91	6	3	Sand	0.7	0.3	0.3	0.8	88.0	10.7	Y
4541	C3	82	12	6	Loamy sand	1.5	0.3	0.4	0.7	81.9	16.6	Y
4542	C4	72	18	10	Sandy Loam	2.5	1.1	0.9	0.8	76.1	21.1	Y
4543	C6	82	11	7	Loamy sand	1.5	0.5	0.2	1.1	83.7	14.4	Y
4544	C7	77	15	8	Sandy Loam	1.8	0.7	0.4	0.9	80.8	17.1	Y
4545	D1	87	9	4	Loamy sand	1.0	2.0	2.8	2.6	80.7	11.9	Y
4546	D2	68	24	8	Sandy Loam	3.8	2.5	1.9	0.6	67.7	27.3	Y
4547	D3	74	20	6	Sandy Loam	1.4	0.8	0.5	0.8	82.2	15.7	Y
4548	D4	76	16	8	Sandy Loam	2.4	0.9	0.4	0.7	80.6	17.3	Y
4549	D5	77	17	6	Loamy sand	2.9	2.9	0.9	0.5	77.7	18.1	Y
4550	D6	91	5	4	Sand	0.6	1.1	0.6	0.9	86.7	10.6	Y
4551	D7	92	4	4	Sand	0.6	0.5	0.4	1.3	91.3	6.5	Y
4552	E2	69	23	8	Sandy Loam	2.7	0.4	0.1	0.9	68.8	29.7	Y
4553	E3	77	16	7	Loamy sand	1.8	1.4	1.1	2.1	79.9	15.6	Y
4554	E4	72	20	8	Sandy Loam	2.6	1.4	0.5	0.5	75.7	21.9	Y
4555	E5	89	7	4	Sand	1.0	6.8	12.0	8.0	60.9	12.3	Y
4556	E6	76	17	7	Sandy Loam	2.4	1.5	0.8	1.2	80.3	16.2	Y
4557	E7	83	11	6	Loamy sand	1.6	1.2	1.5	2.2	77.6	17.5	Y
4558	F1	83	10	7	Loamy sand	1.4	0.1	0.1	0.2	79.5	20.2	Y
4559	F2	71	21	8	Sandy Loam	3.0	2.1	0.8	0.9	73.6	22.6	Y
4560	F3	86	8	6	Loamy sand	1.1	1.0	0.6	0.9	77.0	20.5	Y
4561	F4	89	5	6	Sand	1.0	1.0	2.1	2.8	81.3	12.9	Y
4562	F5	89	7	4	Sand	1.1	0.5	0.7	1.6	82.4	14.8	Y
4563	F6	83	10	8	Loamy sand	1.3	0.5	0.9	1.9	83.1	13.6	Y
4564	G1	76	15	9	Sandy Loam	2.1	1.3	1.7	1.5	79.7	15.7	Y
4565	G2	76	15	9	Sandy Loam	2.1	1.9	1.4	1.4	71.8	23.4	Y
4566	G3	89	6	6	Sand	1.0	1.2	2.4	3.9	79.1	13.4	Y
4567	G4	87	7	6	Loamy sand	1.1	0.1	0.2	0.3	81.2	18.3	Y
4568	G5	84	8	8	Loamy sand	0.9	0.2	0.5	0.7	85.7	13.0	Y
4569	G6	88	6	6	Sand	1.3	1.0	1.4	1.9	79.1	16.7	Y
4570	G7	76	15	9	Sandy Loam	2.3	0.6	0.6	0.3	80.3	18.2	Y
5309	REM 1	99	1	0	Sand	0.1	5.3	32.9	49.0	12.6	0.2	Y

5310	REM 2	99	1	0	Sand	0.1	1.5	11.4	75.6	11.4	0.1	Y
5311	REM 3	100	0	0	Sand	0.1	0.7	29.8	66.6	2.9	0.0	Y
5312	REM 4	99	1	0	Sand	0.1	0.3	15.6	79.6	4.5	0.1	Y
5313	REM 5	100	0	0	Sand	0.4	7.6	42.5	47.6	2.3	0.1	Y
5314	REM 6	100	0	0	Sand	0.2	3.8	39.3	51.2	5.5	0.2	Y
5315	REM 7	100	0	0	Sand	0.3	0.6	31.2	52.9	14.9	0.4	Y
5316	REM 8	100	0	0	Sand	0.2	2.1	18.9	48.0	30.0	1.0	N
5317	REM 9	100	0	0	Sand	0.2	1.3	8.3	51.3	38.0	1.1	N
5318	REM 10	100	0	0	Sand	0.2	1.6	9.1	57.7	28.2	3.3	N
5319	REM 11	100	0	0	Sand	0.2	1.4	11.0	41.2	44.7	1.7	N
5320	REM 12	100	0	0	Sand	0.3	1.3	6.2	17.6	65.5	9.3	Y
5321	REM 13	100	0	0	Sand	0.2	0.4	3.1	26.4	69.1	1.0	Y
5322	REM 14	100	0	0	Sand	0.3	0.2	4.8	48.6	46.2	0.2	N
5323	REM 15	100	0	0	Sand	0.2	0.4	4.7	43.8	50.5	0.6	N
5324	REM 16	100	0	0	Sand	0.4	0.9	4.0	43.9	50.3	0.8	N
5325	REM 17	100	0	0	Sand	0.4	2.3	7.2	42.0	46.8	1.7	N
5326	REM 18	100	0	0	Sand	0.4	5.7	28.0	50.7	15.0	0.6	Y
5327	REM 19	100	0	0	Sand	0.2	0.5	17.0	43.7	38.1	0.6	N
5328	REM 20	100	0	0	Sand	0.0	0.2	9.5	58.1	31.8	0.5	N
5329	REM 21	100	0	0	Sand	0.0	0.3	1.3	60.0	37.8	0.6	Y
5330	REM 22	100	0	0	Sand	0.0	0.9	2.1	47.7	48.7	0.7	N

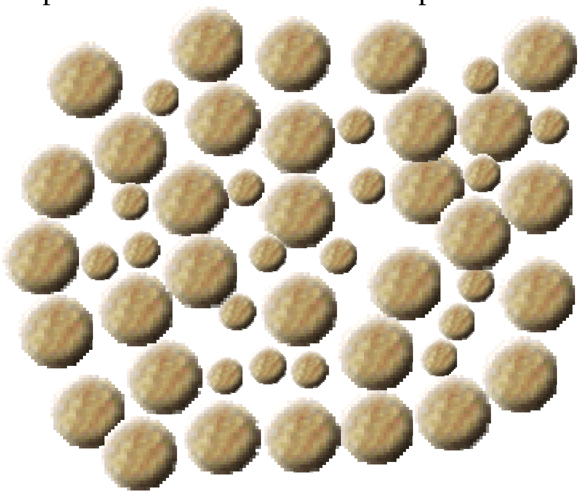
Appendix E. Correct grain count using relative scale on a weight basis converted representative drawings on a volume basis. 100 percent medium sands

100 percent fine sand



The two graphics across the bottom of this page represent the maximum particle size mixing before SAV become posioned with accumulating H_2S.

60 percent medium sand and 40 percent fine



60 percent fine and 40 percent medium