Sediment Accretion and Marsh Elevation in Estuary Enhancement Program Sites

K. R. Philipp Wetlands Research Services P.O. Box 156 Newark, DE 19715

Introduction

The Estuary Enhancement Program (EEP) of the Public Service Enterprise Group (PSEG) restored large areas of tidal marsh within the Delaware River and Bay. Site restoration has brought about a rapid evolution of marsh plains. Monitoring the net change in marsh plain surface elevation and sediment accretion following restoration is a factor in assessing restoration success.

EEP restoration sites (Figure 1) consist of three salt hay sites and four Phragmites sites. Restoration actions in former salt hay farm sites consisted of breaching farm dikes to create new inlets to tidal waters, excavating/dredging new creeks, creating new high marsh areas, and creating new transition and upland protection dikes. Restoration action in former Phragmites australis dominated sites is herbicide application. Restoration construction in salt hay farm sites was completed in 1997 and herbicide application begun in 1997 continues at reduced application levels in most sites.

Methods

Marker horizons of multi-colored glitter and sand were established in pairs of 1.0 m2 areas to sample sediment accretion on all sites. A Russian peat corer, which makes a horizontal cut to minimize sampling compaction, was used to collect cores. Sediment accretion was measured as the depth (+0.25 cm) from the sediment surface to the top of the glitter/sand marker horizon in sampled cores. All initial marsh plain surface elevations and all Commercial Twp elevations were surveyed to a horizontal and vertical accuracy of 0.25 cm using GPS RTK equipment. Phragmites site marsh plain elevation 2012 data had a vertical accuracy of + 8 cm in 2012 data.

Figure 2 shows the installation of pairs of m^2 glitter/sand sampling locations on salt hay farm site in 1997.

Figure 3 is a photograph of a sampling location on salt hay farm site and GPS equipment in 2012.

Photographs of sampling location # 8 on the Commercial Twp. salt hay farm site in 2003 (Figure 4) and in 2012 (Figure 5) illustrate the extent of change in elevation, sediment accretion, and establishment of *Spartina alterniflora* at one location. Prior to 2003 broad sheet flow of water during higher tides, scoured the sediment down to salt hay stems and rhizomes. The early development of flow alignment and channel Formation has allowed high rates of sediment accretion (10 cm/yr) and establishment of *Spartina alterniflora*.

Figure 1

Figure 1 presents the location off EEP restoration sites.

Phragmites Sites		Salt Hay Farm Sites	
Allaways Creek	Rocks	Commercial Twp.	Dennis Creek Twp.
Cohansey River	Cedar Swamp	Maurice River Twp.	

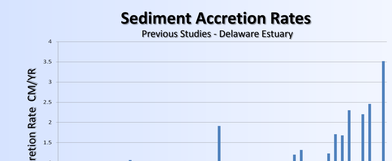

Figure 6

Figure 6 presents sediment accretion rate (cm/yr) data for Delaware Estuary sites as provided in Reed (2008) and Delaware DNREC (Personal communication Bart Wilson 2012). Longer Term refers to methods using Cs^{137} and Pb^{210} isotope methods and Recent refers to Sediment Evaluation Table (SET) methodology.

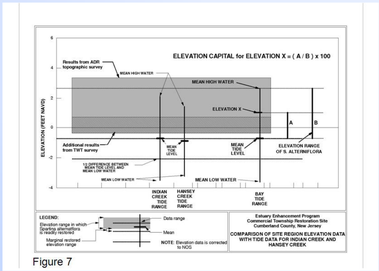

Figure 7

During the EEP site restoration design, we investigated the elevations where *Spartina alterniflora* was observed at all project site locations using photogrammetry and ground elevation surveys (Figure 7). Generally, *Spartina alterniflora* was found within the tidal range of each site location between Mean Tide Level (MTL) to just above Mean High Water (MHW). This general tidal elevation range for *Spartina alterniflora* agrees with the general findings of McKee and Patrick (1988) and Morris et al (2005).

The concept of elevation capital has been introduced and used by Reed (2002) and Cahoon and Gunterspergen (2010) to refer to marsh elevation within the tidal zone in terms of resilience to relative sea level rise. We use elevation capital as a way to compare sediment accretion and elevation change in the EEP tidal wetland restoration sites that differ in local tide ranges and marsh elevations.

The elevation capital expression of a marsh plain elevation value in this study is defined (Figure 7) as a percentage of the tidal range of Salt. (MTL to MHW). Specifically, for a marsh plain elevation of 50.0 cm NAVD 88 on the Commercial Twp. site, where MTL is -17.9 cm and MHW-MTL is 83.8 cm:

Elevation Capital of 50.00 cm = ((50.0 cm - (-17.9 cm))/83.8 cm) x 100 = 81.1 cm

The initial marsh plain elevations at the time of sediment accretion monitoring locations have been expressed in terms of elevation capital to allow for a comparison of sediment accretion data across all EEP restoration sites (Figure 8). Tidal metrics for site locations were used for the nearest NOAA tide prediction stations.

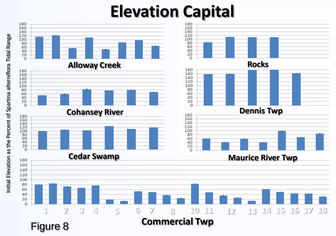

Figure 8

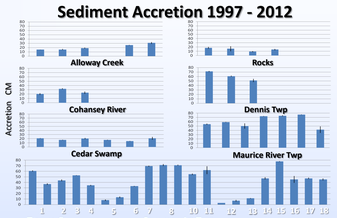

Figure 9

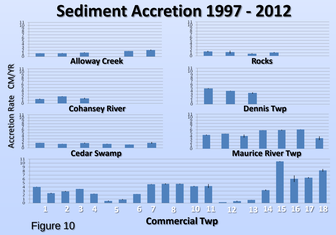

Figure 10

Results and Discussion

Figures 9 and 10 display sediment accretion data for all sites between 1997 and 2012. Significant accretion was observed in all sites.

Sediment accretion in Phragmites sites generally ranged from 10 – 30 cm (1 – 2 cm/yr). These values are in the range of accretion rates shown for Delaware DNREC data (Figure 6). Phragmites site monitoring locations have established vegetative communities of *Spartina alterniflora*, mixed marsh, and Phragmites.

Sediment accretion in salt hay farm sites generally ranged from 2 – 75 cm (0 – 10 cm/yr). Specific monitoring location numbers are shown in all data charts for the Commercial Twp. site. Monitoring locations 5, 12, and 13 experienced scouring and erosion from sheet flow of tidal water, as well as resuspension of sediment from wind during high tides. Commercial Twp. monitoring locations 8 and 18 experienced similar conditions, then rapidly accreted sediment and established *Spartina alterniflora* (Figure 16). Salt hay farm monitoring locations may be characterized as having established *Spartina alterniflora*, early colonizing *Spartina alterniflora*, or mud flats.

Figure 11 – General conceptual relationship of sediment accretion and tidal range elevation (Callaway *et al* 2012).

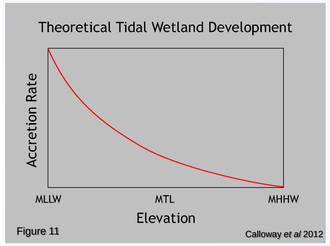

Figure 11

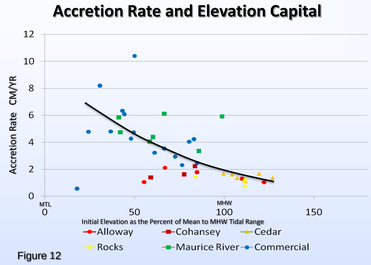

Figure 12

Sediment accretion rate versus the initial elevation of monitoring locations expressed as Elevation Capital for all sites is shown in Figure 12. Salt hay farm sites (Commercial and Maurice River) have high accretion rates for initial low elevations within the tide range of *Spartina alterniflora* (low Elevation Capital). The Phragmites sites have lower accretion rates for relatively higher marsh plain elevations (high Elevation Capital).

This relationship of decreasing sediment accretion rate with increasing relative position in the tide range (Elevation Capital) is as expected and why tidal marshes are generally flat in elevation.

Data for Dennis Creek Twp. are not included in Figure 12, since there appears to be an error in the tidal data available for the site. Calculated Elevation Capital values are too high for the observed marsh plain elevations and sediment accretion rates. Commercial Twp. monitoring locations 5 and 12 are also not included, due to high erosion from early channel development.

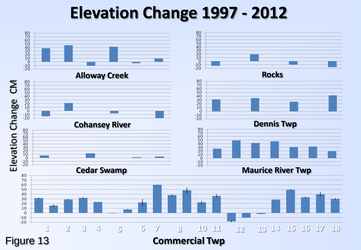

Figure 13

Figure 13 presents the change in monitoring location elevation 1997 to 2012. Phragmites sites display both gain and loss in elevation during a period where there was a general change from a dominance of Phragmites to *Spartina alterniflora* at these locations. Gains in elevation (10-40 cm, 0.7-2.7cm/yr) occurred for both Phragmites to *Spartina alterniflora* (not identified here). Loss in elevation was associated with shoreline erosion (Cohansey River), change from Phragmites to *Spartina alterniflora*, and possibly collapse/decay of Phragmites rhizomes.

Salt hay farm sites generally displayed a significant gain in elevation (15-60 cm, 1-4 cm/yr), largely assumed to be related to the low Elevation Capital of their initial site elevations (Figures 8 and 12). Commercial Twp. locations 5, 8, 12, 13, & 18 were scour-erosion/fetch/low sediment input areas.

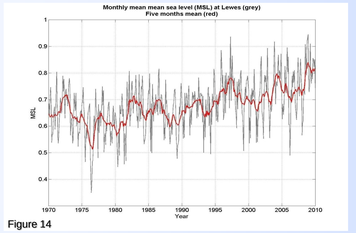

Figure 14

Figure 14 shows the record for Mean Sea Level at Breakwater Harbor, Lewes, Delaware (5 month running average). A rough fit of the trend over the last 30 years suggests rise of about 6 mm/yr.

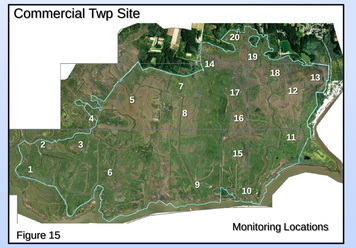

Figure 15

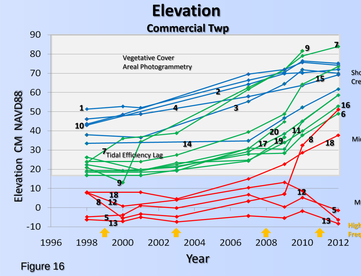

Figure 16

Figure 15 presents monitoring locations at the Commercial Twp. site. Figure 16 presents monitoring location elevation for the period 1998 – 2012. Trend line color groups locations to low, mid and high Elevation Capital ranges. MTL is -18 cm and MHW 66 cm.

Monitoring locations with high Elevation Capital rapidly established stable dominant *Spartina alterniflora* vegetation and displayed steady sediment accretion rates. Locations with mid level Elevation Capital were slower to establish stable vegetation and accrete sediment. Observational data from site field reviews suggest that sediment accretion (and increases in elevation) followed pronounced channel network development that occurred in 2004 – 2006. High accretion rates are seen in this group 2007 – 2012. Low Elevation Capital locations are mud flats that area characterized by low sediment input, poor/slow channel development (and sheet flow hydrology), and swings in elevation gains and losses.

The shaded area indicates monitoring locations/dates that are shown as vegetated in annual remotely sensed site mapping. Monitoring locations 8 and 18 went from mud flats to stable vegetation as shown in their trend lines. The lower edge of the shading corresponds to an Elevation Capital of about 40%. Low Elevation Capital mud flat locations tend to reflect losses in elevation following years of higher coastal storm frequency/severity.

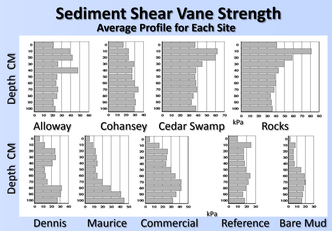

Figure 17

Figure 17 presents preliminary sediment shear stress data for all sites. Phragmites rhizome depth (10-20 cm) and historic salt hay depths (60-80 cm) are clear. The pattern with depth indicating rhizomes may be less clear for the Commercial site due to a more variable depth to the old salt hay mat. The Bare Mud profile is the typical Commercial Twp. mud flat profile. The Reference profile is for an average of reference marshes near the Commercial site that are dominated by *Spartina alterniflora*, *Spartina patens/Distichlis spicata* areas. Shear stress with depth profiles that have low shear stress values near the surface may be related to the initial establishment of *Spartina alterniflora*.

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