Managing Subsided Lands in the Sacramento-San Joaquin Delta

Delta Independent Science Board

Final Prospectus

August 4, 2023

Motivation

Drainage of land in the Sacramento-San Joaquin Delta has caused extensive oxidation of peat soils, lowering approximately 386 mi^2 of land from 10 ft to as much as 29 ft below sea level. Current rates of subsidence (loss of land elevation due to oxidation of peat soils) in the Delta currently range from 0.2 to more than 0.8 in yr^{-1} (Deverel et al., 2020). Although decades of subsidence have already depleted peat soils in areas of the Delta, subsided lands continue to cause significant challenges, such as increasing costs to drain soils, declining arability for agricultural production (Deverel et al., 2010; Deverel et al., 2020), water quality degradation (Deverel et al., 2010; Deverel et al., 2016; Deverel et al., 2017a), vulnerability to levee failure and flooding (Bates and Lund 2013; Deverel et al., 2016; Deverel et al., 2020), and substantial emissions of greenhouse gases in areas where peat soils still remain (Deverel et al., 2017b; Hemes et al., 2019).

The severity and impact of subsidence has prompted the Delta Stewardship Council and Delta Conservancy to promote and evaluate incentives for managing subsided lands (Delta Stewardship Council, 2022). Inundating peat soils to prevent or slow oxidation has emerged as a promising method to manage subsided lands. Carbon credit markets may provide a promising incentive to motivate approaches such as (1) wetland restoration or changes in farming operations (HydroFocus Inc., 2017; Deverel et al., 2020; Windham-Myers et al., 2023), (2) reversal or arresting of land subsidence by managing inundation duration and frequency, and (3) practicing agriculture under wet soil conditions (paludiculture) (HydroFocus Inc., 2017; Deverel et al., 2017b, Deverel et al., 2020; Windham-Myers et al., 2023). Management actions that reduce subsidence may also contribute to alleviating future increases of hydraulic gradient and seepage effects on some levees, depending on the proximity of the levee to subsided land. Reducing subsidence would also mitigate vulnerability to sea level rise, which would increase the difficulty of draining severely subsided land (Bates and Lund 2013; Deverel et al., 2016; Deverel et al., 2020). However, efforts to inundate peat soils to slow, arrest, or reverse subsidence are fragmented throughout the landscape.

A broad cross section of stakeholders, including public agencies and private sector parties, are developing and testing many different approaches to manage subsided lands. When farmers can apply high-quality surface water to fields, they may be able to leach salts (Hanson and Carlton 1979; Meyer et al.,1979; Dr. Michelle Leinfelder-Miles, personal communication, April 19, 2023), which may also slow the oxidation of peat if water levels are above peat soils. However, mitigation is temporary because oxidation resumes when soils are re-exposed to oxygen during cultivation. Some farmers have permanently converted fields to crops that grow with a high-water table, primarily rice, slowing oxidation and associated subsidence. Total cessation of oxidation has been achieved by some public agency landowners who have permanently submerged their land and controlled water levels. This promotes the growth and subsequent accumulation of layers of slowly decomposing wetland vegetation (biomass accretion), which increases land elevations over time (Valach et al., 2021). Land elevations have increased, i.e., subsidence has been reversed, at rates of 1.6 in yr^{-1} (Miller et al., 2008).

In addition to agricultural efforts currently underway to inundate peat soils in the Delta, approximately 25,000 acres of wetland restoration is in progress with a total of 60,000 to 80,000 acres called for in the Delta Plan (Delta Stewardship Council, 2022). The scale of subsidence in the Delta and the severity of its consequences for Delta agriculture, greenhouse gas emissions, and water quality indicates a need to assess existing management of subsided lands and the social, cultural, and economic trade-offs among different management approaches. The goal of this review by the Delta ISB is to synthesize and evaluate the state of science related to management of subsided lands and provide recommendations to address knowledge gaps. The review will explore existing or planned programs, barriers and opportunities, and the science needs for:

1. Land stabilization practices and experiments, including managed soil inundation, subsidence reversal, floating peats, and wetland restoration

2. Biogeochemistry of greenhouse gas emissions, factors influencing the duration of carbon pools, and net carbon sequestration among alternative inundation practices
3. Incentives such as carbon markets and other climate and agricultural policies for different agricultural practices to integrate inundation approaches and/or paludiculture into farming operations
4. Evaluating landscape-scale implications of managing subsided lands.

In addition to summarizing current efforts in the Delta to inundate peat soils and the state of the science, this review will identify knowledge gaps and scientific needs in the existing studies that evaluate economic and community trade-offs associated with different management actions and economic incentives. For example, inundation is potentially compatible with some types of farm operations but may require conversion from current crops, which can entail up-front costs to make infrastructural changes such as leveling and constructing berms (Deverel et al., 2017b). Additionally, incentives provided by some carbon credit markets may not support optimal management of farm operations (Windham-Myers et al., 2023).

Audience

Subsidence and efforts to slow or reverse subsidence directly impact agricultural production, water quality, greenhouse gas emissions, and the future economic and cultural values of the Delta landscape. This review will inform ongoing and future management of subsided lands by describing what is understood about subsidence, determining where science can improve current efforts, identifying knowledge gaps, and summarizing the current and potential incentives for different management actions on subsided lands, including wetland restoration and agricultural land management. The broad nature of the review is intended to serve a diverse audience that includes Delta stakeholders, managers, researchers, legislators, and decision-makers from local, state, and federal agencies.

Input

The primary input to this review will be a two-day public workshop consisting of formal panel presentations by invited experts followed by public discussions. Panelists will be asked to provide perspectives on existing programs, barriers and opportunities, state of scientific understanding, scientific gaps and deficiencies, and economic considerations of managing subsided lands within four panels:

1. Overview of current land inundation practices and experiments
2. Biogeochemistry of carbon sequestration and greenhouse gas emissions in inundated peat soils
3. Economic considerations for inundated agricultural practices
4. Science needs to inform landscape-scale implications of peat soil inundation

The first panel of the workshop will focus on providing an understanding of the scope of current inundation projects, with a focus on land surface elevation changes. The second panel will discuss the biogeochemical mechanisms that regulate greenhouse gas emissions in wetland peat soils to identify gaps in understanding the science related to carbon sequestration. The third panel will address different agricultural and land-use management practices to compare opportunities and barriers for paludiculture or other inundation practices in the Delta and the trade-offs in agricultural practices for managing subsided lands. Lastly, the fourth panel will reflect on the previous three panels and discuss research and data needs towards understanding potential landscape-scale outcomes of soil inundation.

Notably, the 2023 State of Bay-Delta Science review of carbon sequestration and subsidence reversal provided important management recommendations for subsidence reversal and highlighted key uncertainties in carbon sequestration accounting (Windham-Myers et al., 2023). The Delta ISB review will complement this effort by identifying targeted science priorities, examining economic and social science knowledge gaps, and new developments in areas of uncertainty.

Timeframe

Target Date	Benchmark
July 2023	Prospectus finalized
August 2023	Finalize workshop agenda and invite speakers
September 2023	Open registration for workshop
October 2023	Host workshop
January 2024	Release draft workshop summary report for public comments
Spring 2024	Finalize summary report and findings

Related Reviews

Although the Delta ISB has reviewed documents that include consideration of subsidence, it has not engaged in reviews that focused on subsidence *per se* or inundation of Delta soils to manage subsided lands. Relevant reviews include the following:

- 2016 Delta ISB Workshop Report on Earthquakes and High Water as Levee Hazards in the Sacramento-San Joaquin Delta

In addition, key documents that informed this review include:

- Carbon Sequestration and Subsidence Reversal in the Sacramento-San Joaquin Delta and Suisun Bay: Management Opportunities for Climate Mitigation and Adaptation
- Delta Plan Ecosystem Amendment Performance Measures

Expected Products and Outcomes

This review will consist of findings and recommendations based on a synthesis of workshop presentations, panel discussions, and relevant literature. The review builds on previous work by examining the existing heterogeneity of economic incentives and broadening understanding of the range of actions to manage subsided lands within the context of ensuring robustness to climate change. By summarizing the state of science of managing subsided lands, assessing whether current management efforts are consistent with best available science, and identifying any science gaps, this review aims to provide recommendations for key science needs that could guide a more coordinated approach for managing subsided land in the Delta.

References

Bates, M. E., and Lund, J. R. (2013). Delta subsidence reversal, levee failure, and aquatic habitat - A cautionary tale. *San Fr. Estuary Watershed Sci.* 11. doi:10.15447/sfews.2013v11iss1art1. https://escholarship.org/uc/item/9pp3n639

Delta Stewardship Council. 2022. "Chapter 4 - Protect, Restore, and Enhance the Delta Ecosystem (Amended June 2022)." In *The Delta Plan*. https://deltacouncil.ca.gov/pdf/delta-plan/2022-06-29-chapter-4-protect-restore-and-enhance-the-delta-ecosystem.pdf

Deverel, Steven J., and David A. Leighton. 2010. "San Francisco Estuary and Watershed Science Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA." *San Francisco Estuary and Watershed Science* 8 (2): 1–24. https://escholarship.org/uc/item/7xd4x0xw

Deverel, S. J., Bachand, S., Brandenberg, S. J., Jones, C. E., Stewart, J. P., and Zimmaro, P. (2016). Factors and processes affecting delta levee system vulnerability. *San Fr. Estuary Watershed Sci.* 14. doi:10.15447/sfews.2016v14iss4art3. https://escholarship.org/uc/item/36t9s0mp

Deverel, S. J., Leighton, D. A., Lucero, C., and Ingrum, T. (2017a). Simulation of subsidence mitigation effects on island drain flow, seepage, and organic carbon loads on subsided islands, Sacramento-San Joaquin Delta. *San Fr. Estuary Watershed Sci.* 15. doi:10.15447/sfews.2017v15iss4art2. https://escholarship.org/uc/item/4q340190

Deverel, S., Jacobs, P., Lucero, C., Dore, S., and Kelsey, T. R. (2017b). Implications for Greenhouse Gas Emission reductions and economics of a changing agricultural mosaic in the Sacramento - San Joaquin Delta. *San Fr. Estuary Watershed Sci.* 15. doi:10.15447/sfews.2017v15iss3art2. https://escholarship.org/uc/item/99z2z7hb

Deverel, S.J., S. Dore, C. Schmutte (2020) "Solutions for subsidence in the California Delta, USA, an extreme example of organic-soil drainage gone astray." Proc. IAHS 382,837-942.https://piahs.copernicus.org/articles/382/837/2020/piahs-382-837-2020.html

Hanson, Blain R. and Carlton, Alan B., 1979. "Subsurface movement of water and salt in Delta organic soils". *California Agriculture*. November-December 1979.

Hemes, Kyle S., Samuel D. Chamberlain, Elke Eichelmann, Tyler Anthony, Amy Valach, Kuno Kasak, Daphne Szutu, Joe Verfaillie, Whendee L. Silver, and Dennis D. Baldocchi. 2019. "Assessing the Carbon and Climate Benefit of Restoring Degraded Agricultural Peat Soils to Managed Wetlands." *Agricultural and Forest Meteorology* 268 (April): 202–14. https://doi.org/10.1016/j.agrformet.2019.01.017.

HydroFocus, Inc. 2017. "Restoration of California Deltaic and Coastal Wetlands (Version 1.1)." Arlington, VA: American Carbon Registry. https://americancarbonregistry.org/carbon-accounting/standards-methodologies/restoration-of-california-deltaic-and-coastal-wetlands

Meyer J, Prichard T, Kegel F, Mullen R. 1979. Salinity in Delta peat soils. Hilgardia 33(11):10-11. DOI:10.3733/ca.v033n11p10. https://hilgardia.ucanr.edu/fileaccess.cfm?article=172545&p=YMJFJB

Miller, Robin L., Miranda S. Fram, Roger Fujii, and Gail Wheeler. 2008. "San Francisco Estuary and Watershed Science Subsidence Reversal in a Re-Established Wetland in the Sacramento-San Joaquin Delta, California, USA." *San Francisco Estuary & Watershed Science* 6 (3). https://escholarship.org/uc/item/5j76502x

Valach AC, Kasak K, Hemes KS, Anthony TL, Dronova I, Taddeo S, et al. (2021) Productive wetlands restored for carbon sequestration quickly become net CO2 sinks with site-level factors driving uptake variability. PLoS ONE 16(3): e0248398. https://doi.org/10.1371/journal.pone.0248398

Windham–Myers, Lisamarie, Patty Oikawa, Steve Deverel, Dylan Chapple, Judith Drexler, and Dylan Stern. 2023. "Carbon Sequestration and Subsidence Reversal in the Sacramento-San Joaquin Delta and Suisun Bay: Management Opportunities for Climate Mitigation and Adaptation." *San Francisco Estuary and Watershed Science* 20 (4). https://doi.org/10.15447/sfews.2023v20iss4art7.