Processes Governing Tidal Mudflat Width in South San Francisco Bay

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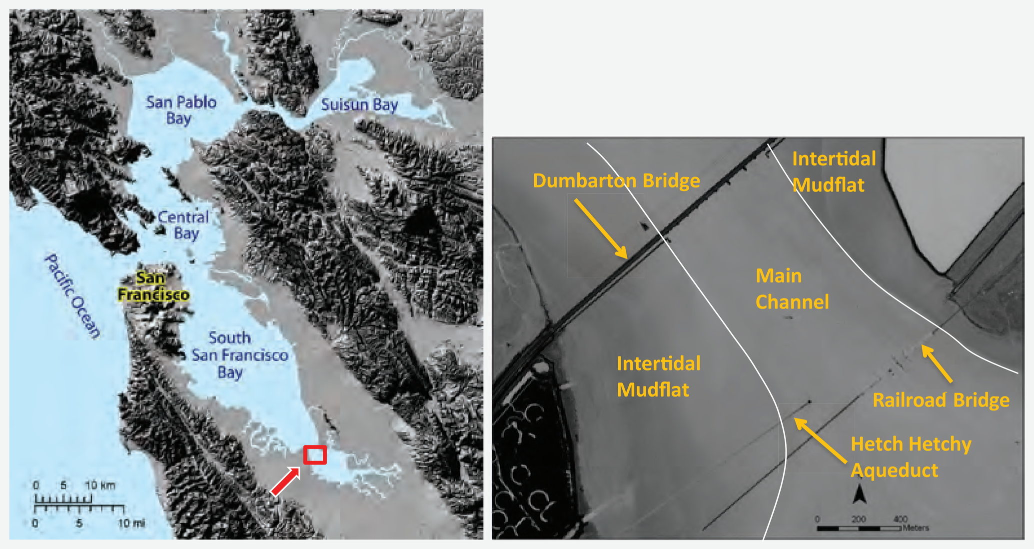
Abstract

Estuarine intertidal flats are rich ecological habitats that evolve morphologically in response to changes in hydrodynamic forces, sediment supply, and sea level rise. To explore the processes governing tidal mudflat width, we use a combination of observations and 1D process-based modeling (Delft3D) of the mudflat-channel system at Dumbarton Bridge in South San Francisco Bay, CA. Bathymetric surveys collected approximately every 30 years from 1858 to 2005 document that mudflat width varied from 550 to 900 m. Mudflat width correlated with overall sediment gains and losses in the lower South Bay. Mudflats widened/narrowed when the lower South Bay was depositional/erosional. Simple 1-D modeling provides a possible explanation for the change in mudflat width at Dumbarton Bridge. Model runs with constant wave and tide forcing show bayward widening of mudflats when sediment supply, parameterized by suspended sediment concentration (SSC), is high. When SSC is low, mudflats narrow from wave erosion. An additional factor that controls mudflat width is the rate of sea level rise. Mudflats narrow when SSC is not high enough to provide the sediment required for the mudflat to vertically accrete at the same rate as the rising sea level. This study will improve our ability to assess the susceptibility of mudflats to human activities that may affect sediment availability, such as ongoing restoration projects and sea level rise.

Study Site

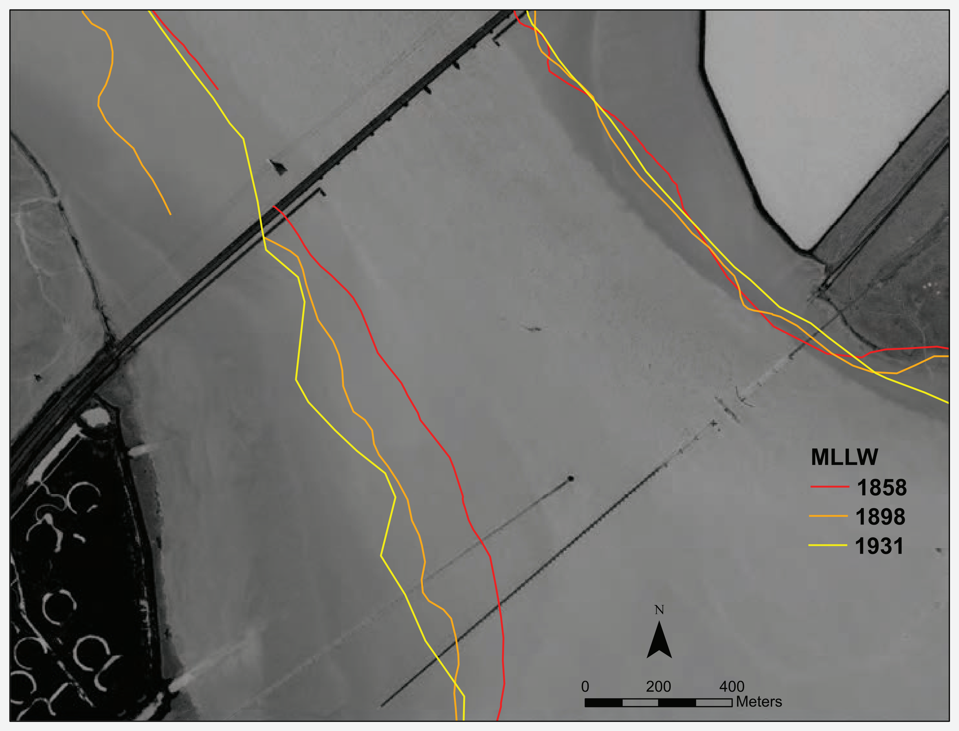


Data Sources

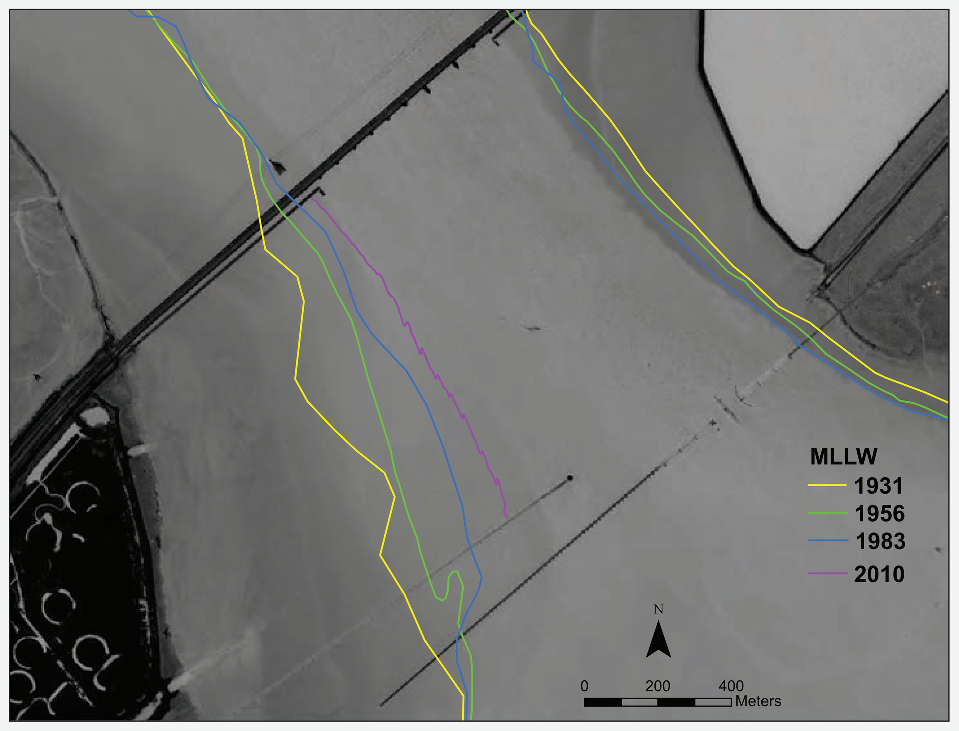
The bathymetry data for South San Francisco Bay was collected using a variety of methods ranging from lead line and poles in the 1800s, to echo sounding in the 1900s, to interferometric sidescan mapping in the 2010 (Foxgrover et al., 2004; Foxgrover et al., 2015). The data in the 1800s and 1900s is swath point data. The 2010 data is very dense, with as much as 50 data points per square meter.

Long-term Change in Mudflat Width

Mudflats on the west side of South San Francisco Bay just south of Dumbarton Bridge are dynamic. The mudflat width, defined as the distance between the shoreline and the MLLW line, changed 300 m. The mudflat was narrowest in 1931 (~600 m) and widest in 2010 (~900 m).



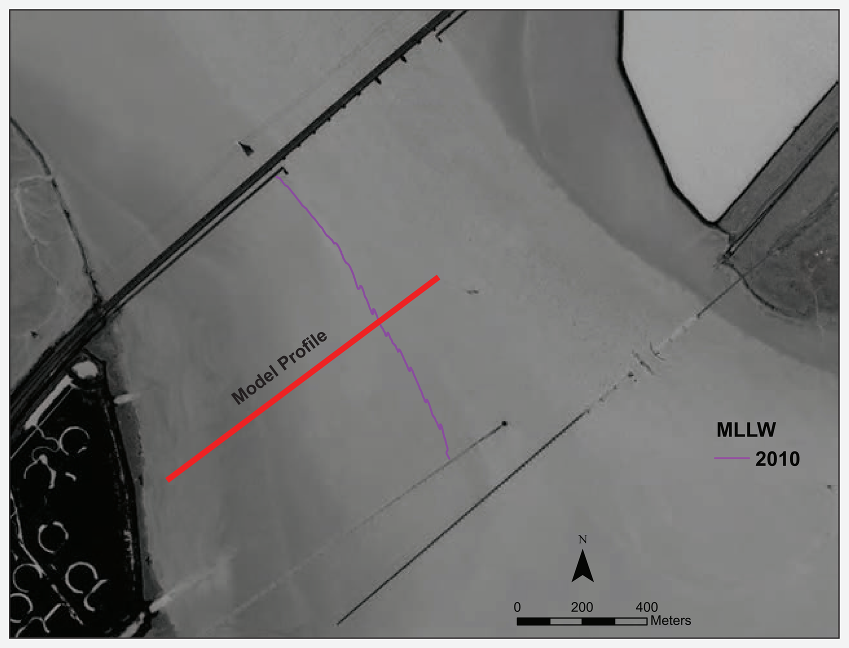
Mudflats narrowed ~200 m from 1858 to 1931.



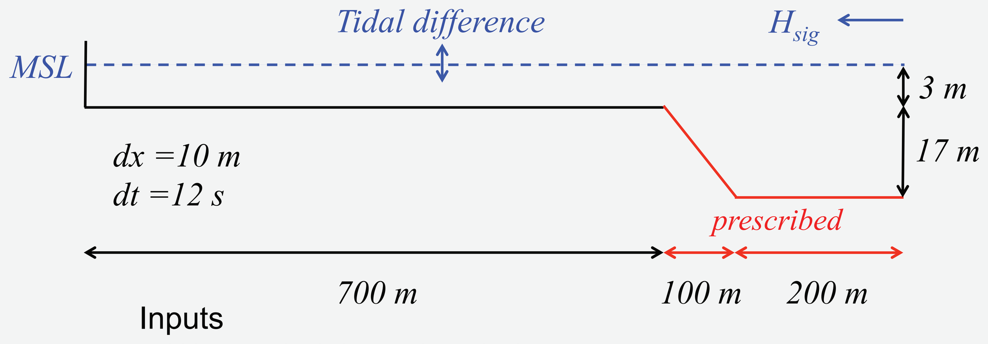
Mudflats widened ~300 m from 1931 to 2010.
Mudflats have accreted to keep up with sea level rise.

Mudflat Evolution Modeling

"All models are wrong, but some are useful"
George Box, 1976



1D Delft3D model

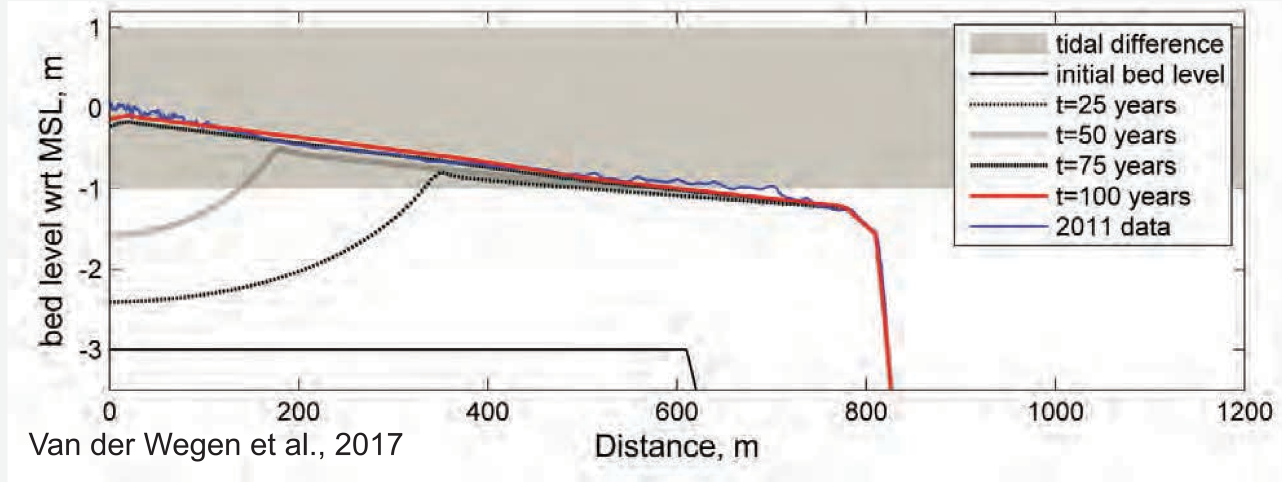


Inputs
- Waves (height and period)
- Tides
- Sediment properties (particle settling velocity, critical erosion stress, bed density)
- Boundary suspended sediment concentration

Parameter	Standard run	Low Run	High Run
Model Inputs			
Boundary SSC, c (mg/l)	45	25	90
Initial mudflat depth, dep_{ini} (m)	3	3	3
Significant wave height, H_s (m)	0.123	0.123	0.123
Tidal amplitude, dH (m)	0.5	0.5	0.5
Peak wave period T_p (s)	2.5	2.5	2.5
Erosion coefficient, M ($kg/m^2/s$)	$5*10^{-4}$	$5*10^{-4}$	$5*10^{-4}$
Dry bed density, ρ_{dry} (kg/m^3)	1200	1200	1200
Critical erosion shear stress, $\tau_{cr,e}$ (Pa)	0.25	0.25	0.25
Fall velocity, w (mm/s)	1	1	1
Model Settings			
Diffusion coefficient, D (m^2/s)	10	10	10
Morphological factor, MF (-)	100	100	100

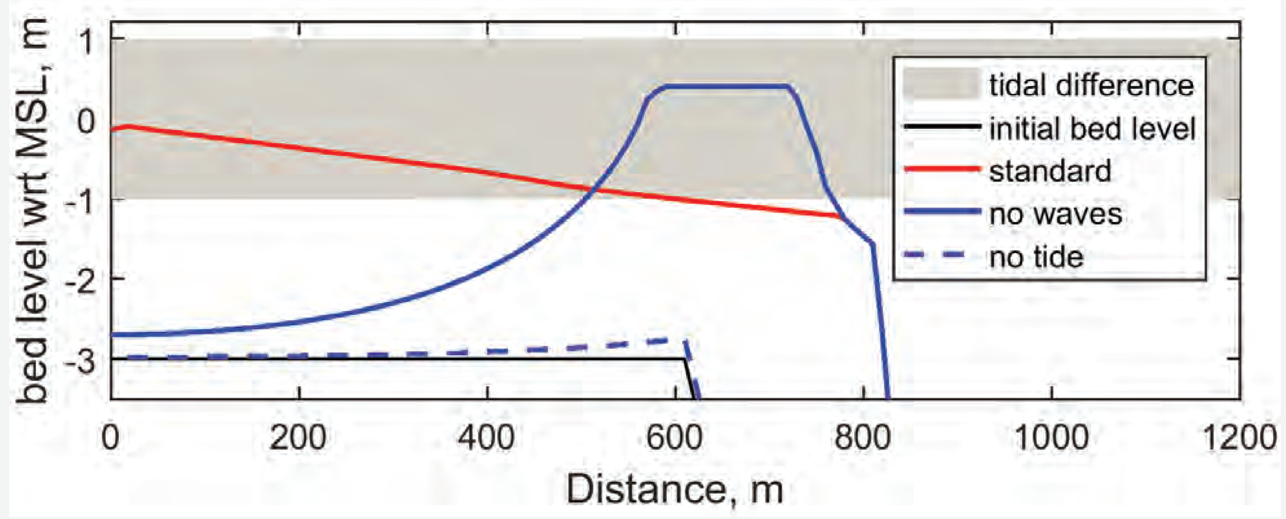
A 1D process-based model, Delft3, was used to explore whether mudflats would develop from a planar shoal 3 m below MSL (Van der Wegen et al., 2016). In this study we investigated the effects of change in the background suspended sediment concentrations.

Mudflat formation from a submerged shoal

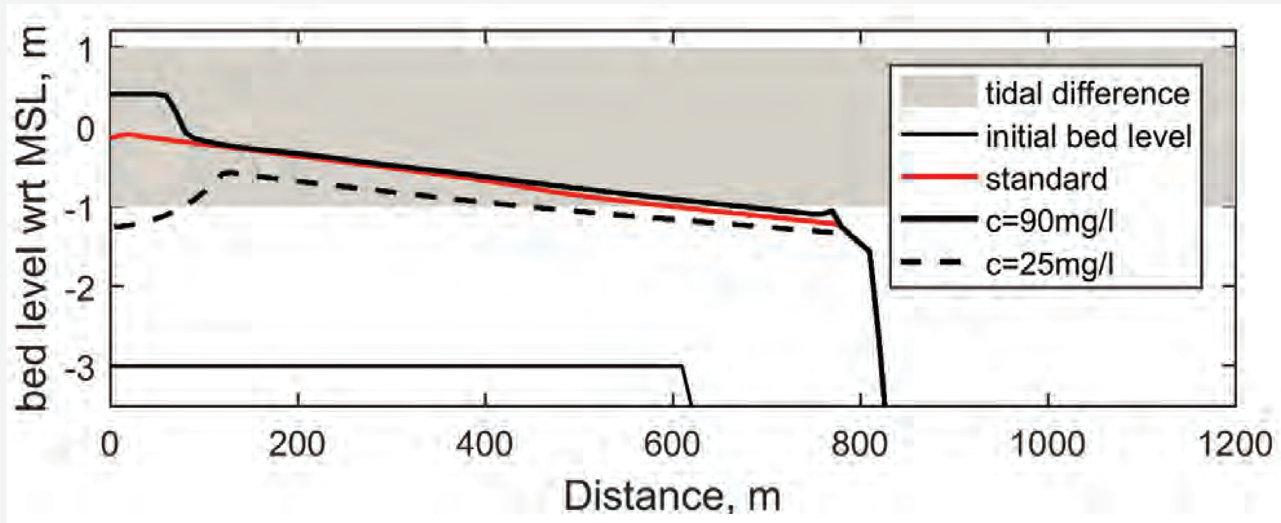


Van der Wegen et al., 2017

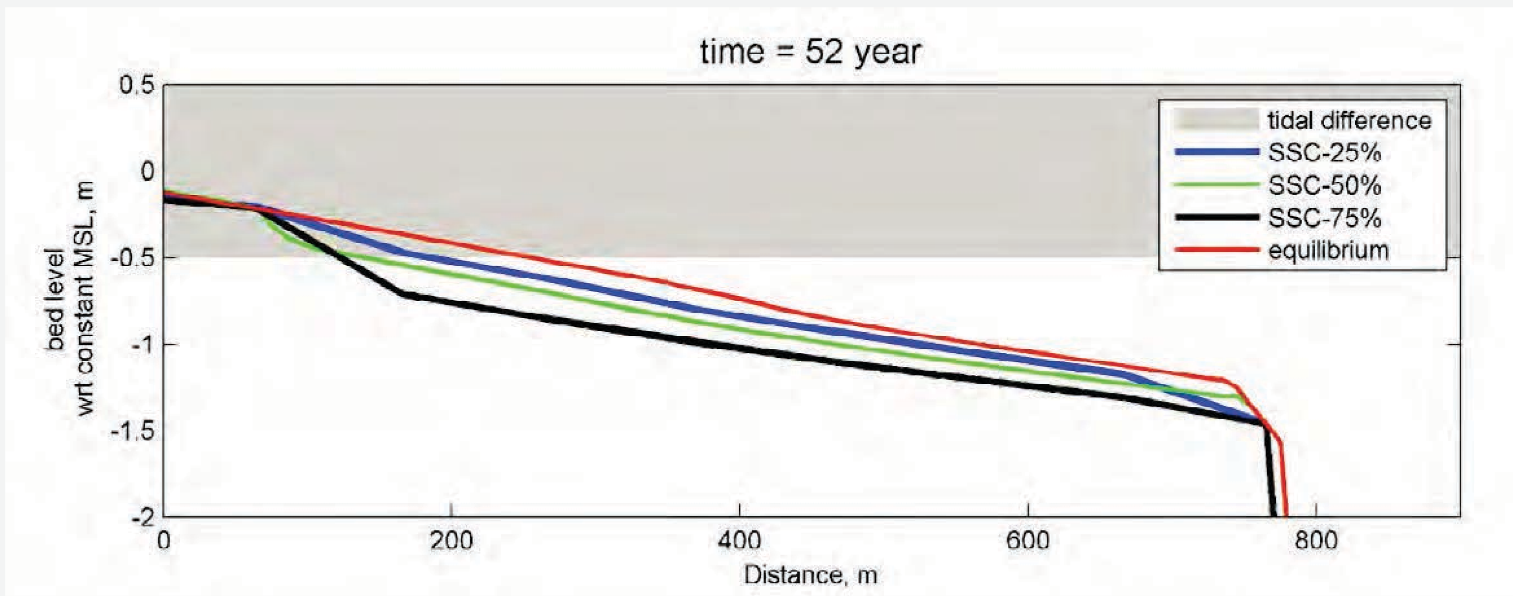
The role of waves and tides on the evolution of mudflats at 100 years



Effects of suspended sediment concentration on evolution of mudflats

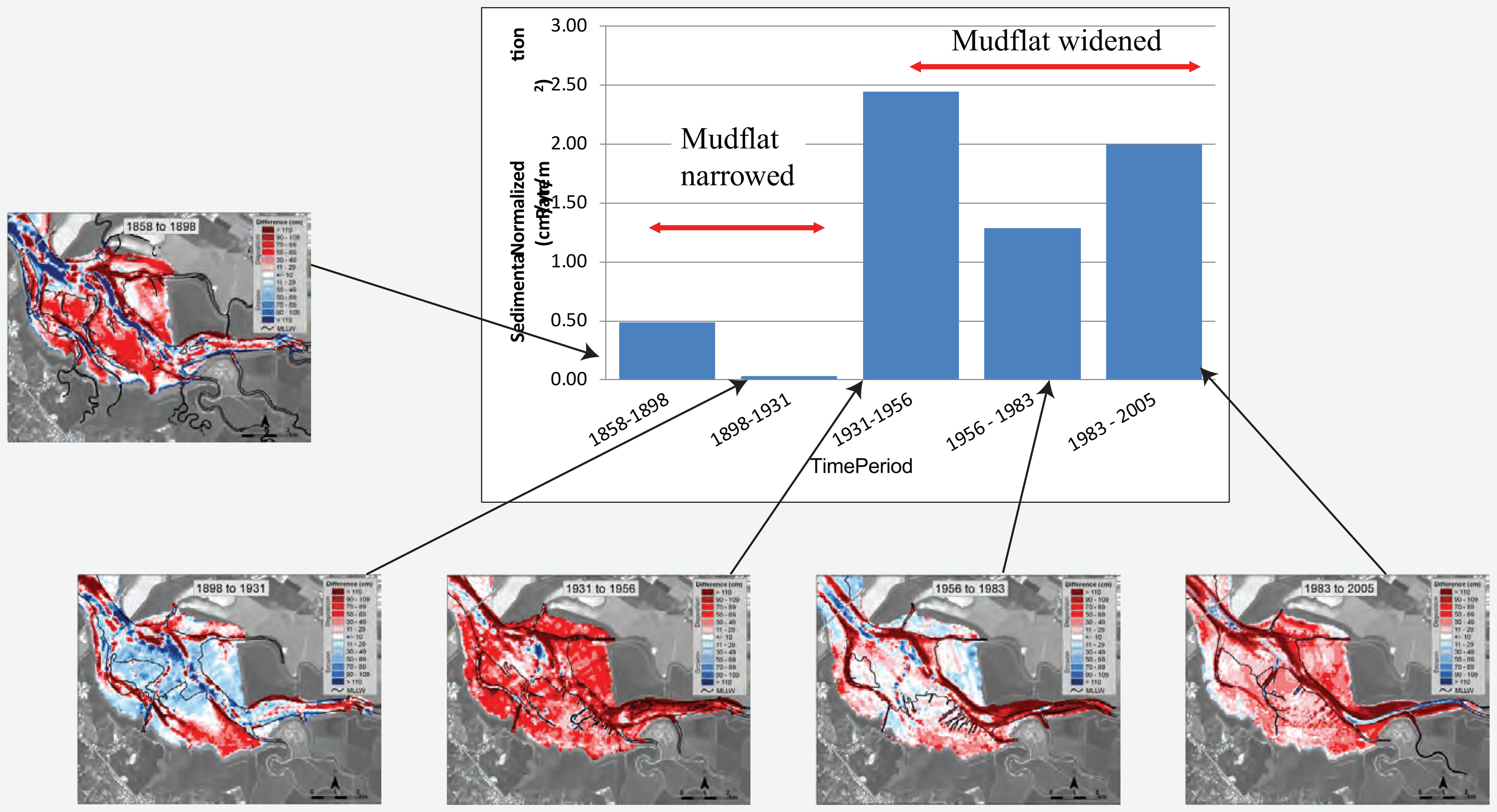


Effects of decrease in suspended sediment concentration on established mudflats



Mudflat Width is Related to Sedimentation

Widening of mudflats is correlated with high rates of sedimentation in the far South Bay. Narrowing of mudflats is correlated with low rates of sedimentation. This suggests that there is a sediment threshold for maintaining or growing mudflats, below which mudflats narrow.



Summary:

- Historical data indicate link between sediment availability and mudflat width
- 1D modeling is able to evolve observed mudflat profile from a submerged
- Decreasing background suspended sediment concentration (model input) deflates and narrows mudflat

Ongoing and Future work:

- Explore "uniqueness" of solution: Does a mudflat that matches the observed profile evolve for different combinations of waves, tides, sediment properties
- Investigate the effects of wave climatology (esp. storms) on mudflat evolution
- 2D modeling of mudflat evolution

Talking Points:

- Why does a 1D model work in a 2D envrionment?
- Why does the low wave height reproduce the mudflat profile?

References:

Box, G. E. P., 1976, Science and Statistics, Journal of the American Statistical Association 71, 791-799, doi:10.1080/01621459.1976.10480949.

Foxgrover, A.C., Higgins, S.A., Ingraca, M.K., Jaffe, B.E., and Smith, R.E., 2004, Deposition, erosion, and bathymetric change in South San Francisco Bay: 1858-1983: U.S. Geological Survey Open-File Report 2004-1192, 25 p. [URL: http://pubs.usgs.gov/of/2004/1192].

Foxgrover, A.C., Finlayson, D.P., Jaffe, B.E., and Fregoso, T.A., 2015, Bathymetry and Digital Elevation Models of Coyote Creek and Alviso Slough, South San Francisco Bay, California (ver. 3, September, 2015): U.S. Geological Survey Open-File Report 2011-1315, 23 p., http://dx.doi.org/10.3133/ofr20111315.

Shellenbarger, Wright, and Schoellhamer, 2013, 10.1016/j.margeo.2013.05.007

Van der Wegen, M., Jaffe, B., Foxgrover, A., and Roelvink, D., 2017, Mudflat Morphodynamics and the Impact of Sea Level Rise in South San FranciscoBay, Estuaries and Coast 40(1) 37-49. doi:10.1007/s12237-016-0129-6.

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