Will Knowing Tidal Elevation Help Explain Variations in Sediment Chemistry and Microbial Processes Among Sample Plots in Tidal Marshes?

A Brief Explanatory Note

Joshua N. Collins, Ph.D.
San Francisco Estuary Institute
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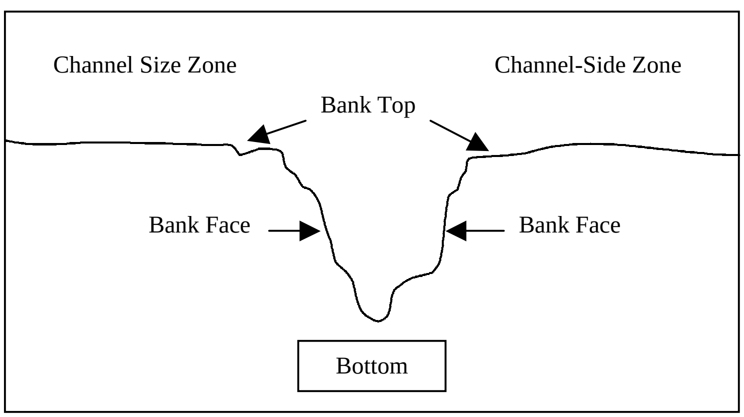
Questions have arisen about the need to measure tidal elevation along tidal marsh channels where samples of sediment and interstitial water are being taken by PEEIR investigators. This is a brief rationale for tidal elevation surveys.

Basic Features of the Cross –section of a Typical Tidal Marsh Channel

The diagram below shows the basic features of a tidal marsh channel. Here we regard the channel in cross-section as having a point of maximum depth at the *bottom*, with *bank faces* that slope upward from either side of the channel bottom, a *bank top* at the upper limit of each bank face, and a *channel-side zone* perhaps as wide as 2x bank face height that extends across the marsh surface away from each bank edge.



An important feature of the channel cross-section not shown in this diagram is the usual change in sediment type with distance away from the bank face. The channel bottom and banks mostly consist of inorganic sands, silts, and clays that are carried into the marsh and deposited by the tides. The amount of organic sediment in the form of plant roots and detritus produced in place increases with distance away from the bank. Most of the filtering or entrapment of suspended sediment by vegetation happens in the channel-side zone.

As will be shown below, the channel-side zone is indicated by a unique plant assemblage. For plant species of this assemblage that also occur in other parts of the marsh, the morphometery is distinctive within the channel-side zone. For example, pickleweed tends to be taller and woodier along channels than on the marsh plain outside of the channel-side zone. The zone is indicated below ground by the lateral extent of the drawdown curve of the near-surface water table.

Channel-Side Hydrology

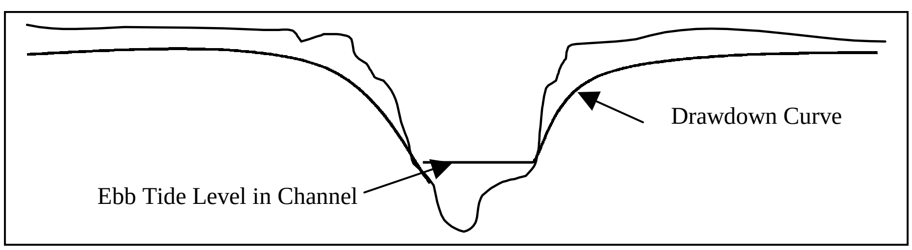
As the flood tide rises against the banks, water begins to infiltrate horizontally into the interstitial spaces in the bank sediments. This is slow because the banks are clayey, and clays reduce hydraulic conductivity.

A bankfull tide just rises to the bank tops, but does not spill over onto the channel side zone. A tide that rises above the bankfull stage is termed an over-bank tide. The terms bankfull and over-bank tide do not have the same meaning in tidal systems as they do in fluvial systems. In tidal system, the terms simply refer to tides that either reach the bank top (bankfull tide) or reach above the bank top (over-bank tide).

A tide that rises above the bank top crosses the channel side zone and begins to inundate the marsh plain. As the tide crosses the channel size zone, water begins to infiltrate vertically. This is slower near the bank edge, where clays are most abundant, and faster away from the bank, where the clays are less abundant.

Vertical infiltration is fastest around the bases of plant stems, where the water can follow the stems and roots downward.

As the tide reverses and starts to ebb, the water drops much faster in the channel than from the marsh plain. Water that has infiltrated the banks begins to seep from the exposed bank faces. Seepage is usually most obvious from the exposed root zone. The rate of groundwater movement toward the bank face decreases with distance into the banks. This, when view in cross-section, produces a subterranean drawdown curve inside each bank and below the channel-side zone, as shown below.

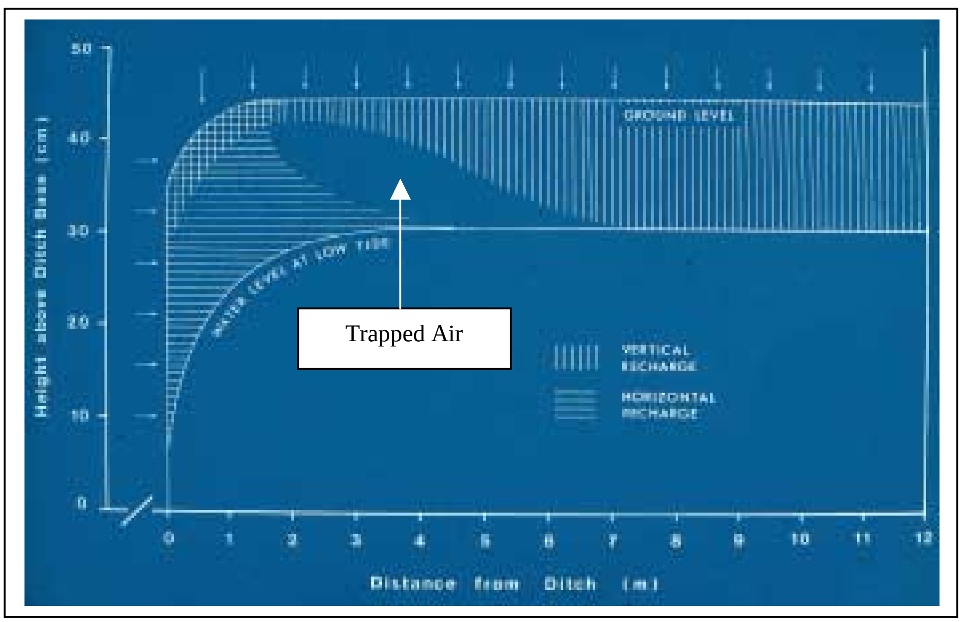


The horizontal extent of the drawdown curve and the steepness of the curve indicate the extent and rate of tidal flushing of the bank sediments.

At places on the marsh outside of the channel-side zone, and thus beyond the lateral extent of the drawdown curve, the near-surface groundwater moves vertically through the sediments due to vertical infiltration (over-bank tides raise the water table), evapotranspiration (this lowers the water table), and capillary action (this keeps the sediments above the near surface water table wet but not necessarily saturated, even when the water table is depressed by ongoing evapotranspiration during a lack of over-bank tides. There is essentially no advective or horizontal movement of the near-surface water table outside of the channel-side zone, and hence no tidal flushing of solutes, etc. In places away from the channel-side zone, the groundwater can have very high concentrations of salts and other materials, due to local sequestering of these materials and high evapotranspiration rates.

One of the interesting things about channel-side hydrology is that the hydraulic conductivity of clayey banks is so slow that the vertical and horizontal infiltrations are seldom complete. That is, the banks seldom completely fill with water from top to bottom. Because of the slow horizontal and vertical infiltration rates near the bank, there is often an area below the bank top where air is trapped at high tide. If you walk from the bank top across the marsh plain when it is inundated by high tide, and stab a stick 30-40 cm into the marsh surface with each step, bubbles will emerge from the stab wounds at places within the first third of the channel-side zone. These bubbles come from the air trapped below the vertical infiltration at the bank top and behind the horizontal infiltration at the bank face, as the diagram below shows. This little field exercise works most of the time. When it doesn't you have to wonder why.

In this diagram, substitute the word channel for ditch. The diagram is based on empirical observations of infiltration rate and drawdown curves at Petaluma marsh. The source of data is a study I did of the effects of mosquito control ditches on vegetation in Petaluma marsh.



It is hypothesized that this area of trapped air enables some species of channel-side plants, such as Grendelia and Baccharis, which cannot tolerate long periods of root saturation, to survive along channels. It is also hypothesized that, for plant species that grow along banks and also on the marsh plain, their more robust stature along channels relates to tidal flushing of sediments in the banks. Who knows.

Another interesting thing is that the horizontal extent of the drawdown curve away from the bank face is a function of the height of the bank face (the higher face is exposed above the tide longer an thus has longer to dewater). And, the height of the face is a function of the channel order. The smaller (low-order) channels are less deep than the larger (high-order) channels. This means that small channels have narrower channel-side zones and less amplitude to their drawdown curves than large channels. Furthermore, large channels will be deeper in marshes with a large tidal range than in marshes with a low tidal range (Mean High Water minus Mean Low Water).

So What?

For any place above the minimum height of the tide, tidal elevation controls the frequency, timing, duration, and depth of inundation. These parameters constitute the tidal hydroperiod of a site.

The tidal hydroperiod controls the amount of tidal flushing on the marsh surface and at any depth below the marsh surface and above the near-surface water table. Furthermore, for any sediment type, the steepness and extent of the drawdown curve is controlled by tidal elevation, since this controls the height of the bank face.

In essence the tidal hydroperiod and the nature of the near surface water table are controlled by tidal elevation and distance from channel bank.

If the chemistry of the sediments is affected by the rate of tidal flushing, then it will vary with elevation of the marsh surface and distance away from the bank face.

Details

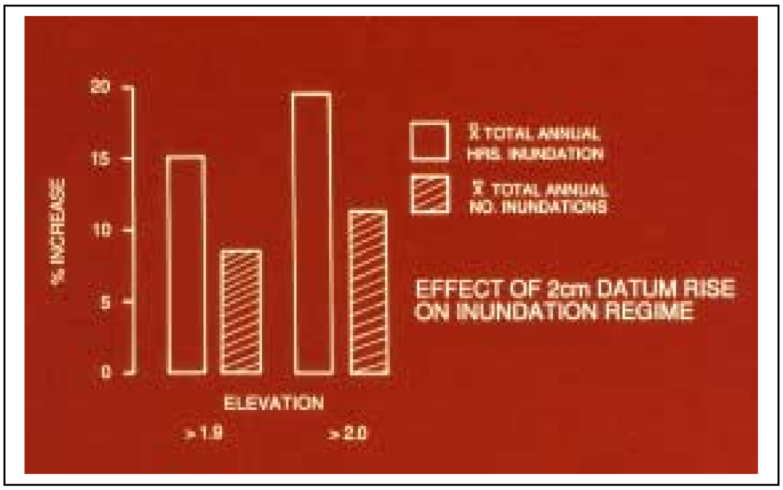
We have tides of the mixed-diurnal type. There are two highs and two lows each lunar day, and, except when the moon is on the equator, all four slack waters are different heights. Plus, the highs are higher and the lows are lower during spring tides (the week around new moon and the week around full moon) than during neap tides (around the quarter moons).

If we go out to sample interstitial water within the channel-side zone at the end of a neap series of tides, we may have to dig deep. The marsh will be dry above the drawdown curve that has been depressed by the lack of tides above bankfull height. And what we find will have been subjected to much evapotranspiration. If we go out at the end of a spring series, the sediment will be saturated (except on the bank top of very high marshes, or in the area of trapped air).

If we sample away from the channel-side zone we get into interstitial water that has nowhere to go except out into the air, and whatever falls there from the air tends to stay put. The chemistry of the interstitial water away from the channel-side zone must reflect the lack of flushing and the ongoing delivery of new stuff in the tides plus the products of plant metabolism and degradation, etc.

So, given all of this, a decision might be made to sample interstitial water at a depth of perhaps 10 cm (in the root zone) at the end of spring tide in two strata, the bank top and the marsh plain outside of the channel-side zone. This gives us pretty good horizontal and temporal control over tidal hydroperiod (the frequency, timing, duration, and depth of surface inundation) and subterranean tidal flushing, within a site (at one cross-section). But to get really good control of the variance between cross-sections (between sites along a channel or between channels), we need to stratify by tidal elevation. Not all bank tops or channel-side zones have the same tidal elevations.

How accurate and precise do our measures of elevation need to be? I don't know, but here are some considerations. The hydroperiod decreases exponentially with increasing elevation (due to the shape of the relationship between tide height and time over a tide cycle). The higher the marsh, the greater the change in hydroperiod per unit change in elevation. If the marsh surface is very near the upper limit of the tide, then slight change in elevation can have big effects on hydro period.



The chart at left says that a 2 cm rise in high tide (or a 2 cm drop in marsh elevation) causes a 15% increase in hrs of inundation at 1.9 m above low tide, and a 20% increase at 2.0 m above low tide. The source of data is a study I did of the effects of mosquito control ditches of tidal hydroperiod in Petaluma Marsh.

Given that the total range in elevation along any 10-m length of the bank edge might be 20 cm (personal observation), then it seems important to know (plus or minus 2 cm or less) at what elevations the sediment samples are taken, when they are taken relative to freshwater input (season), when they are taken relative to moon phase (spring or neap tides), and where they are taken relative to the bank top.

How to get the elevation data that might be needed

I suggest we established a tide gage at each site to estimate the local Mean High Water tidal datums. Every sample plot of any kind should be marked on-center with PVC or similar marker, and fixed with a unique code. After the datum has been established, then the sample plot elevations can be determined by surveying between the sample plots and the tide gages. This is the only way to find out if elevation matters or not. Until we find out, I think we have to assume elevation matters a lot.

References

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