Climatic Impacts of Tidal Restriction and Restoration in the Herring River Project: Projecting Carbon and Greenhouse Gas Budgets through the 21st Century

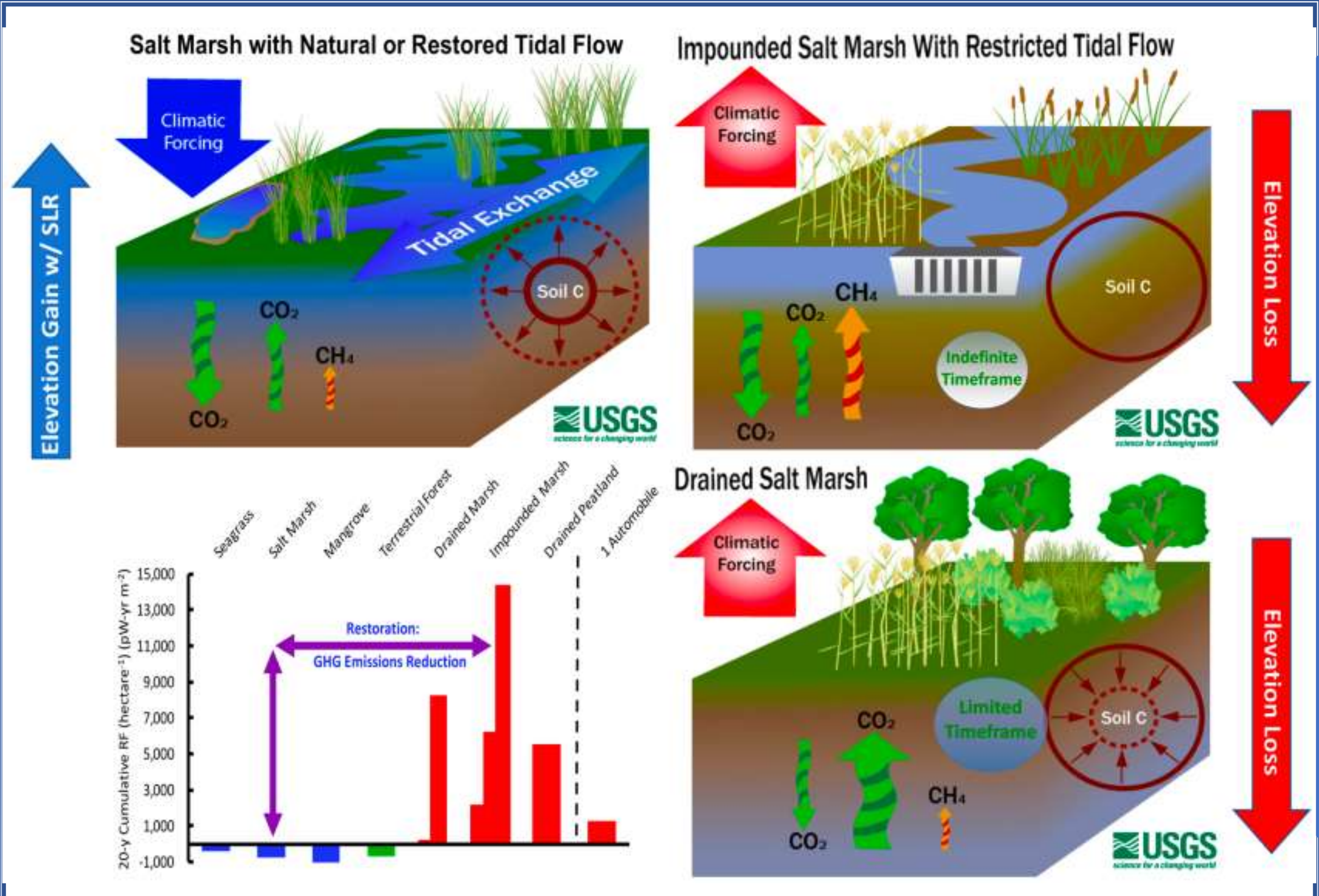
Kevin D. Kroeger, Meagan E. Gonneea, Jianwu Tang, Faming Wang, Omar Abdul-Aziz, Timothy Smith, Jacqueline Fouse, Serena Moseman-Valtierra, Kevin Befus, Alexander Kurnizki

Within the BWM project, we identified tidally restricted, impounded/freshened wetlands as an important coastal C feature, and estimated that such wetlands could be important, and manageable, methane sources.

Kroeger, Crooks, Moseman-Valtierra, Tang, 2017

USGS science for a changing world

Hydrological management can have substantial consequences for carbon and methane processes, as well as elevation trajectory and resilience.



Kroeger et al. 2017

<u>Broad Objectives</u>:

- Assessment of coastal carbon as a resource, leading to development actionable knowledge and management guidance
- Understanding of the linkages between sea level rise, hydrological management, vegetation habitat, elevation resilience, and carbon
- Wetland C & GHG processes reflected in national and state-level GHG inventories, and emissions reduction targets
- Comprehensive consideration of wetland persistence and GHG processes in coastal adaptation plans
- Project-level consideration of GHG in wetland management decisions

USGS
science for a changing world

Due to their widespread occurrence across the U.S. and globally, tidally-restricted and freshened wetlands are estimated to generate significant anthropogenic methane emissions.

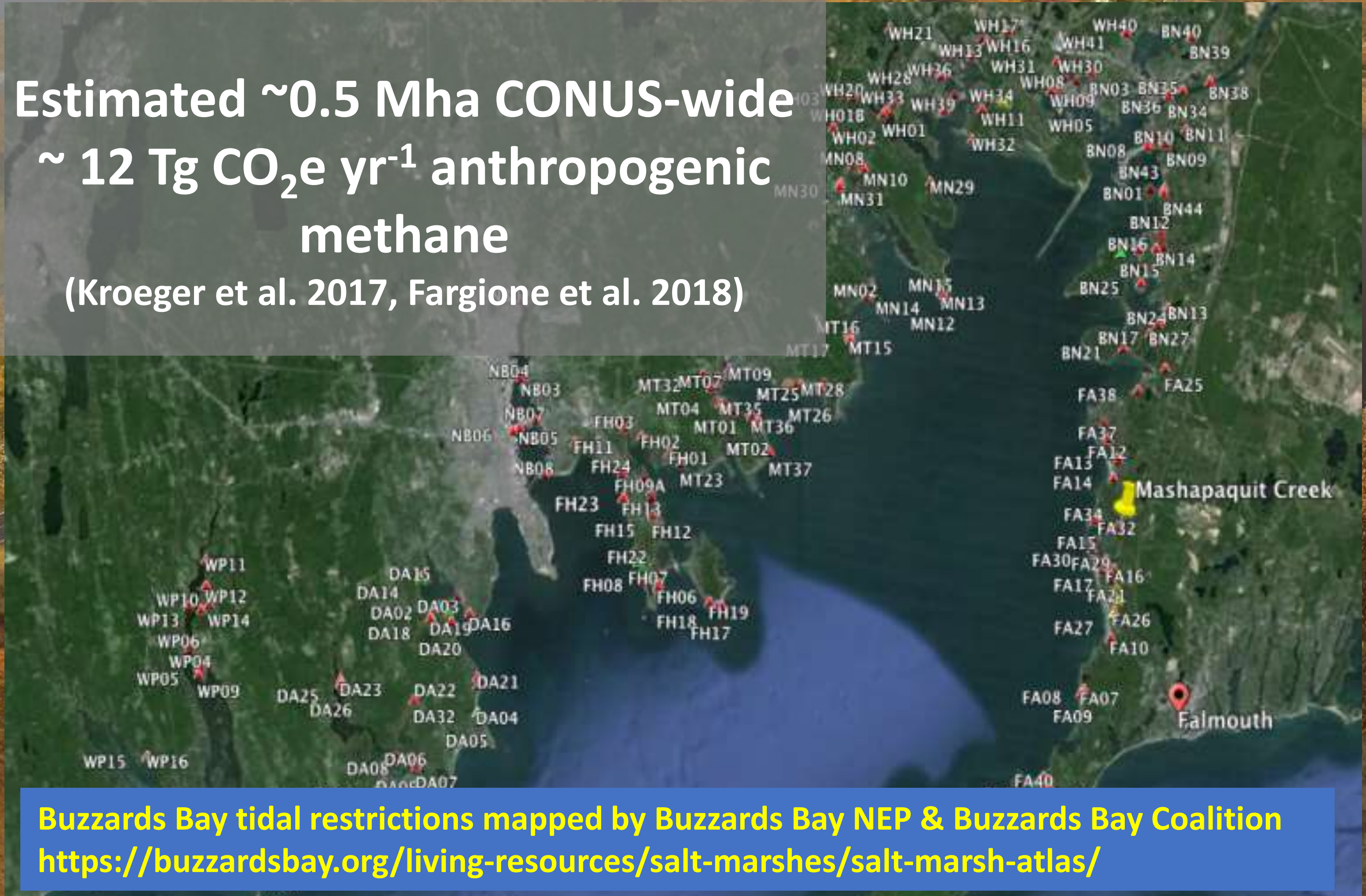
GEOGRAPHY

Nearly 600 in state of Massachusetts alone

Estimated ~0.5 Mha CONUS-wide

~ 12 Tg CO_2e yr^{-1} anthropogenic methane

(Kroeger et al. 2017, Fargione et al. 2018)



Buzzards Bay tidal restrictions mapped by Buzzards Bay NEP & Buzzards Bay Coalition
https://buzzardsbay.org/living-resources/salt-marshes/salt-marsh-atlas/

USGS
science for a changing world

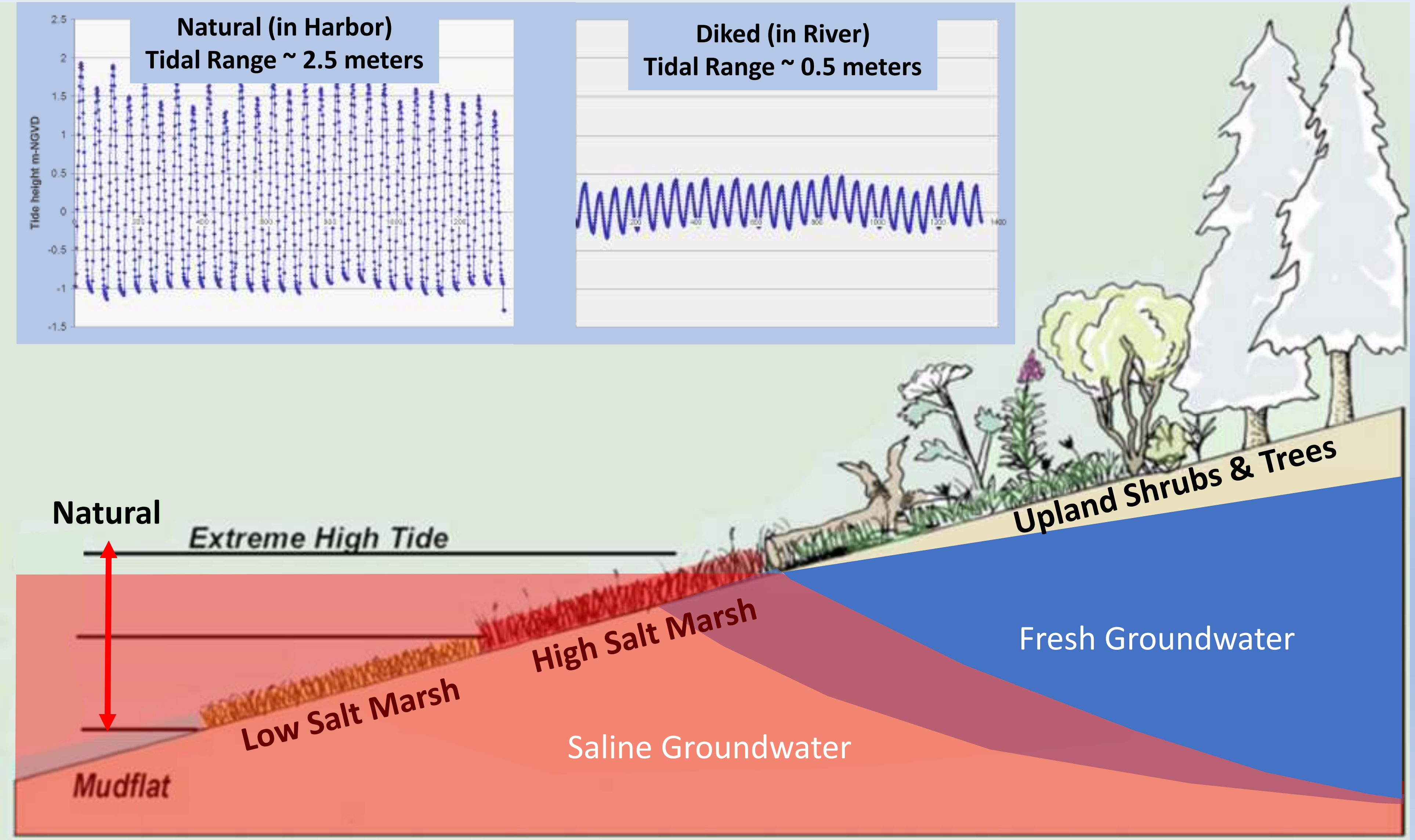
Diked, drained landscapes are also abundant:

- ~0.24 million hectares of drained, formerly tidal wetland within US (Crooks et al. 2018)
- Commonly for farming or development
- Increased and enhanced deployment in response to sea level rise is likely.
- Result in non-resilient landscapes:
  - Elevation loss
  - Diminished SLR-induced accretion
  - Enhanced fire risk

USGS
science for a changing world

Hydrology is a master driver of ecological conditions and processes

Tide range controls distribution of intertidal salt marsh

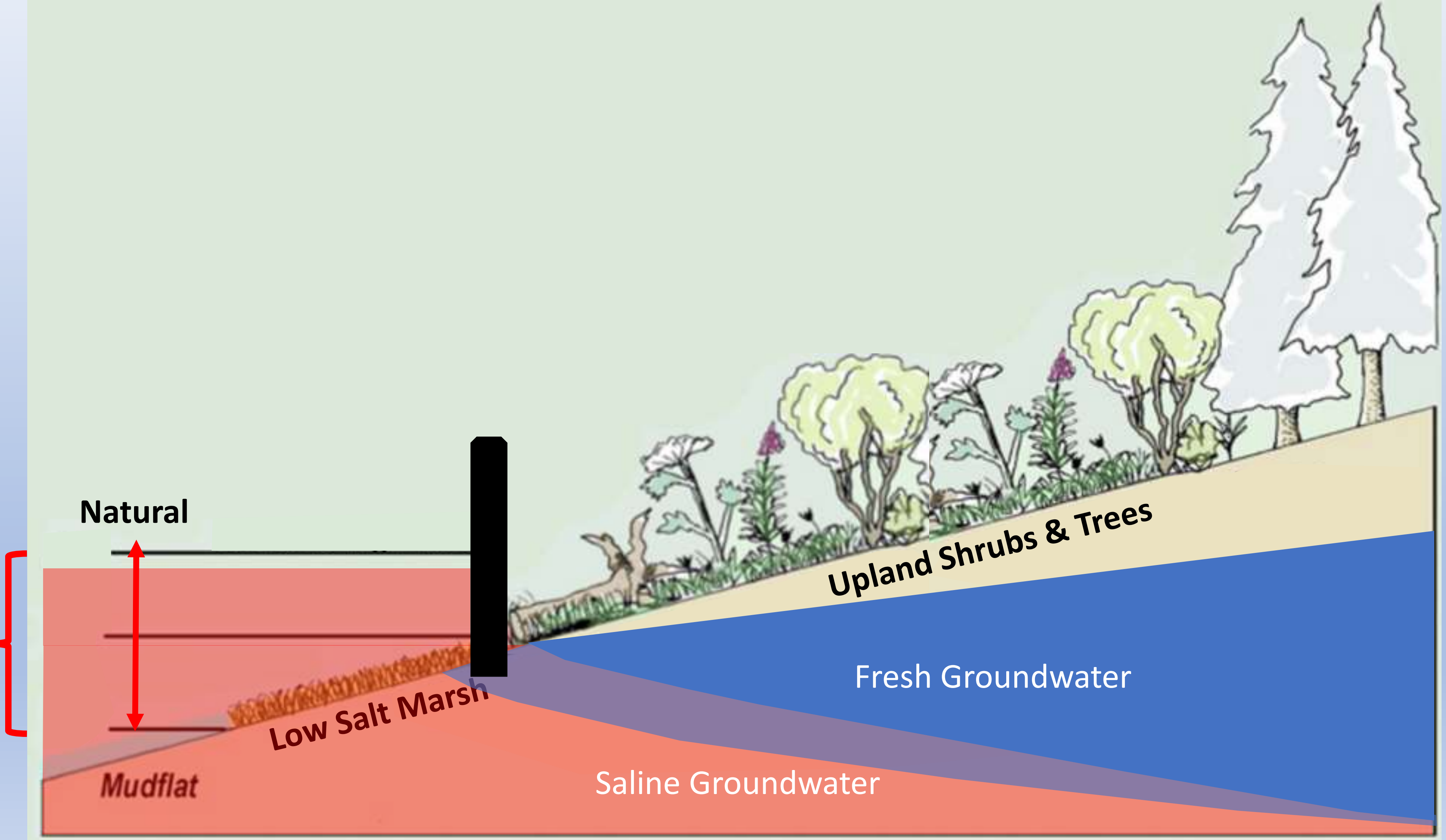


Upland vegetation distribution largely controlled by water table depth

Fresh aquifer hydrostatically -poised against sea level

With diking and flapper gates, changes in water levels and flows cascade through the entire ecosystem

The dike holds back high tides

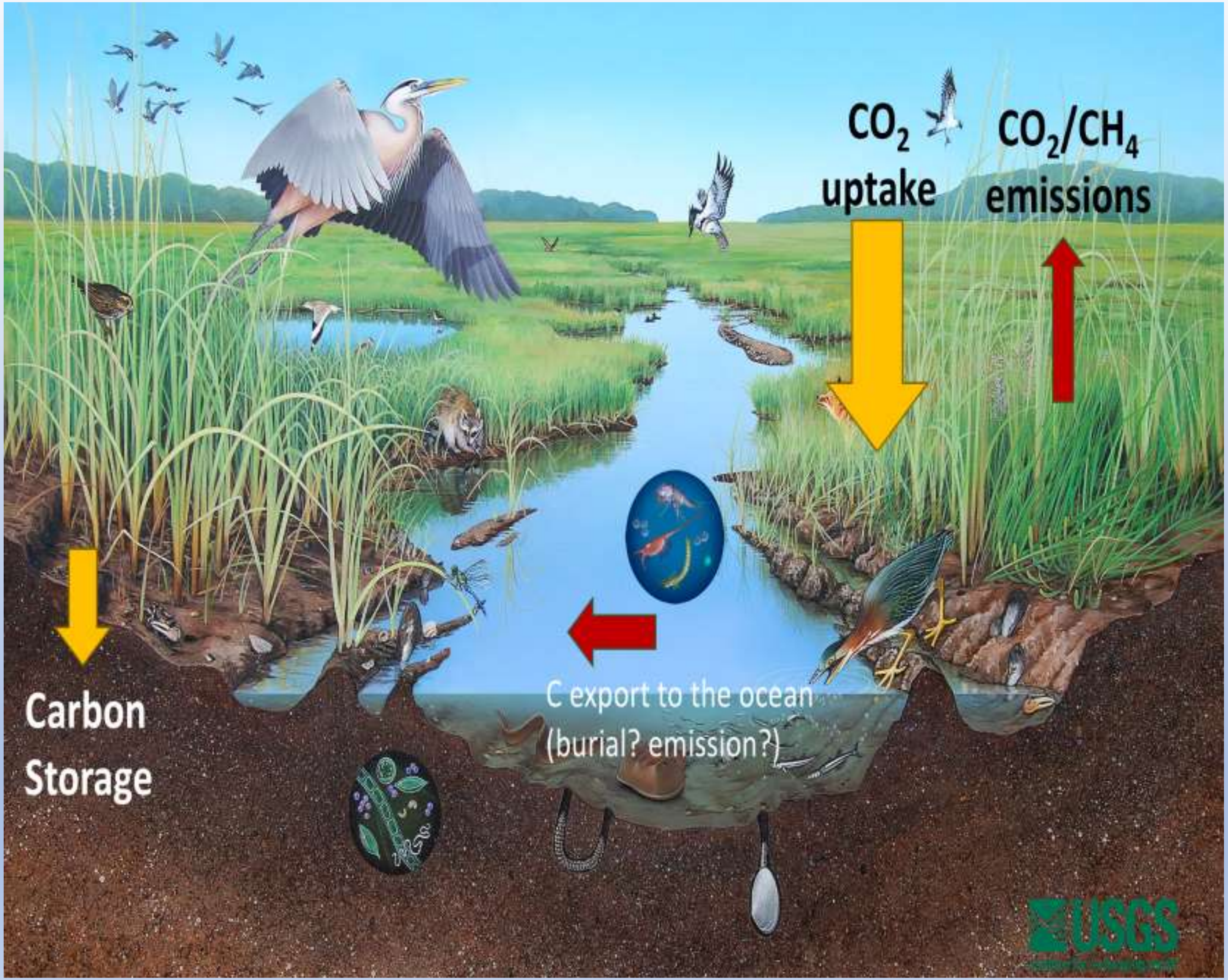


A deeper water table allows upland vegetation to replace salt marsh

A lower seawater head causes the water table to drop

Proposed tidal restoration at Herring River, CCNS:

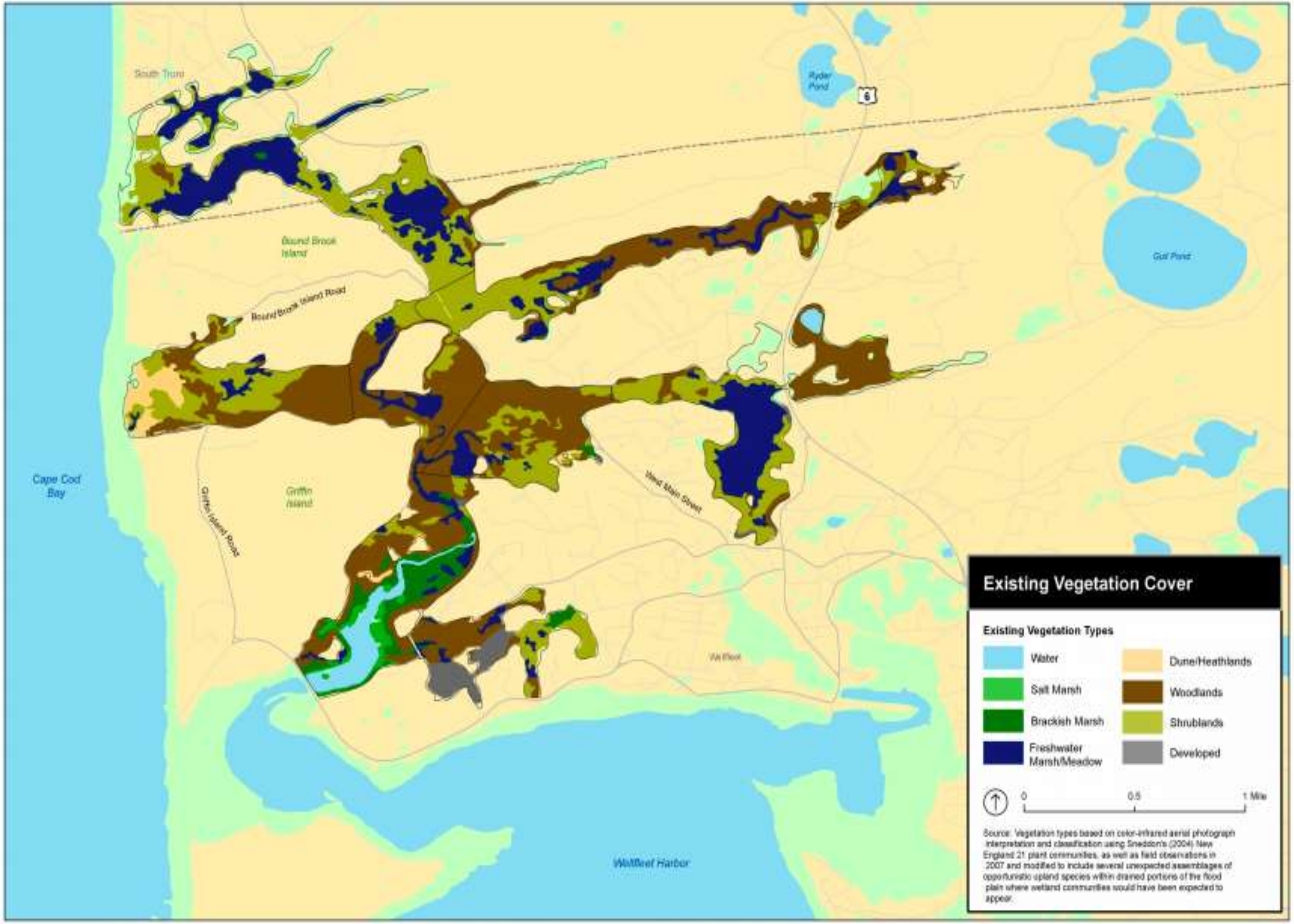
- Can such a project help to reach GHG emission reduction goals, and is Herring River a suitable carbon market project? Complex questions to answer.
- 400 hectares of drained & impounded landscapes:
  - Salt marsh
  - Phragmites
  - Typha & other fresh emergent
  - Wet shrub
  - Wet forest
  - Dry forest



To quantify the carbon and GHG consequences of diking and restoration, we need to measure and predict rates for each of the major processes, as presented earlier in this session.

The major processes considered are changes in soil C storage, methane emissions, and vegetation biomass, in response to changes in water level and salinity.

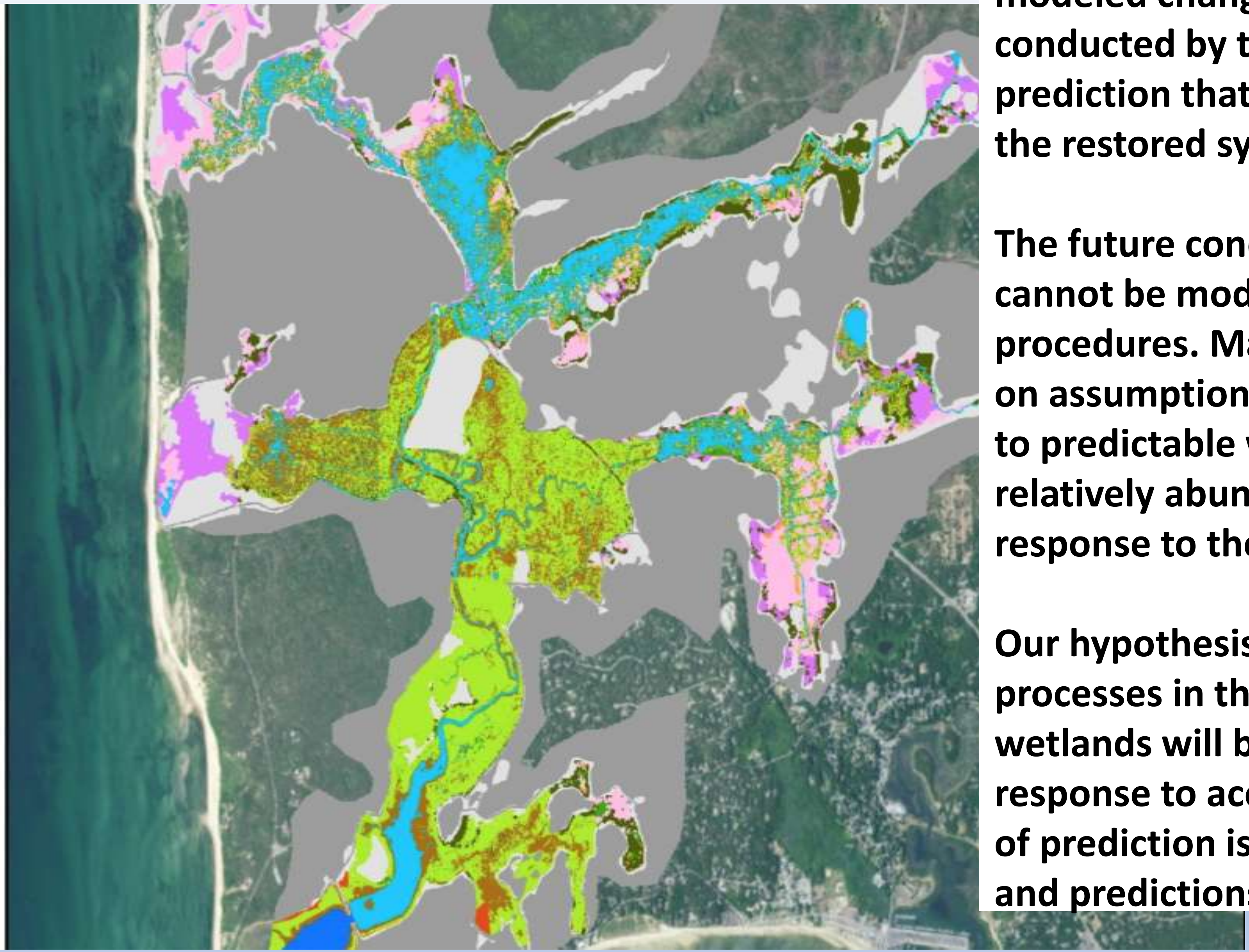
Critically, the proper comparison is future scenarios of no action vs. restoration.



The magnitudes of emissions are based on rates measured in current-day hydrology and vegetation covers, hindcasting based on emissions and elevation trajectories in nearby non-diked marshes.

Currently, primary land covers are tree and shrub growth on drained wetland, and freshwater wetland vegetation.

USGS
science for a changing world

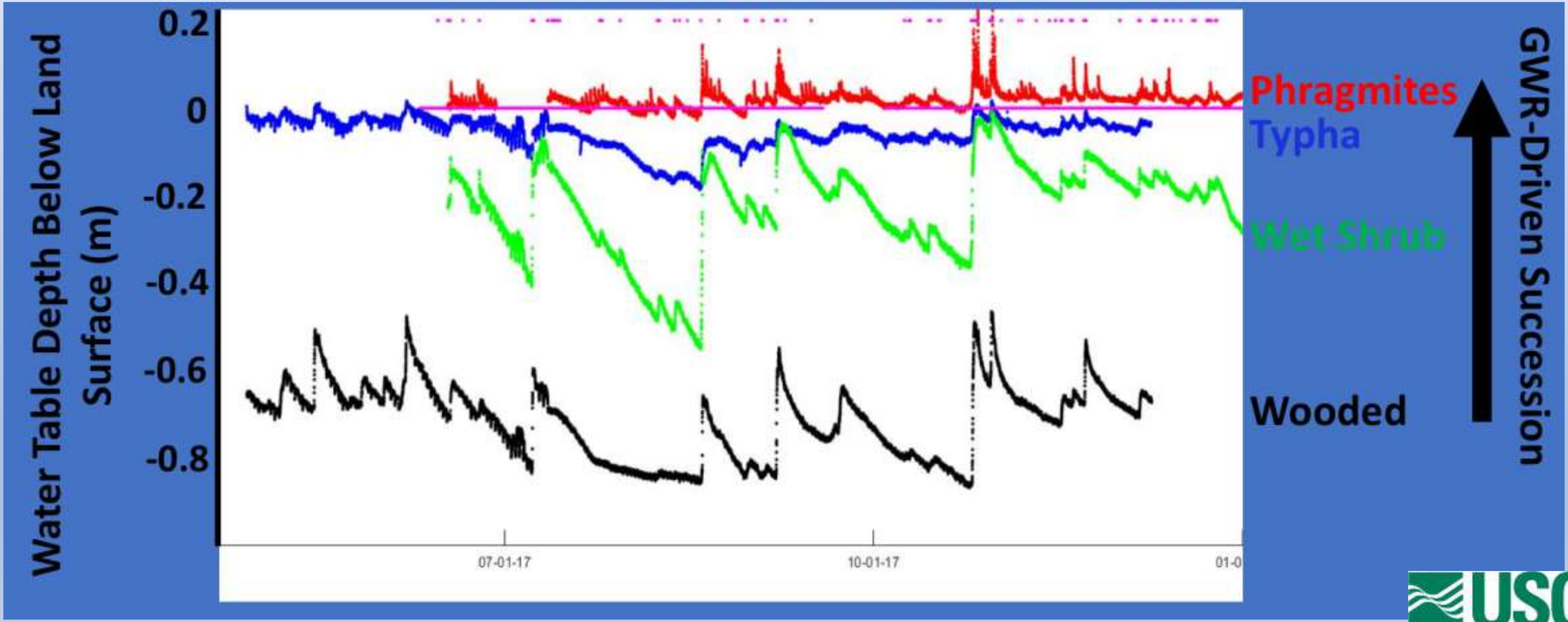


Future projections under full restoration are based on modeled changes in vegetation cover using SLAMM, conducted by the Woods Hole Group, with a prediction that salt marsh vegetation will dominate the restored system.

The future condition without restoration, however, cannot be modeled using established modeling procedures. Marsh models such as SLAMM are based on assumption of direct contact with the sea, leading to predictable water levels and salinity, and based on relatively abundant experience with wetland response to those hydrological drivers.

Our hypothesis is that vegetation, soil, and GHG processes in the Herring River and other diked wetlands will be controlled instead by aquifer rise in response to accelerating SLR. Therefore, a new kind of prediction is needed based on modeled GW rise and predictions of vegetation response.

- Given their initial low, intertidal elevation, followed by subsidence and muted elevation gain, these upland forest and shrub ecosystems have extremely shallow (fresh) water tables.
- We suggest that decreasing depth to groundwater, driven by SLR, will be a predictive driver of ecosystem change, leading to succession from upland to fresh wetland land covers
- Consequences for GHG budgets will be substantial: Tree mortality/respiration of woody biomass, enhanced methane emissions, increased soil C storage.



Kroeger et al. unpubl.

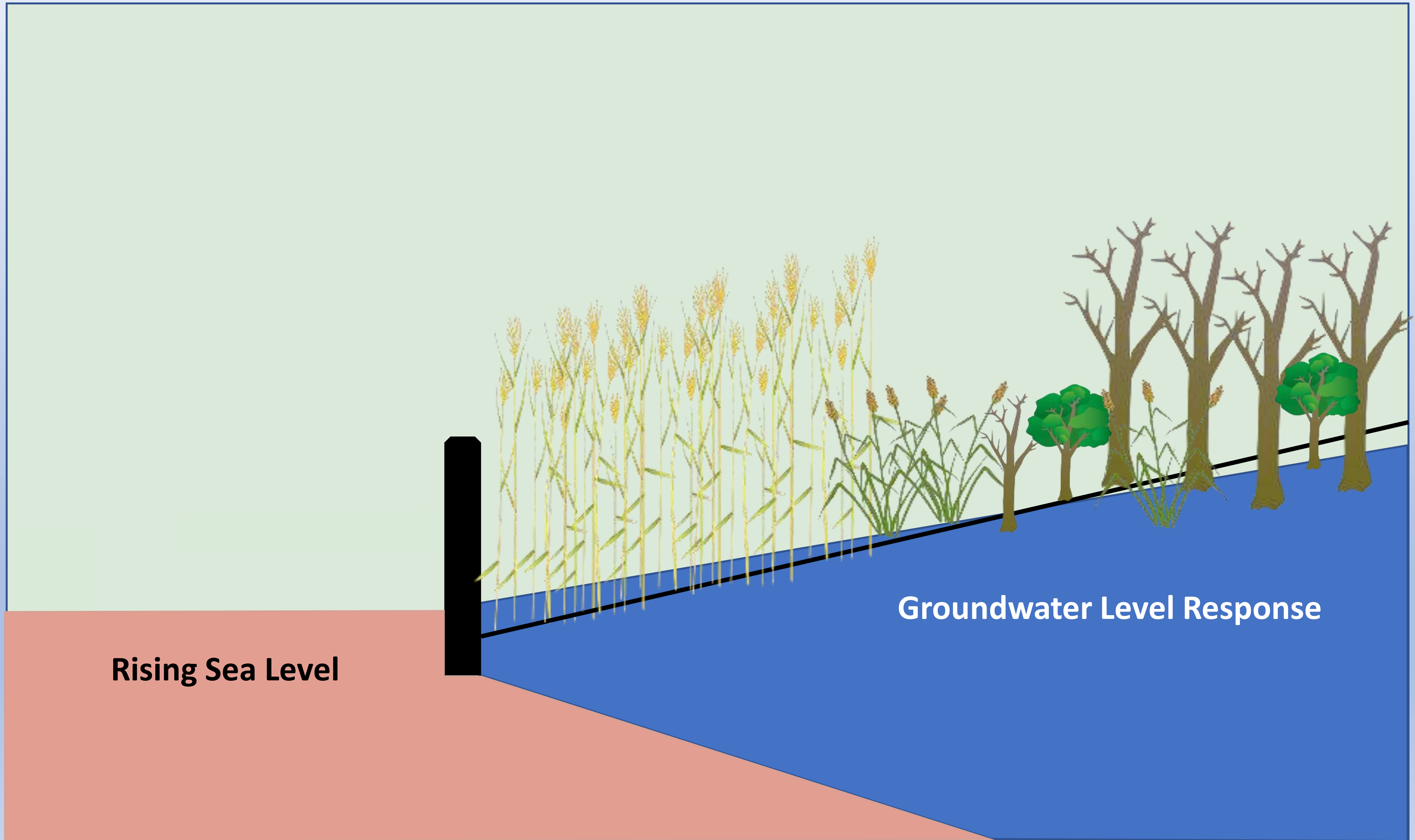
Based on local SLR projections, a developing groundwater model, and soil accretion predictions, we are predicting relative elevation change. A preliminary analysis suggests that under a 1 m global sea level projection, forest and shrub ecosystems are expected to transition to herbaceous wetland ~2040 to 2050, and the entire system to transition to very low elevation fresh to brackish wetland. Substantial coverage by invasive Phragmites is likely. Our data, presented today by Jim Tang, indicate that the existing Phragmites wetland has an extremely high methane emission rate

Groundwater rise as a driver of change in vegetation, carbon stocks, and methane

- Currently HR is a subsided landscape with a mix of upland and low salinity wetland vegetation
- Widespread mortality of trees and shrubs may be an indicator of rising groundwater

Groundwater rise as a driver of change in vegetation, carbon stocks, and methane

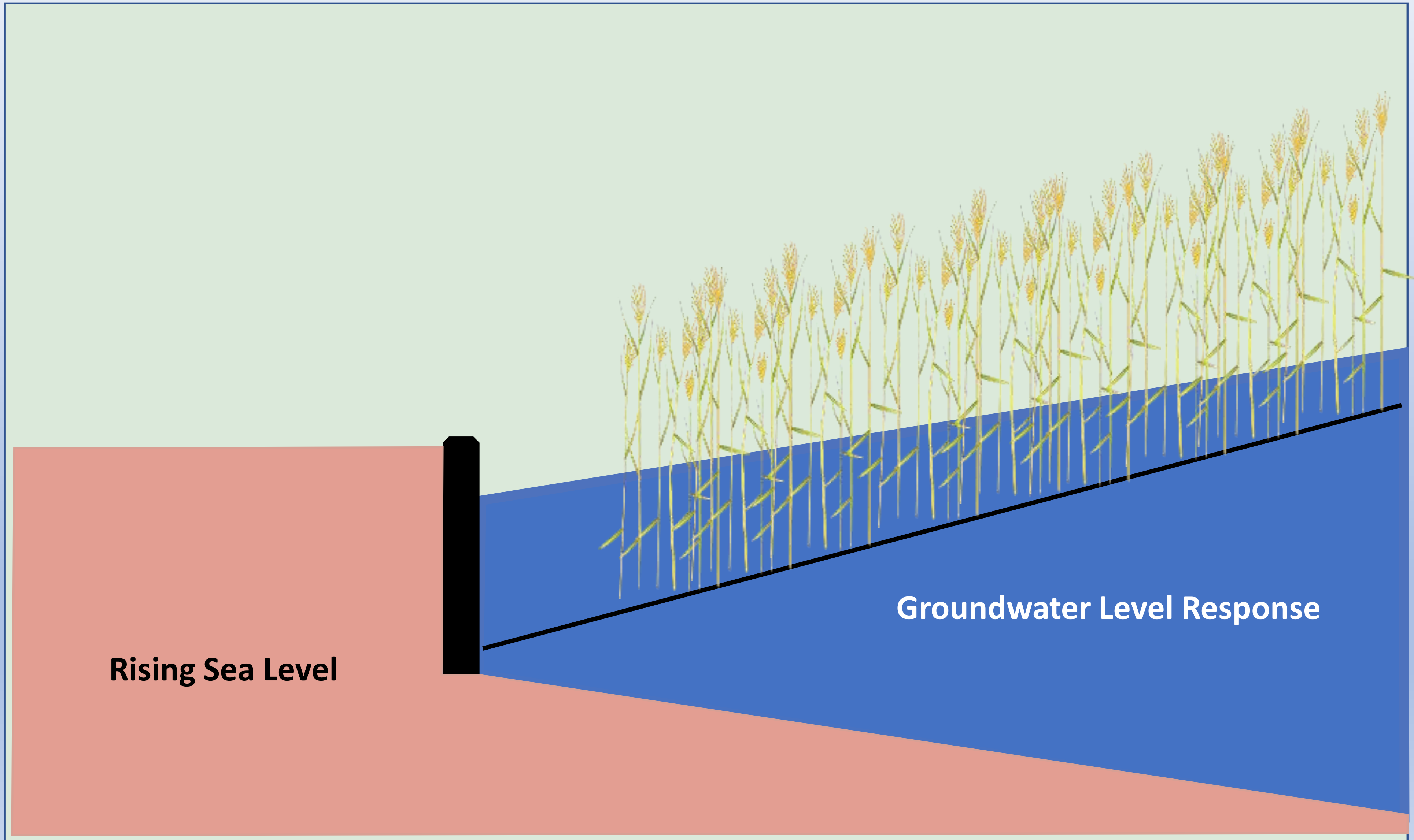
- With predicted future sea levels with 1 meter of 21st Century SLR, groundwater will become shallow enough to drive widespread vegetation transitions prior to mid-century



Mortality of upland vegetation and replacement with wetland in response to groundwater rise

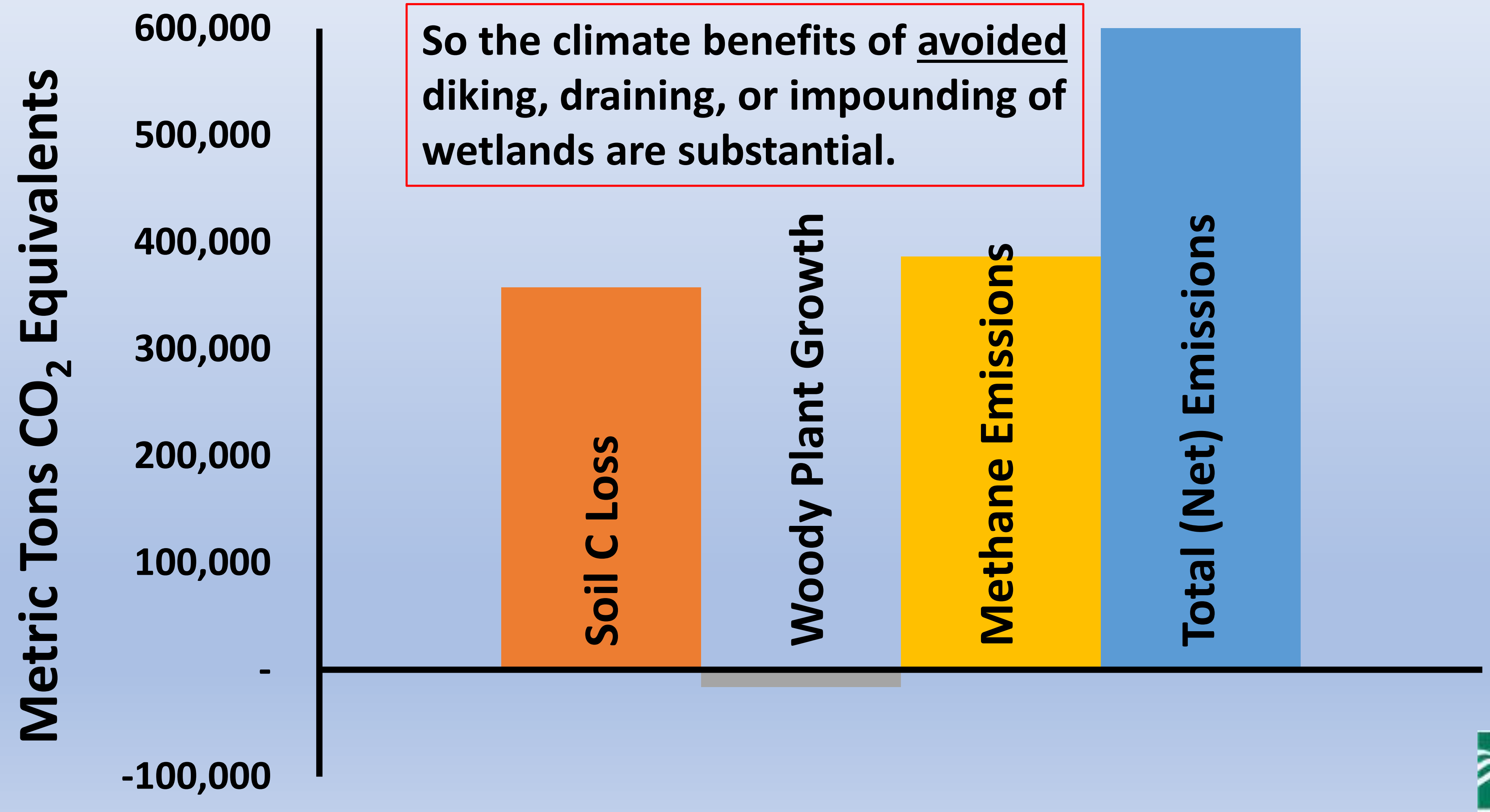
Groundwater rise as a driver of change in vegetation, carbon stocks, and methane

- During the second half of the century groundwater levels are expected to be at or above soil level throughout former salt marsh areas



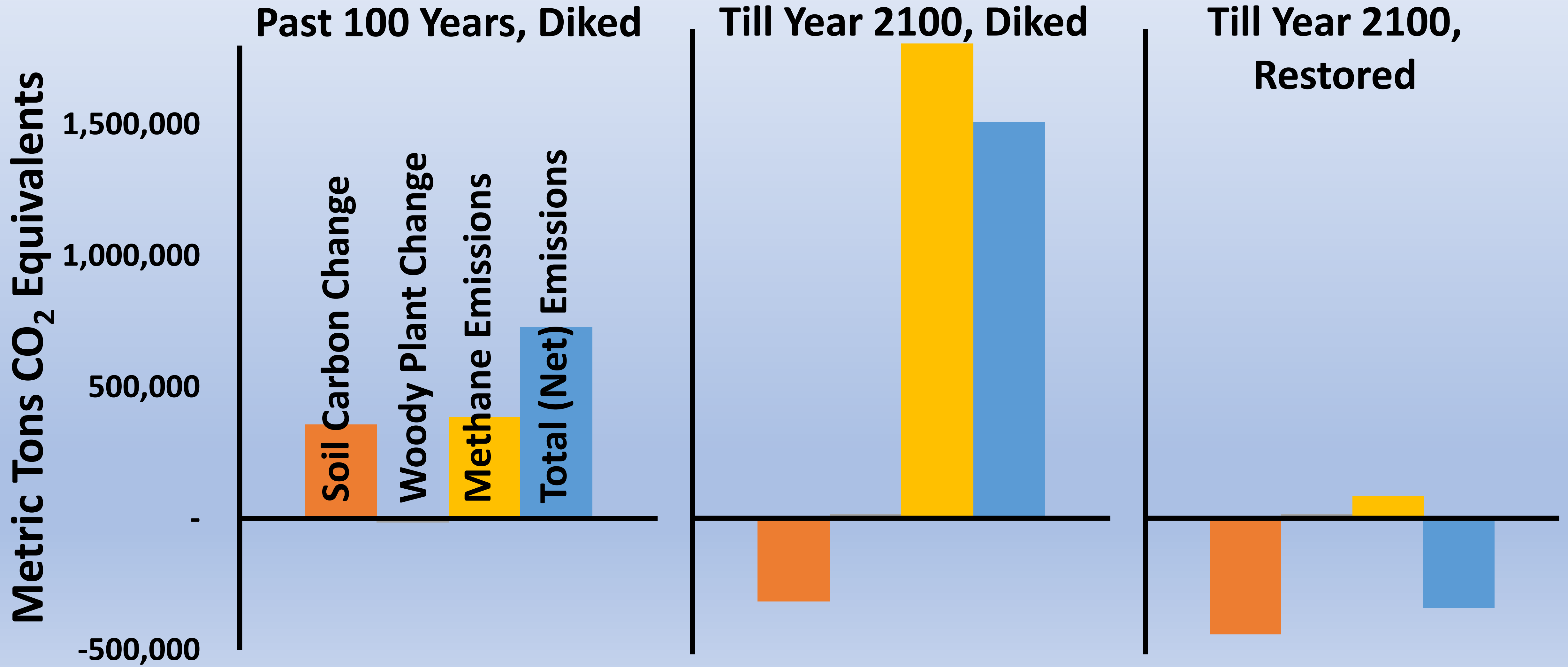
Fresh and brackish wetland replace vegetation throughout low-elevation former salt marsh areas

Preliminary Estimate of Greenhouse Gas Emissions to the Atmosphere in the 100 Years Since Herring River was Diked: Equivalent to Driving 155,000 Average U.S. Automobiles for 1 Year.



USGS
science for a changing world

Past vs Future Emissions: Under influence of 1 m of 21st century global mean sea level rise, with diked vs. restored future scenarios. The benefit or restoration is estimated as the difference between restored and non-restored futures, and is ~1.8MMt CO_2e, equivalent to not driving 380,000 cars for 1 year.



Take-home messages

- Diked/drained landscapes progressively lose elevation, and on some timescale are unsustainable.
- The timescales of change may be predictable based on modeled GWR and soil accretion or loss.
- There is a risk that poor wetland management can cause soil carbon to be returned to the atmosphere as methane or carbon dioxide.
- Degraded or altered wetlands are an opportunity to reduce an anthropogenic greenhouse gas emission, while enhancing elevation resilience.
- The biggest opportunities for greenhouse gas management are 1) avoided degradation and destruction, and 2) restoration of tidally-restricted wetlands.
- Restoration of the Herring River system is expected to produce substantial climate change mitigation benefit, reversing a portion of the warming that has already occurred due to the dike.

Acknowledgements…

- Collaborators: Meagan Gonneea, Kevin Befus, Jianwu Tang, Faming Wang, Serena Moseman-Valtierra, Steve Crooks, Amanda C. Spivak, Neil K. Ganju, John W. Pohlman, Aleck Wang, Adrian Mann, Sandra Brosnahan, T. W. Brooks, Jennifer O'Keefe, Michael Casso, Omar-Abdul Aziz, Scott Settelmyer, Steve Emmett-Mattox, Stefanie Simpson, Jordan Mora, Christopher Weidman, Kate Morkeski, Linda Kraemer, Thomas Kraemer, Sophie Chu, Joanna Carey, P. Ganguli, E. Bergeron, Najjar et al., Windham-Meyers et al., J. Colman, T. Smith, J. Rassman, T. Surgeon-Rogers, others
- **Funding Sources:**
  - **USGS LandCarbon Program**
  - **USGS Coastal & Marine Geology Program**
  - **NOAA Science Collaborative**
  - **NOAA WHOI & MIT Sea Grant**
  - **NSF Chemical Oceanography; Postdoctoral Fellowship Program**
  - **National Park Service**
  - **Friends of Herring River**