Applications of Blue Carbon

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Mission-Aransas National Estuarine Research Reserve,
Port Aransas,
November 5th, *2015*

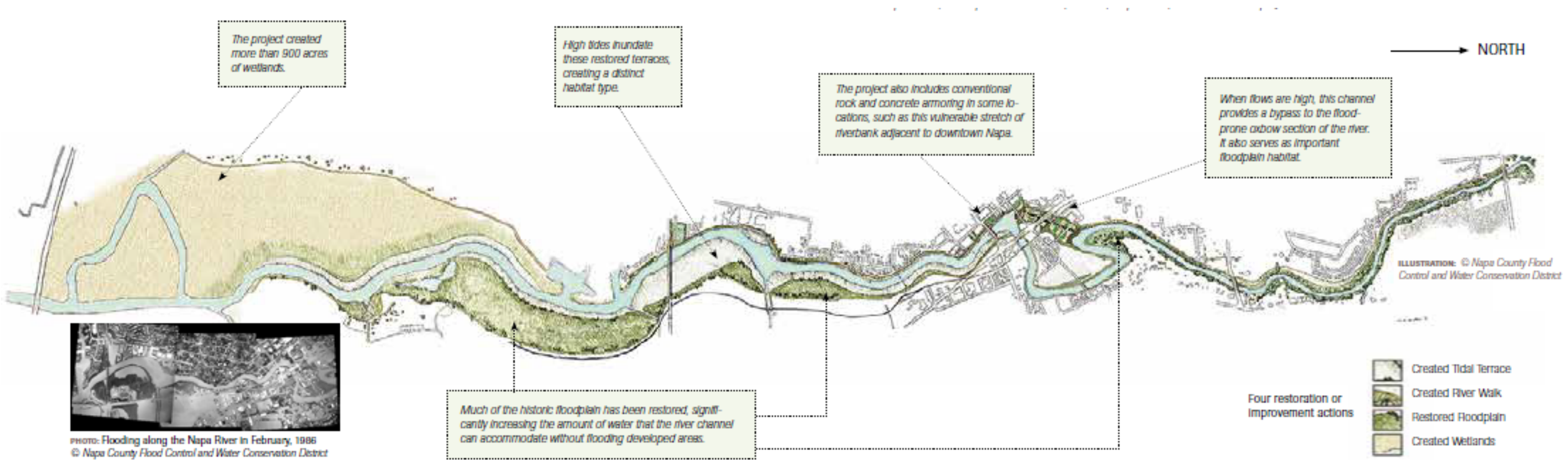
Ecosystem services of Coastal Blue Carbon ecosystems: mangroves, seagrass and marshes

- Biological diversity
- Water quality
- Flood and storm protection
- Forest and non-timber forest products
- Aesthetic and ecotourism values
- Fish and Shellfish
- Carbon Sinks

Field Missions

Linking Blue Carbon With Green - Grey Infrastructure – building natural and urban resilience

Benefits – reduced flood risk, improved river ecosystem



The project created more than 900 acres of wetlands.

High tides inundate these restored terraces, creating a distinct habitat type.

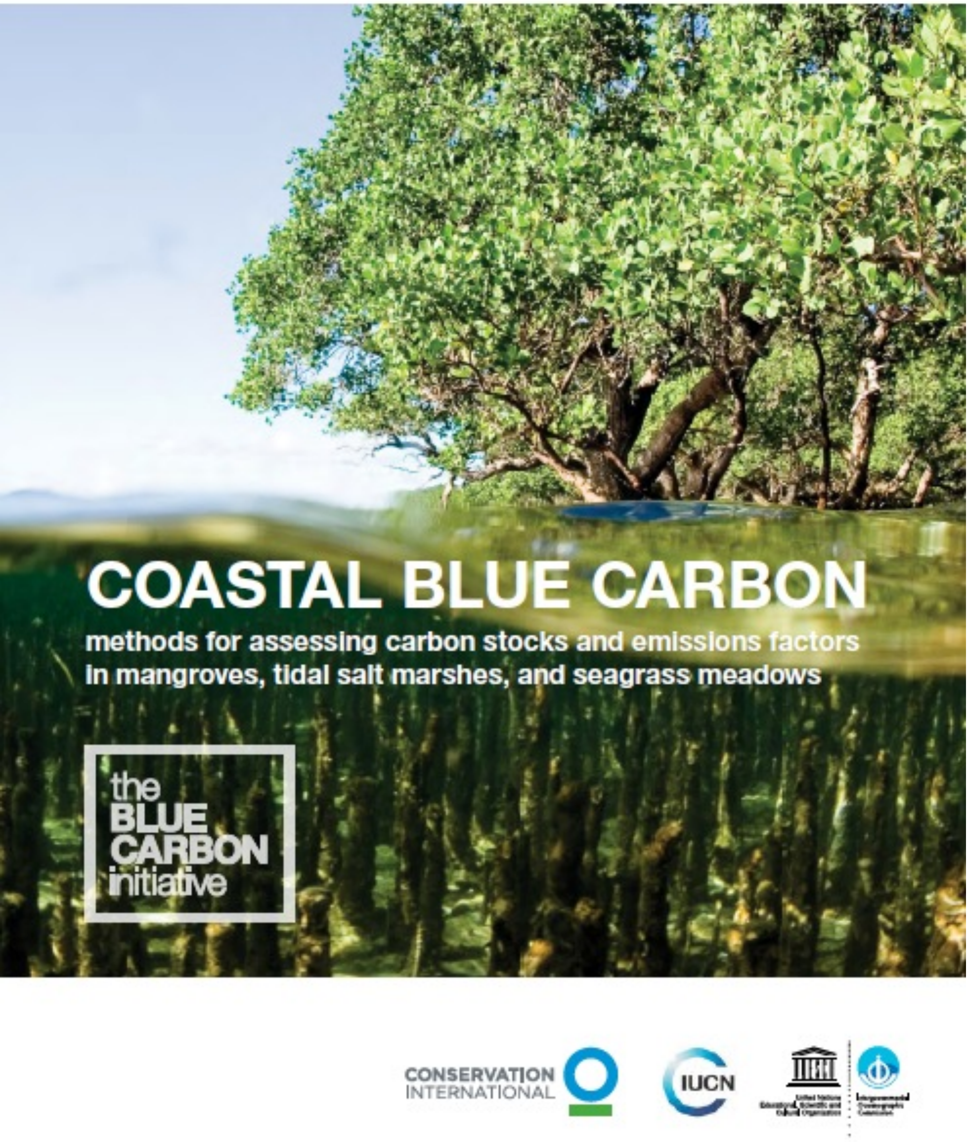
The project also includes conventional rock and concrete armoring in some locations, such as this vulnerable stretch of riverbank adjacent to downtown Napa.

When flows are high, this channel provides a bypass to the flood-prone oxbow section of the river. It also serves as important floodplain habitat.

Much of the historic floodplain has been restored, significantly increasing the amount of water that the river channel can accommodate without flooding developed areas.

PHOTO: Flooding along the Napa River in February, 1986
© Napa County Flood Control and Water Conservation District

ILLUSTRATION: © Napa County Flood Control and Water Conservation District



COASTAL BLUE CARBON

methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows

the BLUE CARBON initiative

CONSERVATION INTERNATIONAL

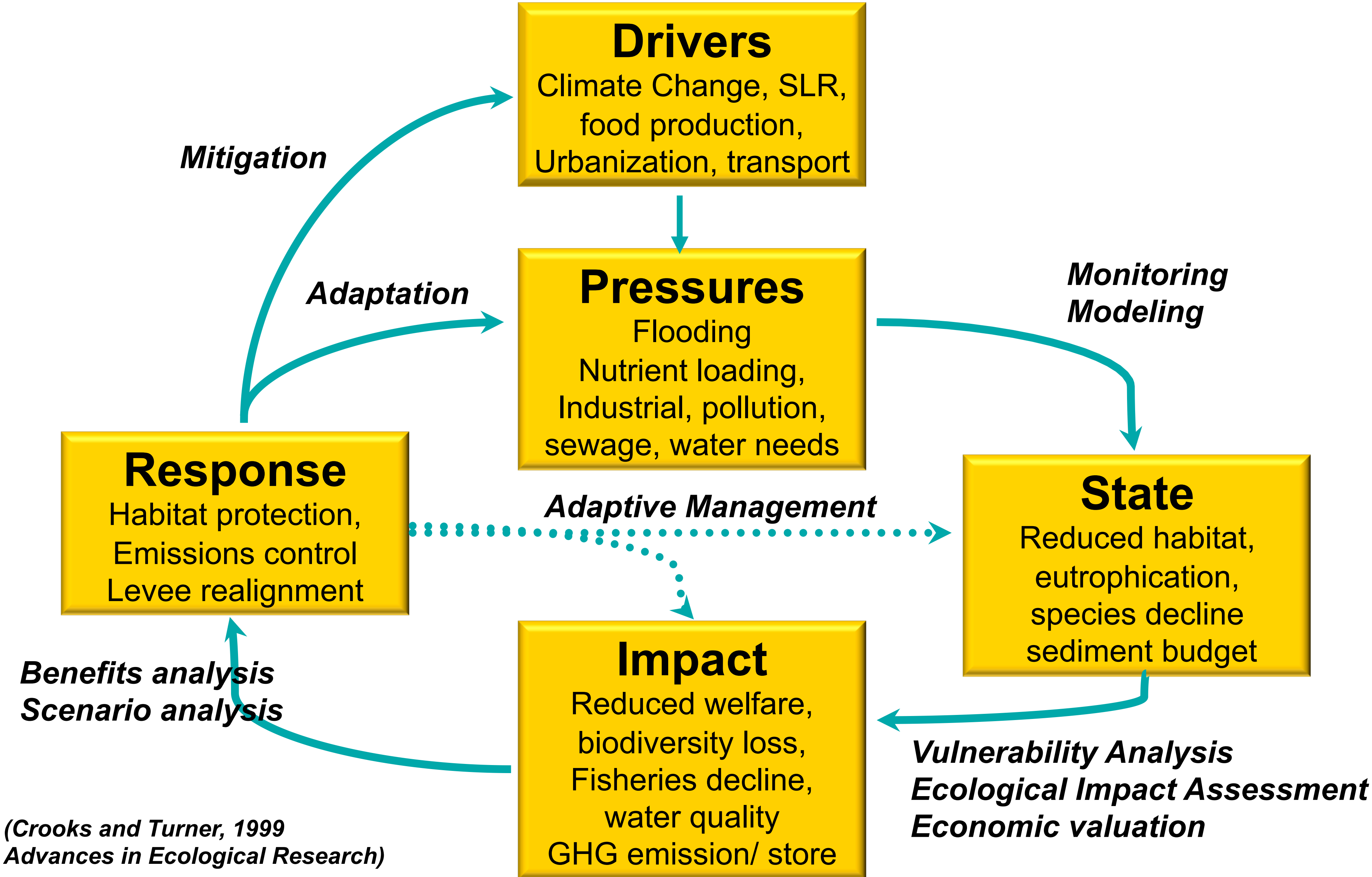
IUCN

Contents

- Why measure C stocks?
- Field Campaign Planning
- Sampling Soils
- Sampling Vegetation
- Estimating Emissions
- Remote Sensing and Mapping
- Data Management

BlueCarbonInitiative.org

Sustainable Management



Drivers
Climate Change, SLR,
food production,
Urbanization, transport

Pressures
Flooding
Nutrient loading,
Industrial, pollution,
sewage, water needs

State
Reduced habitat,
eutrophication,
species decline
sediment budget

Impact
Reduced welfare,
biodiversity loss,
Fisheries decline,
water quality
GHG emission/ store

Response
Habitat protection,
Emissions control
Levee realignment

Mitigation

Adaptation

Monitoring
Modeling

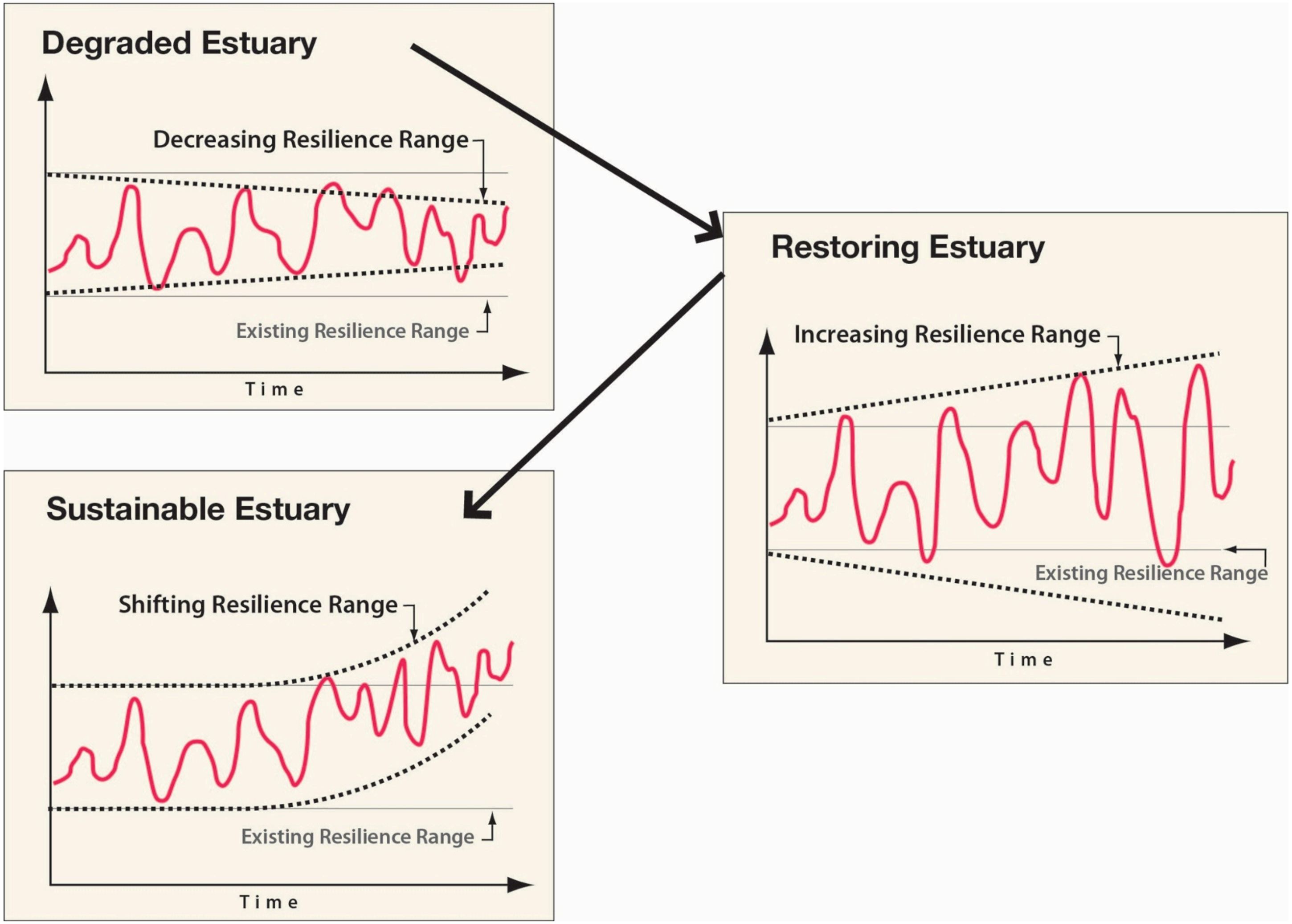
Adaptive Management

Vulnerability Analysis
Ecological Impact Assessment
Economic valuation

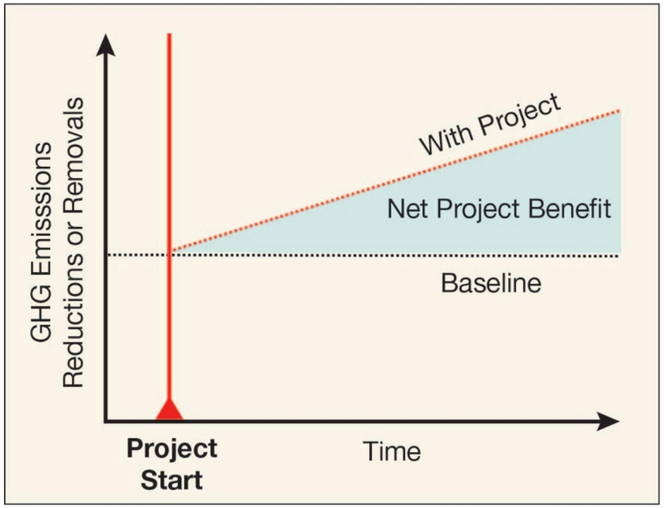
Benefits analysis
Scenario analysis

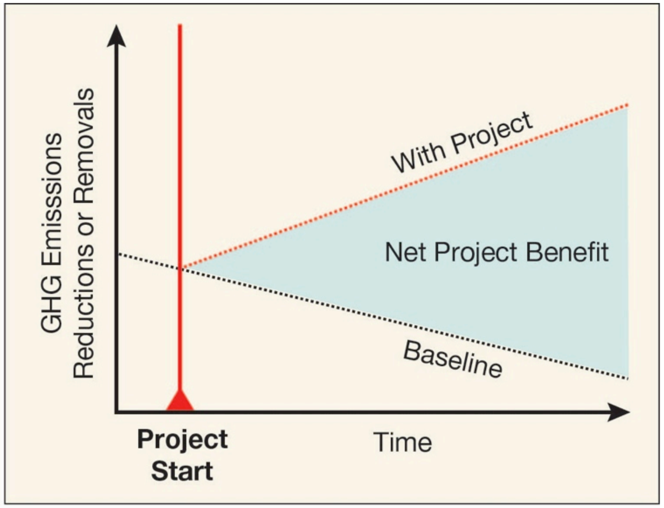
(Crooks and Turner, 1999
Advances in Ecological Research)

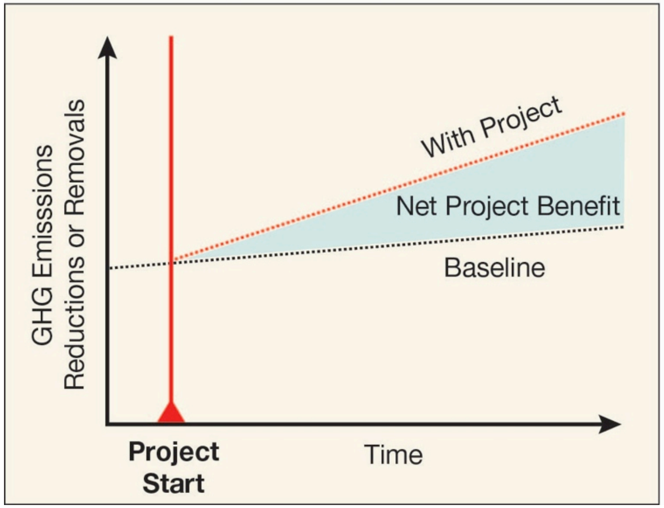
Goal of Restoration (Adaptation)

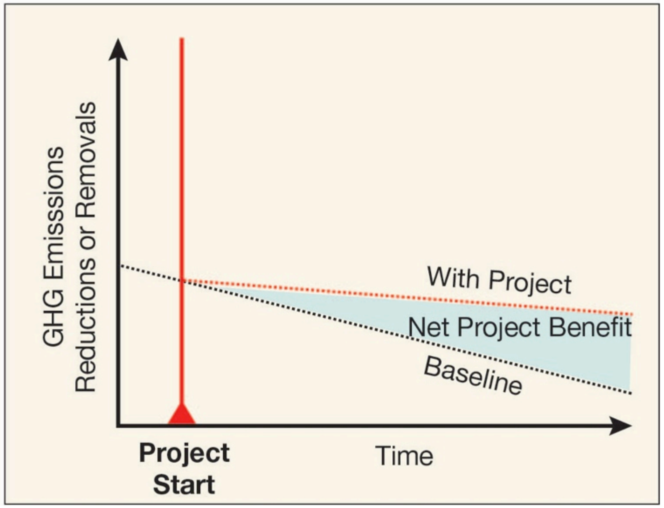


Goal of Carbon Management









Source: Forest Trends

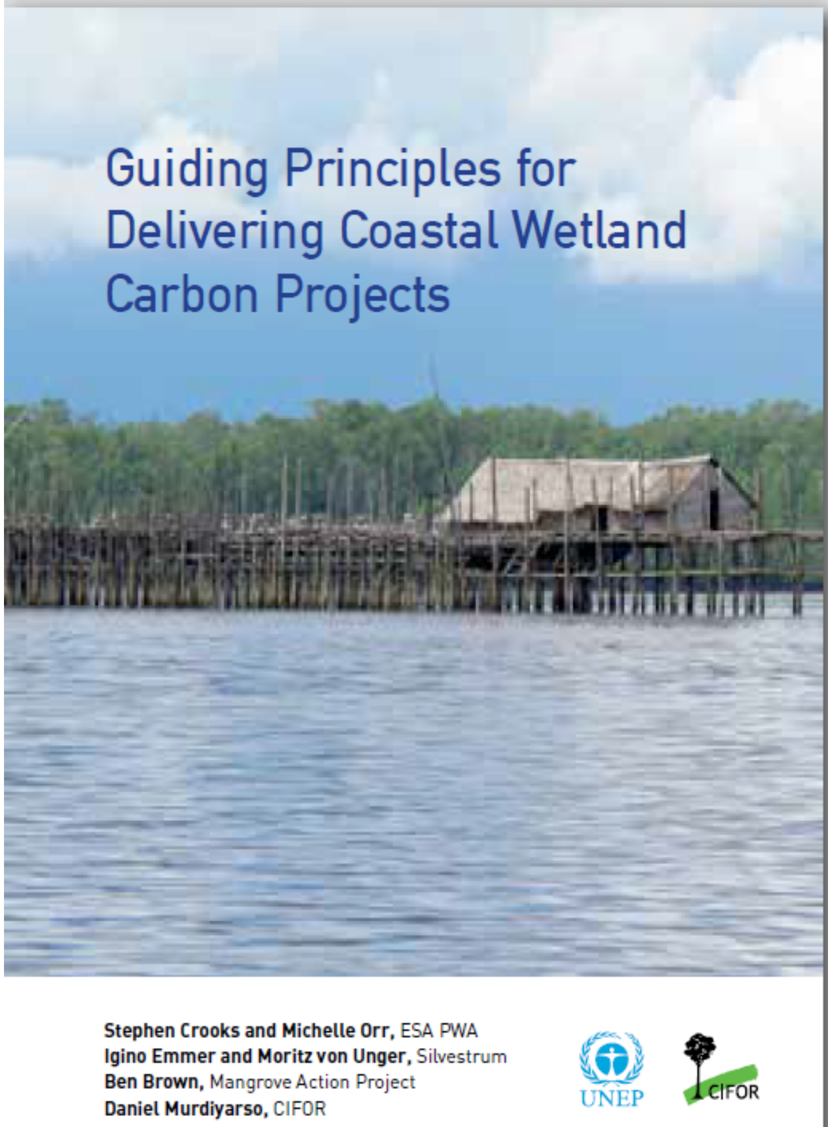
Wetland Management Learning Curve

1. Recognize value of wetland management
2. Establish examples of good practice
3. Achieve multi-use functional landscape

4. Adaptation to climate change
5. Incorporate GHG fluxes and storage

Blue Carbon Interventions:

Policy adjustment
Management actions
Carbon finance projects



Guiding Principles for
Delivering Coastal Wetland
Carbon Projects

Stephen Crooks and Michelle Orr, ESA PWA
Igino Emmer and Moritz von Unger, Silvestrum
Ben Brown, Mangrove Action Project
Daniel Murdiyarso, CIFOR

UNEP
CIFOR

Ecosystems in focus for climate change mitigation

Forest

Peatland

Mangroves

Tidal Marshes

Seagrass

Long-term carbon sequestration and storage

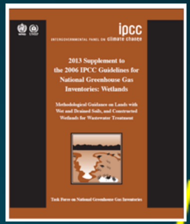
Carbon from plants gather in soil and builds up over thousands of years

The state of blue carbon science:

a short review of achievements and gaps

Chmura et al 2003

Duarte et al 2005



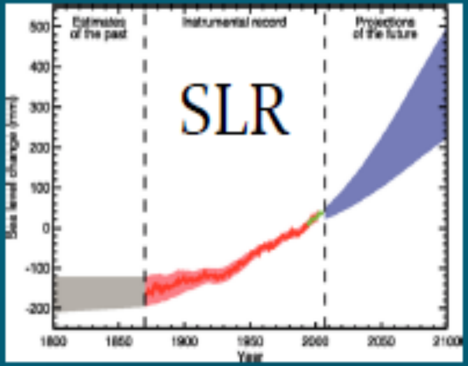
ipcc

INTERGOVERNMENTAL PANEL ON climate change

2013 Supplement to
the 2006 IPCC Guidelines for
National Greenhouse Gas
Inventories: Wetlands

Methodological Guidance on Lands with
Wet and Drained Soils, and Constructed
Wetlands for Wastewater Treatment

Task Force on National Greenhouse Gas Inventories



Currently coastal wetlands are being lost at around 1% per year.

Upstream disruptions

Salt Ponds

Aquaculture

Rice/Agriculture

Road development /hydrological disruptions

Coastal development

Changes in Wetlands of Coastal Watersheds, U.S.

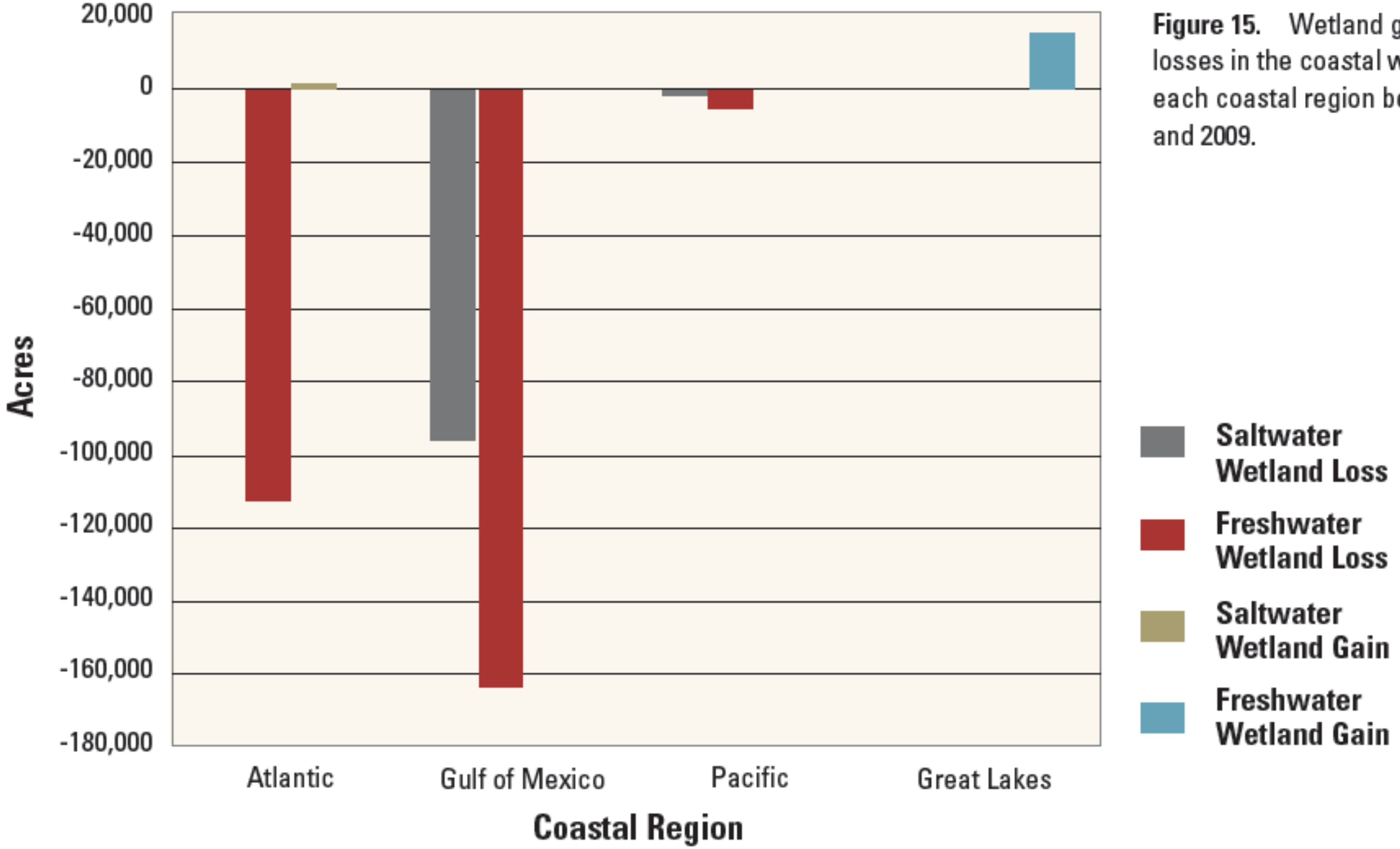
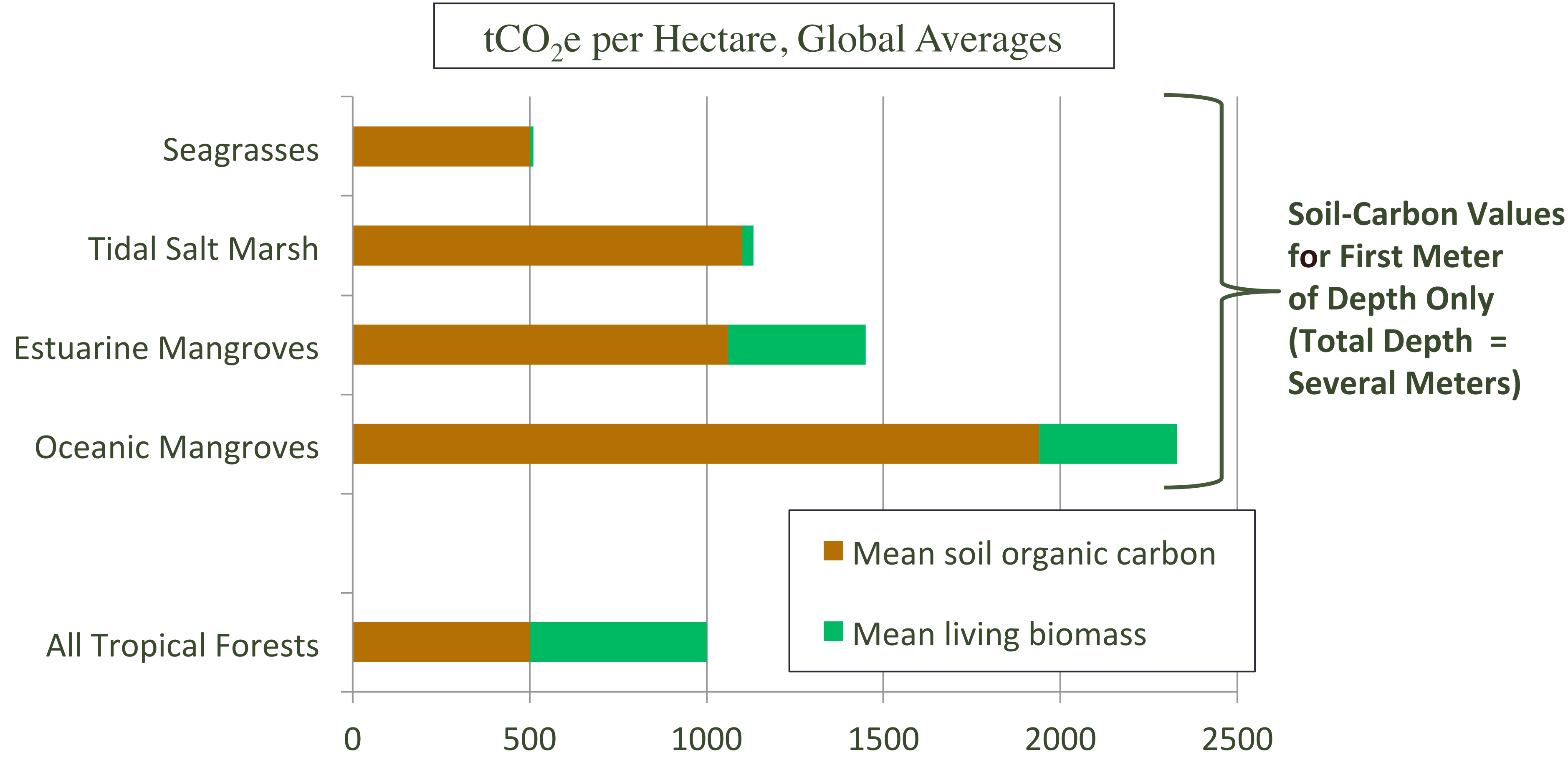


Figure 15. Wetland gains and losses in the coastal watersheds of each coastal region between 2004 and 2009.

T.E. Dahl and S.M. Stedman. 2013. Status and trends of wetlands in the coastal watersheds of the Conterminous United States 2004 to 2009. U.S. Department of the Interior, Fish and Wildlife Service and National Oceanic and Atmospheric Administration, National Marine Fisheries Service. (46 p.)

Distribution of carbon in coastal ecosystems



Data summarized in Crooks *et al*., 2011; Murray *et al*., 2011, Donato et al., 2011, Fourqurean et al 2013

U.S. Regional Carbon Stocks

Soil C pool (tonnes CO2e ha^{-1})

SALT MARSH

climate	**C pool (tonnes CO2e/ha)**	**SE**	**range**	**n**
temperate cold	1,285	101	859 - 2,017	11
temperate warm	1,147	59	134 - 2,210	77
mediterranean	1,093	65	699 - 1,760	21
subtropical - all	1,459	168	359 - 6,967	61
subtropical - LA only	1,623	264	359 - 6,967	37
subtropical - rest	1,126	78	440 - 1,908	24
forested, subtropical	985	402	103 - 2497	6

MANGROVE

climate	**C pool (tonnes CO2e/ha)**	**SE**	**range**	**n**
subtropical	1,562	77	796 - 2,457	27

SEAGRASS

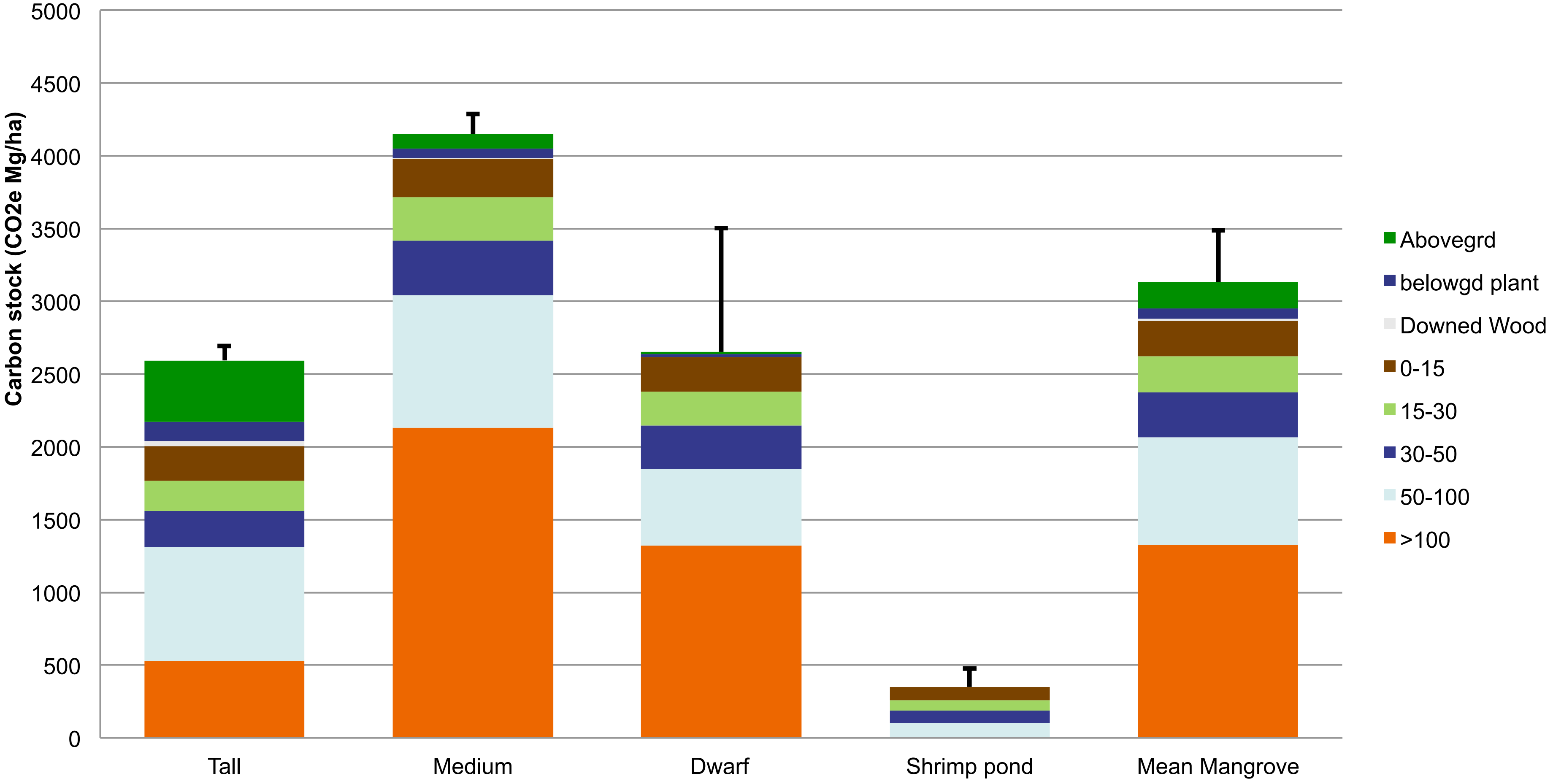
climate	**C pool (tonnes CO2e/ha)**	**SE**	**range**	**n**
temperate warm	-	-	-	0
mediterranean	-	-	-	0
subtropical	525	88	133 - 786	8

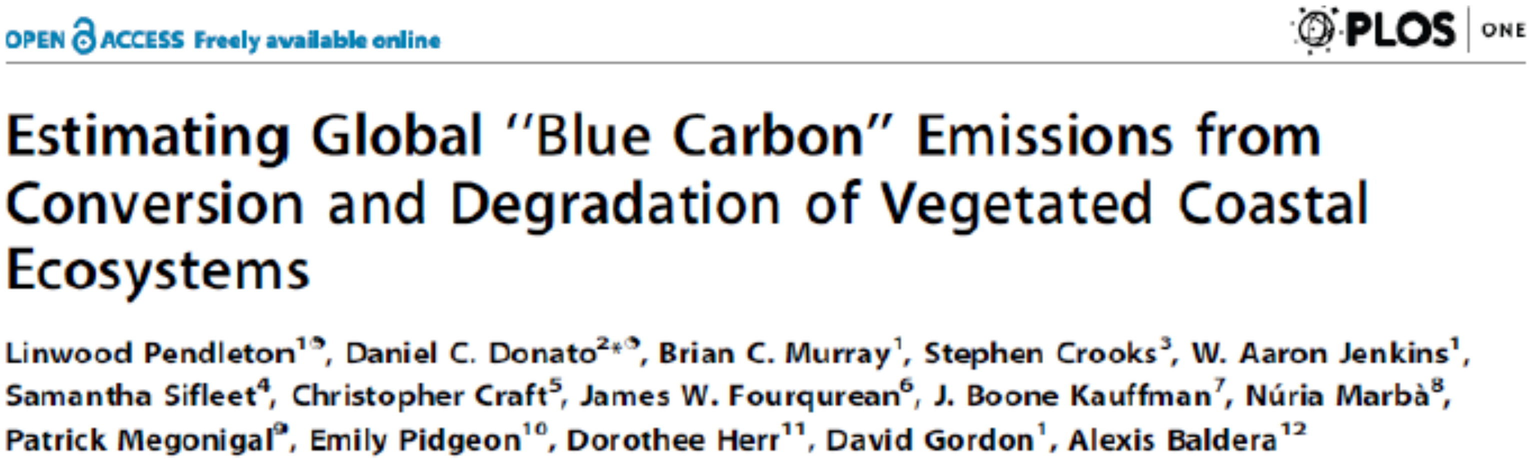
Smithsonian Environmental Research Center – Analysis On Going

CARBON STOCKS OF NEOTROPICAL MANGROVES ARE AMONG THE LARGEST OF ALL TROPICAL FORESTS

Ecosystem C stocks in CO_2e, Republica Dominicana 2012

Kauffman et al. 2013)





OPEN ACCESS Freely available online

PLOS ONE

Estimating Global "Blue Carbon" Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems

Linwood Pendleton[1], Daniel C. Donato[2*], Brian C. Murray[1], Stephen Crooks[3], W. Aaron Jenkins[1], Samantha Sifleet[4], Christopher Craft[5], James W. Fourqurean[6], J. Boone Kauffman[7], Núria Marbà[8], Patrick Megonigal[9], Emily Pidgeon[10], Dorothee Herr[11], David Gordon[1], Alexis Baldera[12]

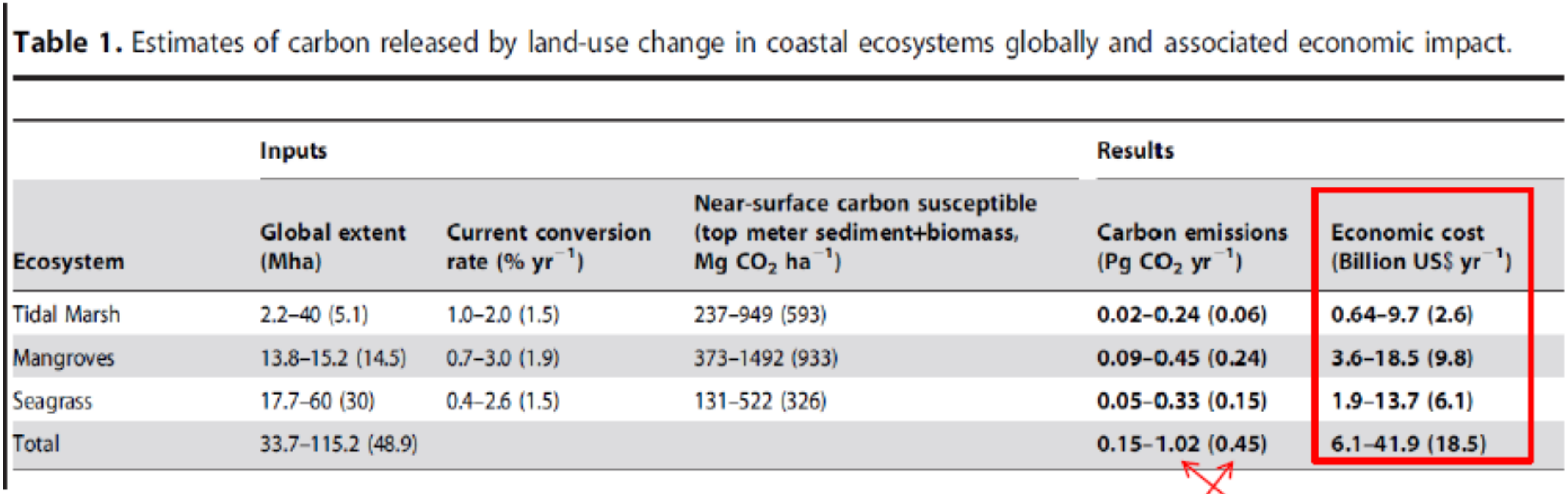


Table 1. Estimates of carbon released by land-use change in coastal ecosystems globally and associated economic impact.

	Inputs			Results	
Ecosystem	Global extent (Mha)	Current conversion rate (% yr^{-1})	Near-surface carbon susceptible (top meter sediment+biomass, Mg CO_2 ha^{-1})	Carbon emissions (Pg CO_2 yr^{-1})	Economic cost (Billion US$ yr^{-1})
Tidal Marsh	2.2–40 (5.1)	1.0–2.0 (1.5)	237–949 (593)	**0.02–0.24 (0.06)**	**0.64–9.7 (2.6)**
Mangroves	13.8–15.2 (14.5)	0.7–3.0 (1.9)	373–1492 (933)	**0.09–0.45 (0.24)**	**3.6–18.5 (9.8)**
Seagrass	17.7–60 (30)	0.4–2.6 (1.5)	131–522 (326)	**0.05–0.33 (0.15)**	**1.9–13.7 (6.1)**
Total	33.7–115.2 (48.9)			**0.15–1.02 (0.45)**	**6.1–41.9 (18.5)**

Compare to national emissions from all sources

Poland

Japan

Blue Carbon: The Game Plan

- United Nations Framework Convention on Climate Change
  - Brief national climate change negotiators
  - Identify policy opportunities
  - Engage IPCC and SBSTA
  - Multi-national demonstration projects

- National Governments
  - Establish programs and science research
  - Recognize wetlands in national accounting
  - Agency awareness, action, funding

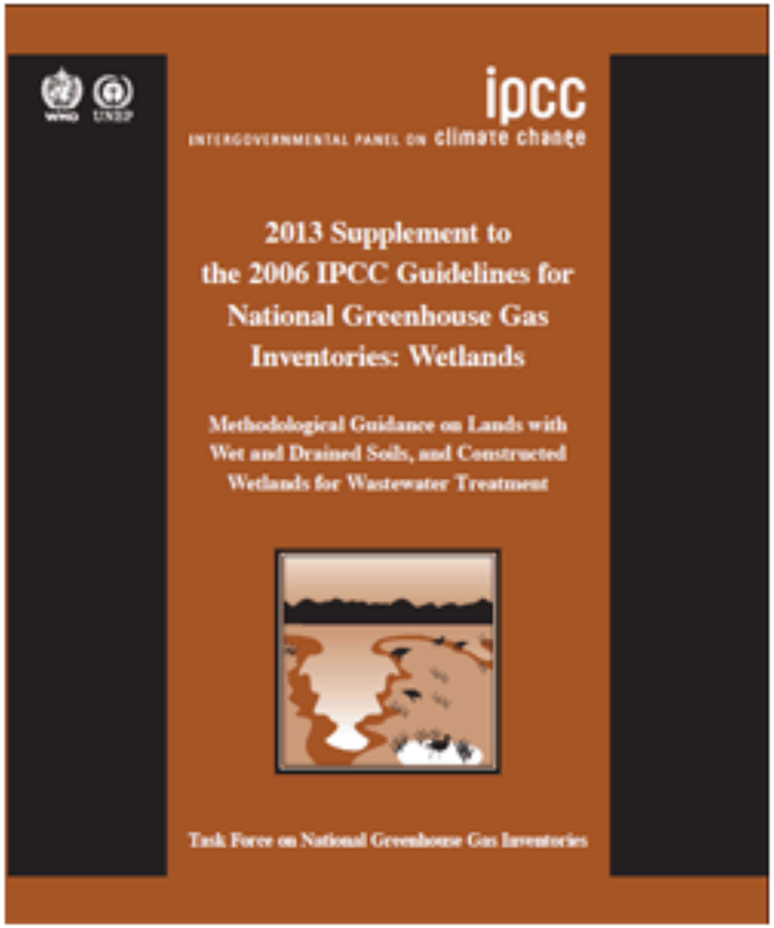
- Local Demonstration and Activities
  - Landscape level accounting
  - Establish carbon market opportunities
  - Look for synergistic conservation benefits
  - Demonstration projects and public awareness

Methodological Guidance for Coastal Wetlands in the
2013 SUPPLEMENT TO THE 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES: WETLANDS

2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands

1. Introduction
2. Drained Inland Organic Soils
3. Rewetted Organic Soils
4. Coastal Wetlands
5. Inland Wetland Mineral Soils
6. Constructed Wetlands for Wastewater Treatment
7. Cross-cutting Issues and Reporting

Adopted by IPCC Oct 2013, Published Feb 2014
http://www.ipcc-nggip.iges.or.jp/



WMO UNEP

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Task Force on National Greenhouse Gas Inventories

Chapter 4: Coastal Wetlands

This chapter updates guidance contained in the *2006 IPCC Guidelines* to:

- Provide default data for estimation of C stock changes in mangroves living biomass and dead wood pools for coastal wetlands at Tier 1

This chapter gives new:

- Guidance for CO_2 emissions and removals from organic and mineral soils for the management activities of extraction (including construction of aquaculture and salt production), drainage and rewetting and revegetation
- Default data for the estimation of anthropogenic CO_2 emissions and removals for soil in mangrove, tidal marsh and seagrass meadows.
- Guidance for N_2O emissions during aquaculture use.
- Guidance for CH_4 emissions for rewetting and revegetation of mangroves and tidal marshes.

U.S. Coastal Wetlands:
Potential Emissions and Removal

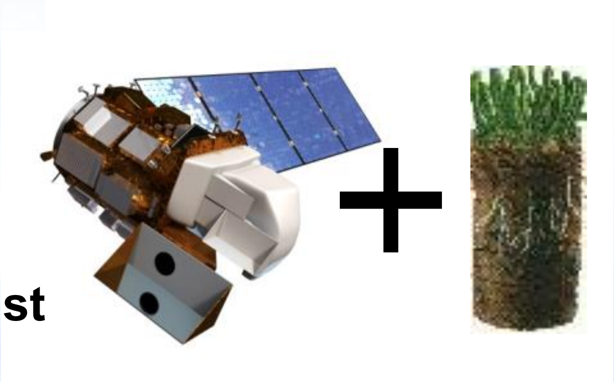
- **Drainage and excavation**
- **Human induced subsidence of wetlands (erosion)**
  - **(e.g. Mississippi Delta)**
- **Methane emissions from tidally disconnected /impounded waters**
- **Forestry Activities on Coastal Wetlands.**
- **Restoration of coastal wetlands and seagrasses**
- **Aquaculture (operations)**

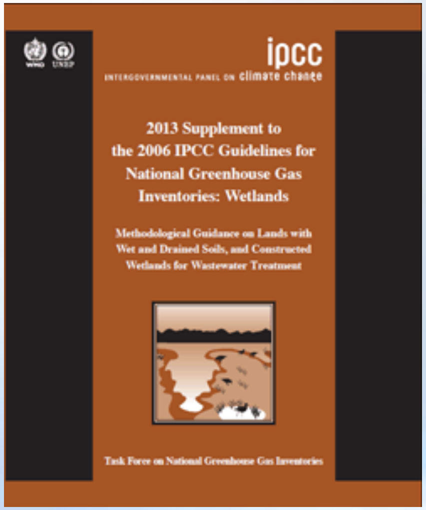
“Blue” Carbon Monitoring System

Linking soil and satellite data to reduce uncertainty in coastal wetland carbon burial: a policy-relevant, cross-disciplinary, national-scale approach

Lisamarie Windham-Myers (18 Science PIs; October 2014-17)

Federal		Non Federal	
USGS	Brian Bergamaschi	U. South Carolina	Jim Morris
	Kristin Byrd	U. Maryland/NOAA	Ariana Sutton-Grier
	Judith Drexler	U. San Francisco	John Callaway
	Kevin Kroeger	Florida Intl. U.	Tiffany Troxler
	John Takekawa	Texas A&M U.	Rusty Feagin
	Isa Woo	Independent	Stephen Crooks
Postdoc:	Meagan Gonneea		
NOAA-NERR	Matt Ferner		
Smithsonian	Pat Megonigal		
	Don Weller		
	Lisa Schile		
Postdoc:	**James Holmquist**		
NASA-JPL	Marc Simard		





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INTERGOVERNMENTAL PANEL ON climate change

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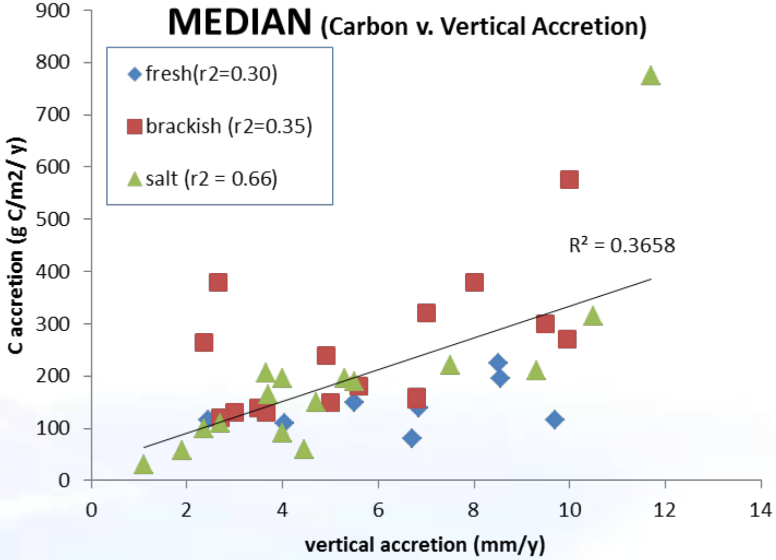
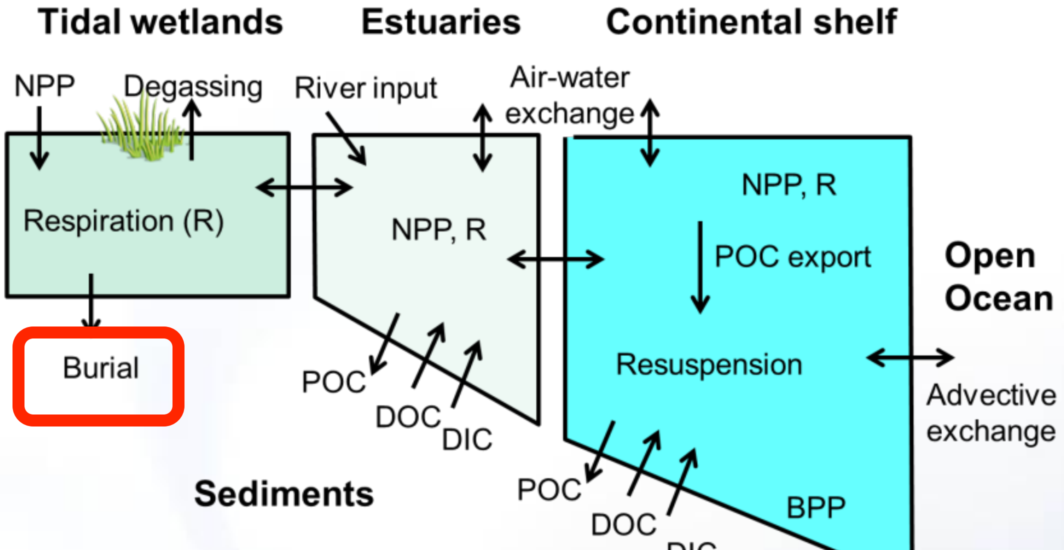
Task Force on National Greenhouse Gas Inventories

"Blue" CMS Need – *reduce uncertainty*

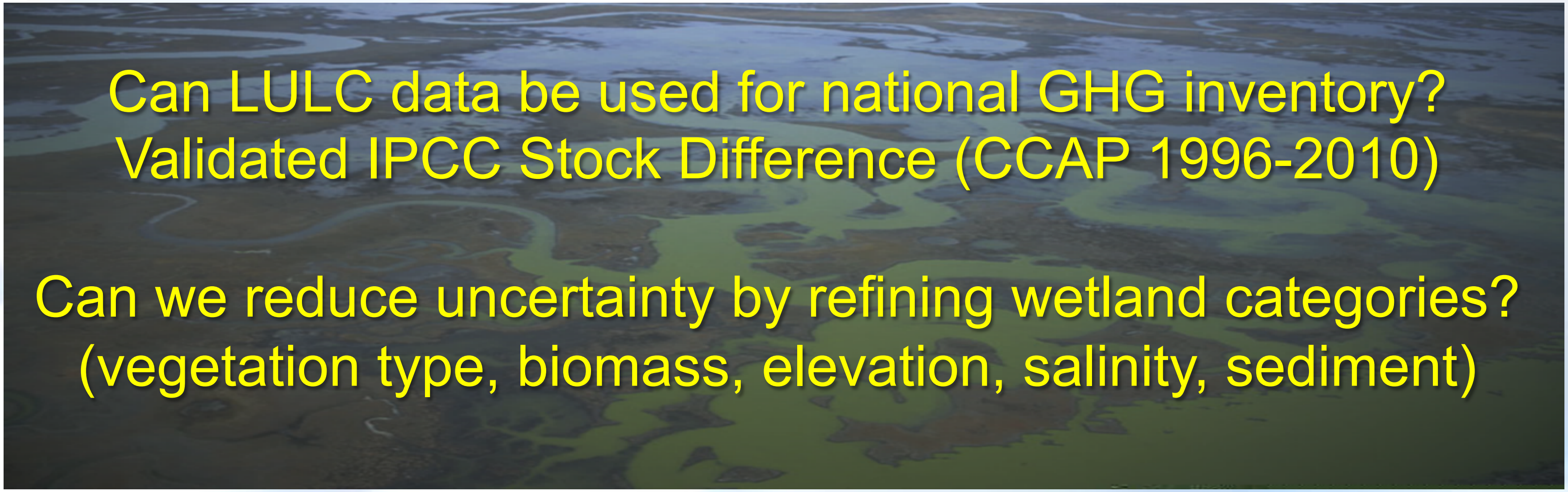
Source: Craft 2007, L&O



Source: OCB- CoastalCARbonSynthesis



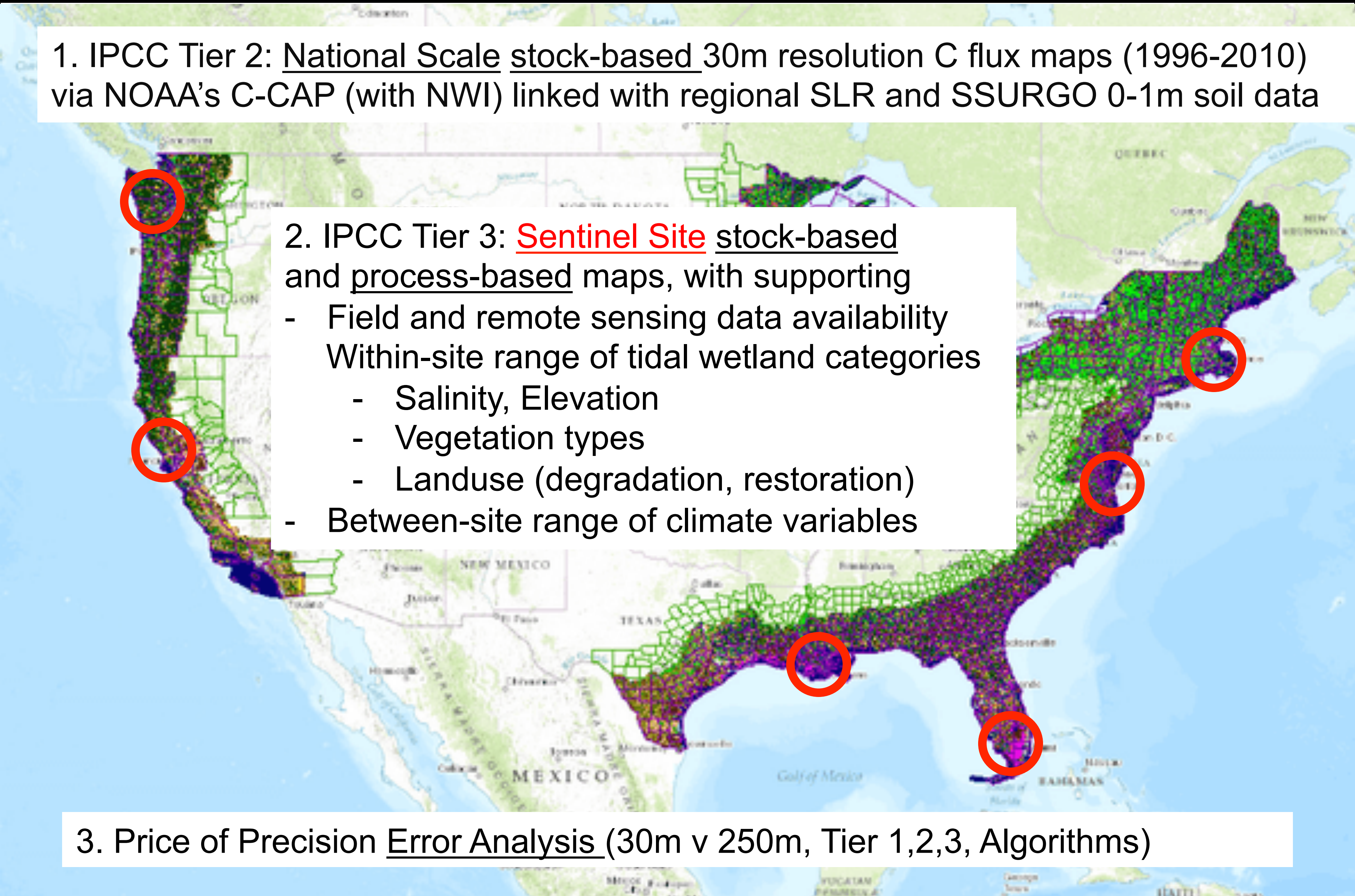
Also see Najjar et al. project



Can LULC data be used for national GHG inventory?
Validated IPCC Stock Difference (CCAP 1996-2010)

Can we reduce uncertainty by refining wetland categories?
(vegetation type, biomass, elevation, salinity, sediment)

“Blue” CMS – Product Goals

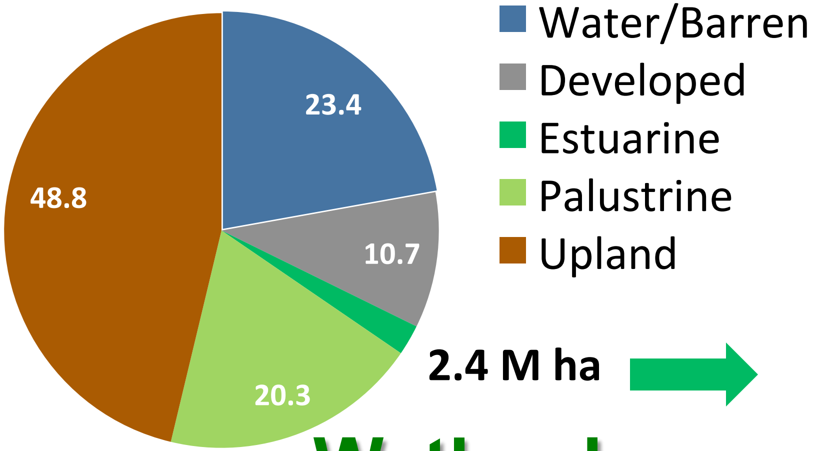


1. IPCC Tier 2: National Scale stock-based 30m resolution C flux maps (1996-2010) via NOAA’s C-CAP (with NWI) linked with regional SLR and SSURGO 0-1m soil data

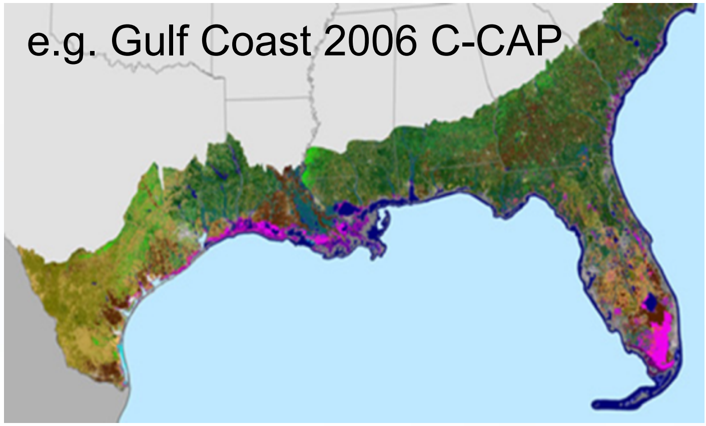
2. IPCC Tier 3: Sentinel Site stock-based and process-based maps, with supporting
- Field and remote sensing data availability
  Within-site range of tidal wetland categories
    - Salinity, Elevation
    - Vegetation types
    - Landuse (degradation, restoration)
- Between-site range of climate variables

3. Price of Precision Error Analysis (30m v 250m, Tier 1,2,3, Algorithms)

U.S. NOAA C-CAP 2010 – tidal wetlands

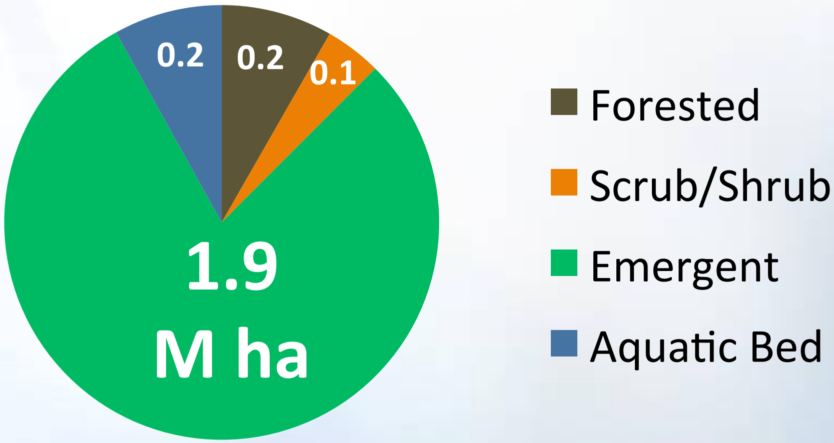


2.4 M ha →

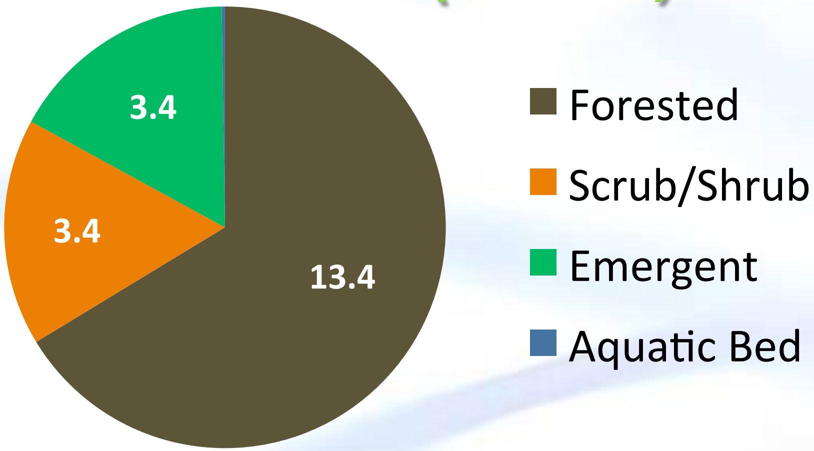


Wetlands
23 M ha

Estuarine (Saline)



Palustrine (Fresh)



IPCC Default sed burial = 3.2 Tg
(2.3Mha x 1.4T ha^{-1} y^{-1})

“Blue” CMS Approach – national data

USDA SSURGO NOAA CCAP/FWS NWI NOAA tidegauges/LIDAR

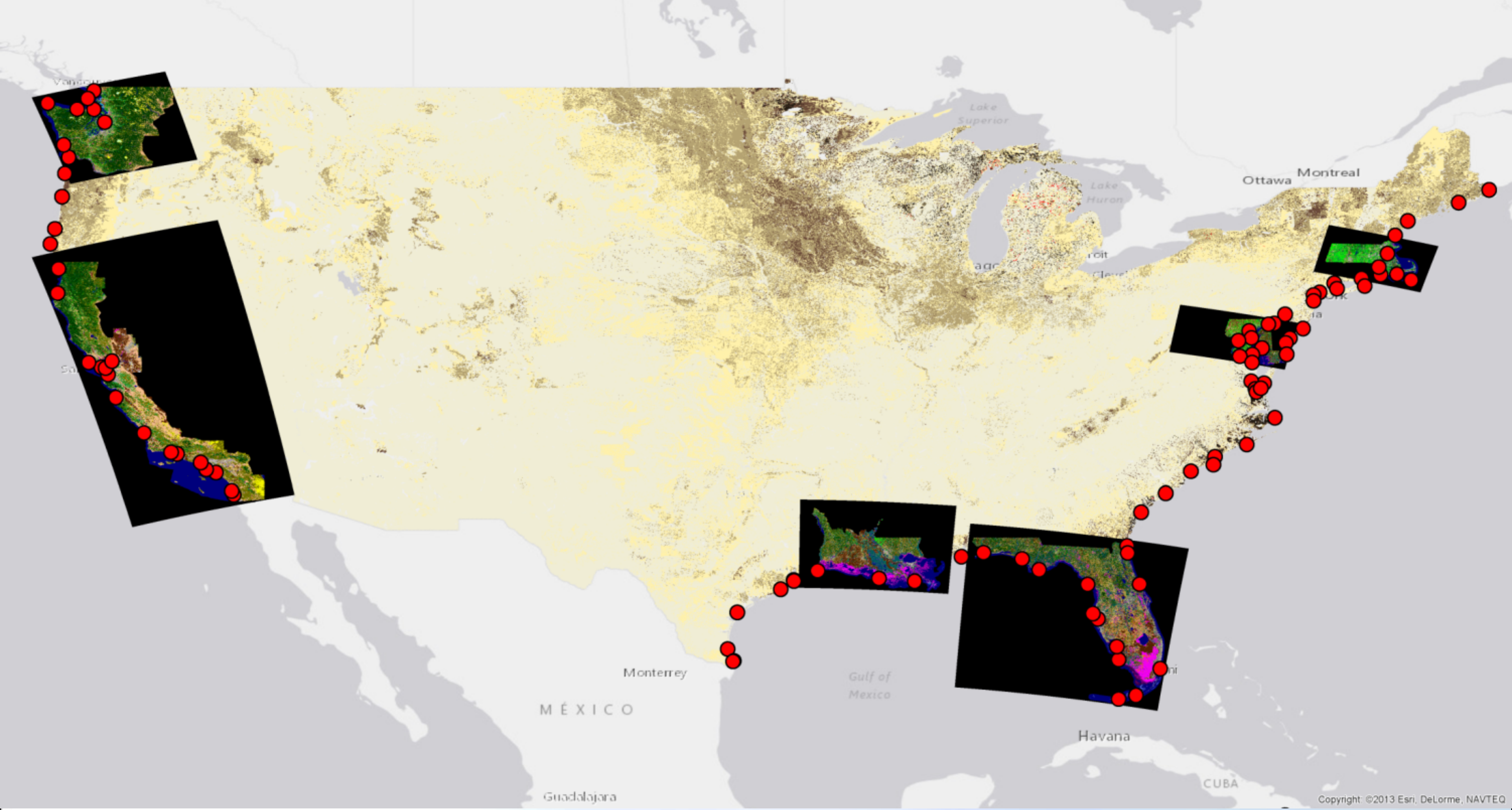
Land Use Conversions:
- No change (Wetland Remaining Wetland)
  - Wetland categories (Palustrine EM to Estuarine EM)
- Wetland to Open Water
- Agriculture (Cultivated) to Wetland
- Forest to Wetland
- Wetland to Developed

SIMPLE MATH

$$\text{Soil C density } (\text{g C cm}^{-3}) \times 10{,}000 \text{ cm}^{-2}/\text{m}^{-2} \times \text{Elevation change } (\text{cm y}^{-1}) = \text{C burial flux g C m}^{-2}\text{ y}^{-1}$$

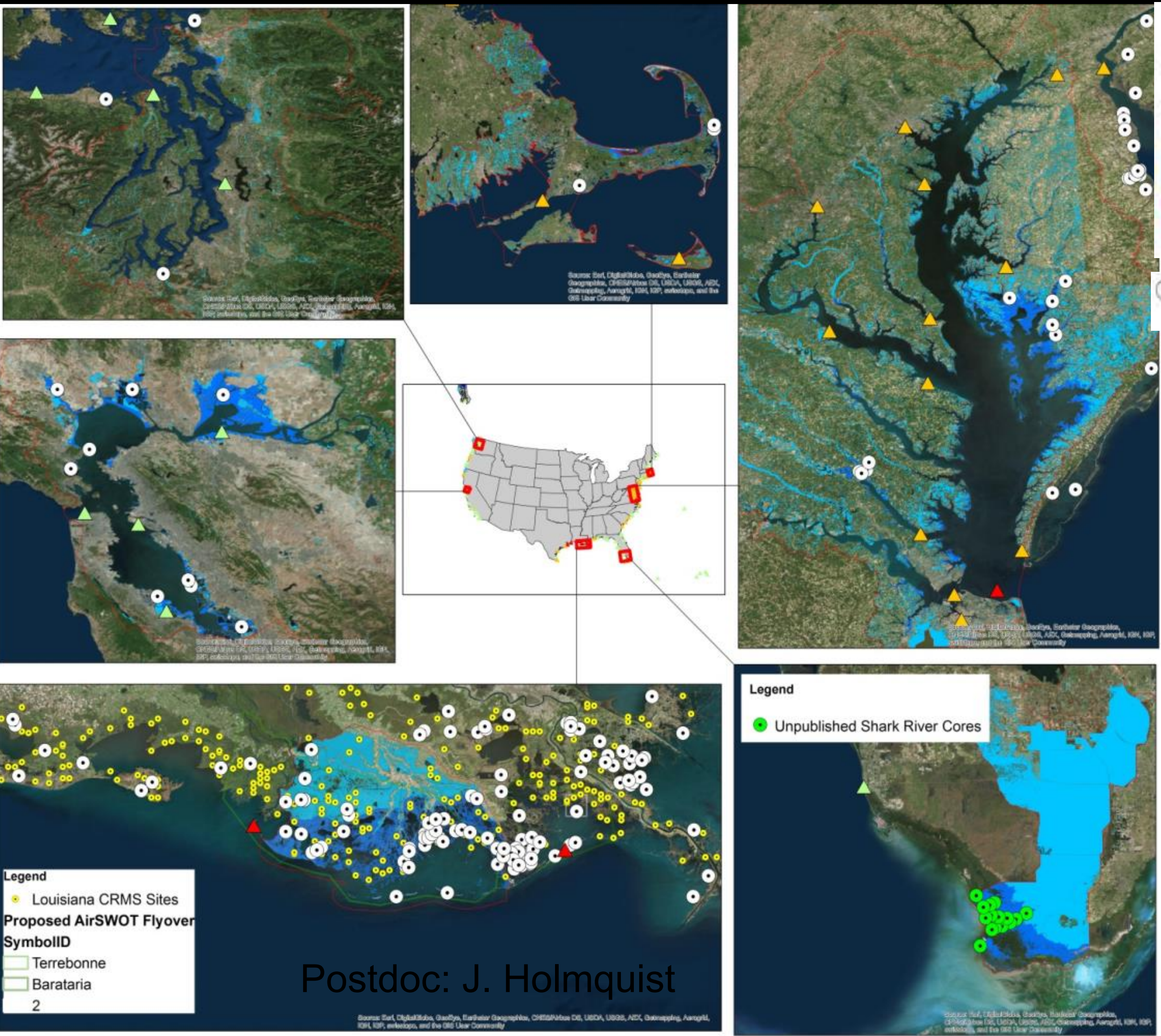
“Blue” CMS Approach – national data

USDA SSURGO NOAA CCAP/LIDAR/tidegauge USFWS NWI



Model data

“Blue” CMS Approach – field validation



Postdoc: J. Holmquist

C-CAP Data Class Names

🟦 Estuarine Wetlands

🟦 Palustrine Wetlands

⊙ Cs-137 and Pb-210 Dated Cores

6 sites chosen for dated cores, tidegauges, DEMs, range of hydrologic conditions and restoration status, as well as:

- Soil data
- Accretion data
- Biomass data
- Soil Salinity
- Methane fluxes
- NASA campaigns

“Blue” CMS Approach – *field validation (500+)*

NATIONAL VALIDATION DATASET/ARCHIVE - please contribute!

Useful C flux validation data

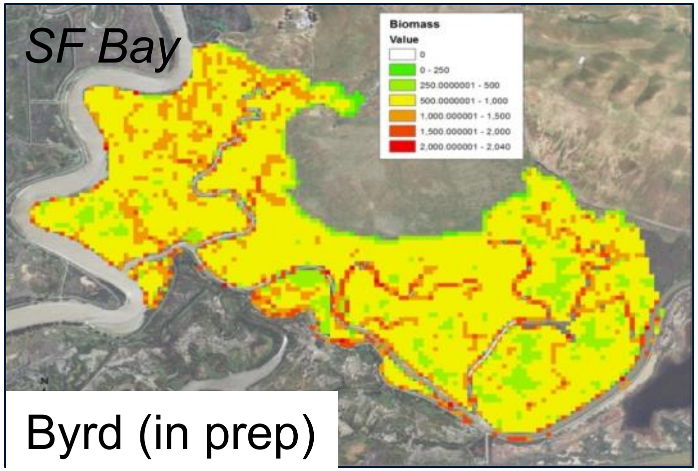
Useful C flux validation data	Suggested units	Range of data useful
Soil organic matter	% Loss on Ignition	0-100cm or more
Soil organic carbon	%C (excluding inorganic)	0-100cm or more
Bulk density	g cm^{-3}	0-100cm or more
Carbon density	g C cm^{-3}	0-100cm or more
Soil accretion or loss	cm y^{-1}	10 y, 50 y or 100 y or more
C accretion or loss	g C m^{-2} y^{-1}	10 y, 50 y or 100 y or more
Relative Sea Level Rise	cm y^{-1}	10 y, 50 y or 100 y or more
Plant biomass (aboveground)	g m^{-2}	Stock of live biomass and species
Plant biomass (belowground)	g m^{-2}	Stock of live biomass and species
Soil Salinity	Parts per thousand	Annual range
Methane fluxes	mg CH_4 m^{-2} y^{-1}	Any information is useful

Needed Metadata

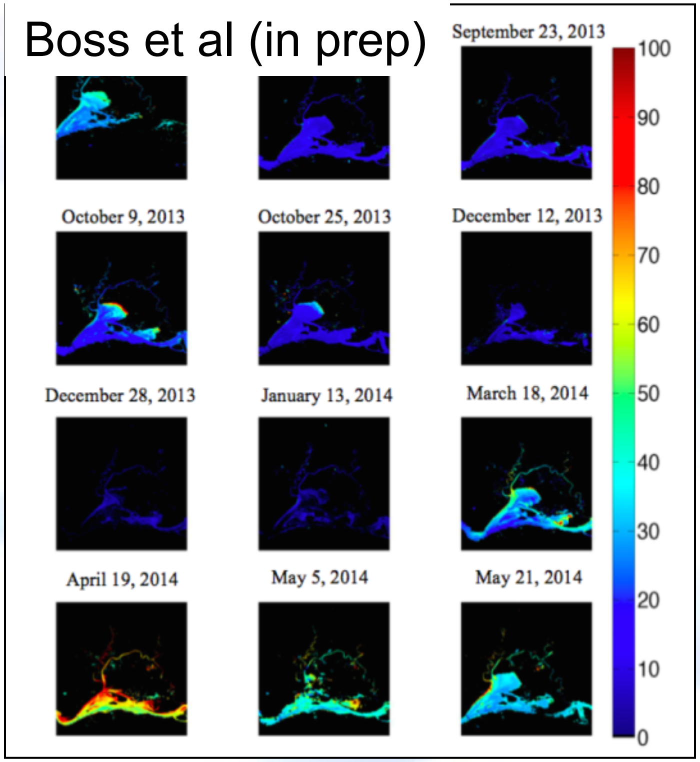
Latitude (dd)	Longitude (dd)	Site status (any info)	Date(s) collected	Method used	Source of data	Data owner	Permission
4 decimals	4 decimals	Natural? Restored? Restoring?	Range is fine	Citation if possible	Citation	Name, contact info	Use/share/contact prior to distribution

If enough data exist, owners may request to serve as secondary sites

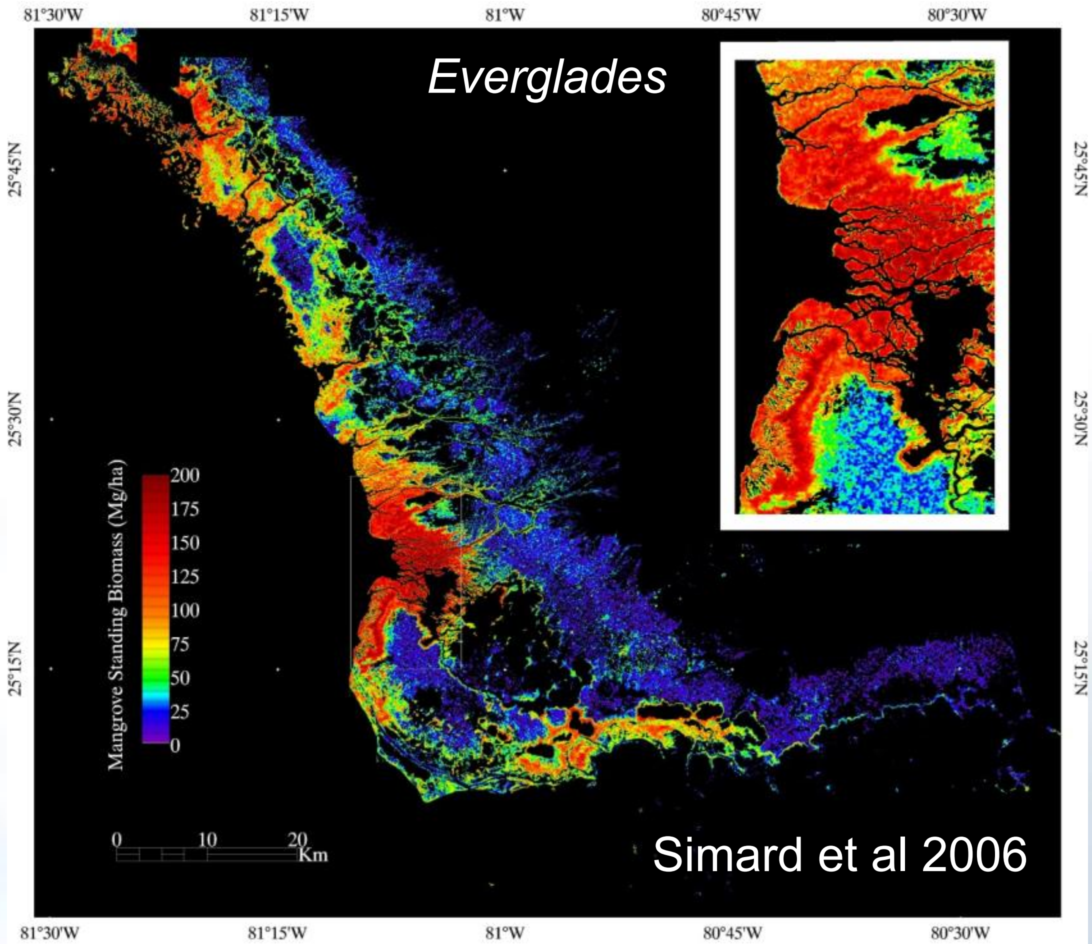
“Blue” CMS –Aqueous&Biomass Remote Sensing



Byrd (in prep)



Boss et al (in prep)



Simard et al 2006

	Sensor	RMSE	%
Biomass (T ha^{-1})	Landsat8 (marsh)	3.3	14
	SRTM (mangrove)	20	20
SSC (mg/L)	Landsat8 (marsh)	3.4	10

“Blue” CMS – Process-based Model

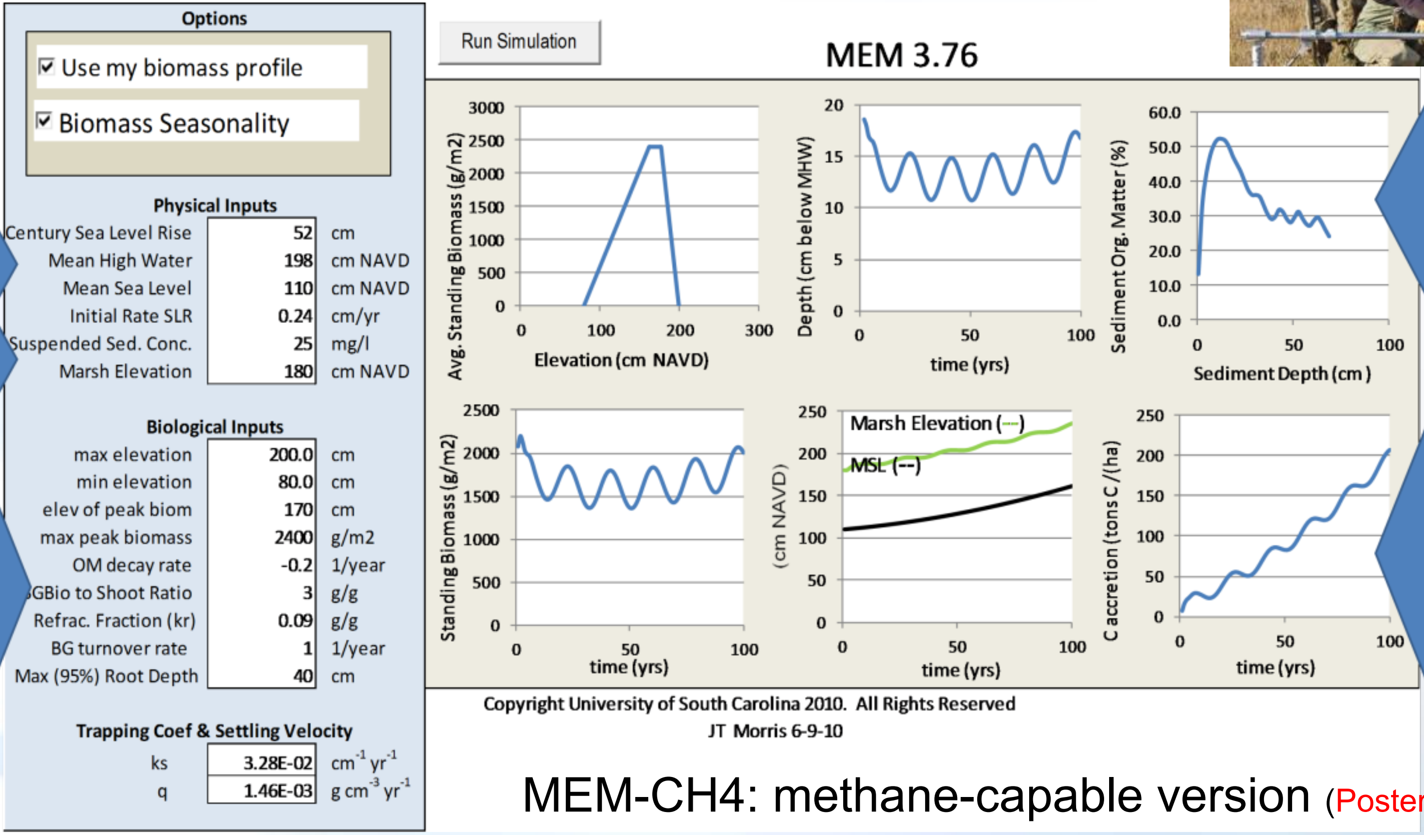
From past and present, project future

Marsh Equilibrium Model (version 5.4):
mechanistic, annual cohort, 1D accretion

SLR

SSC

Elevation of Peak Biomass and g/m²



Options

☑ Use my biomass profile

☑ Biomass Seasonality

Run Simulation

MEM 3.76

Physical Inputs

Century Sea Level Rise	52	cm
Mean High Water	198	cm NAVD
Mean Sea Level	110	cm NAVD
Initial Rate SLR	0.24	cm/yr
Suspended Sed. Conc.	25	mg/l
Marsh Elevation	180	cm NAVD

Biological Inputs

max elevation	200.0	cm
min elevation	80.0	cm
elev of peak biom	170	cm
max peak biomass	2400	g/m2
OM decay rate	-0.2	1/year
GBio to Shoot Ratio	3	g/g
Refrac. Fraction (kr)	0.09	g/g
BG turnover rate	1	1/year
Max (95%) Root Depth	40	cm

Trapping Coef & Settling Velocity

ks	3.28E-02	$cm^{-1} yr^{-1}$
q	1.46E-03	$g\ cm^{-3} yr^{-1}$

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JT Morris 6-9-10

Core profile for hindcast validation

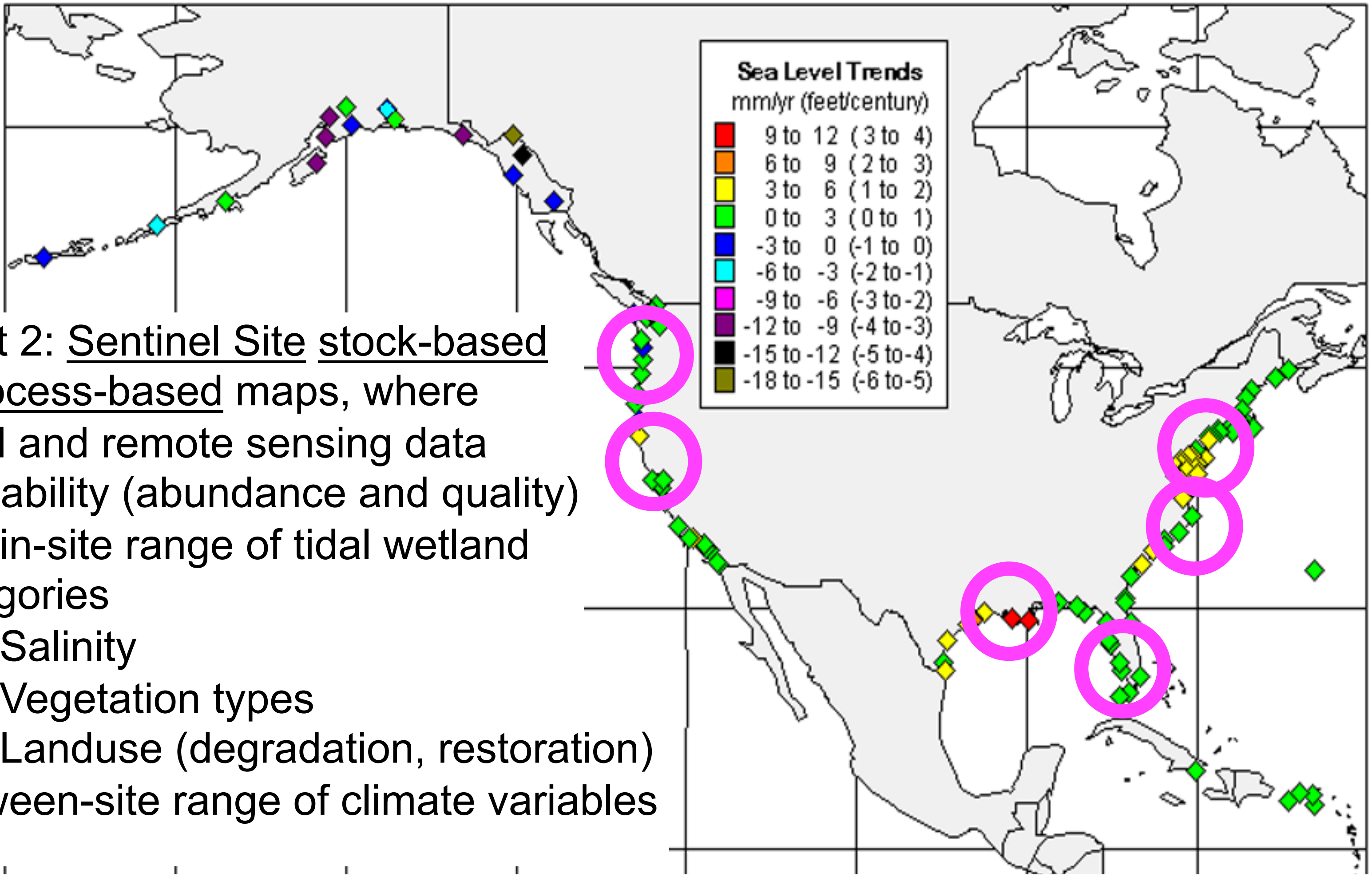
Equilibrium Long-term Carbon Accretion Rate

MEM-CH4: methane-capable version (Poster*)

Once calibrated, relative elevation is used to estimate cumulative accretion, water depth, flooding frequency, aboveground and belowground biomass, and carbon stored.

"Blue" Carbon Monitoring System

Product 1: National Scale stock-based 30m resolution C pool maps (1992-2011) via NOAA's C-CAP (NLCD) linked with regional SLR and SSURGO 1m soil data



Product 2: Sentinel Site stock-based and process-based maps, where

- Field and remote sensing data availability (abundance and quality)
- Within-site range of tidal wetland categories
    - Salinity
    - Vegetation types
    - Landuse (degradation, restoration)
- Between-site range of climate variables

Product 3: Price of Precision Error Analysis (30m v 250m, Tier 1,2,3, Algorithms)

Greenhouse gases

Gas	Current (1998) Amount by volume	Global warming Potential	Percent increase since 1750	Radiative forcing (W/m²)
Carbon dioxide CO_2	365 ppm	1	31%	1.46
Methane CH_4	1,745 ppb	21 (25, 34)	150%	0.48
Nitrous oxide N_2O	314 ppb	310	16%	0.15

ESA PWA

Net Carbon Sequestration Potential

Wetland Type	**Carbon Sequestration Potential** (tons CO_2e/acre/year)	**Methane Production Potential** (tons CO_2e/acre/year)	**Net balance**
Mudflat (saline)	Low (< 0.74)	Low (< 0.2)	Low C sequestration
Salt Marsh (salinity >20ppt)	**High (0.74 – 3.71)**	**Low (< 0.2)**	**High C sequestration**
Mangrove	High (0.74 – 3.71)	Low – High	Depends on salinity
Brackish Tidal Marsh (salinity <20 ppt)	High (0.74 – 6.68)	High (0.51 – 10.12)	Unclear[1]
Freshwater Tidal Marsh (Managed)	**Very High (8 - 25)**	**Very High (5 - 12)**	**Potential very high C sequestration**
Freshwater Tidal Marsh	Very High (2.02+)	Medium to very high	Unclear – Net GHG emissions uncertain[2]
Estuarine Forest	High (1.49 – 3.71)	Low (< 1.01)	High C sequestration

[1] Too few studies to draw firm conclusions. CH_4 emissions brackish wetlands may negate carbon sequestration within soils. Further research required.

[2] Too few studies to draw firm conclusions. CH_4 emissions from freshwater tidal wetlands may partially or fully negate carbon sequestration within soils.

Source: Crooks et al. 2009

Example Project Activities

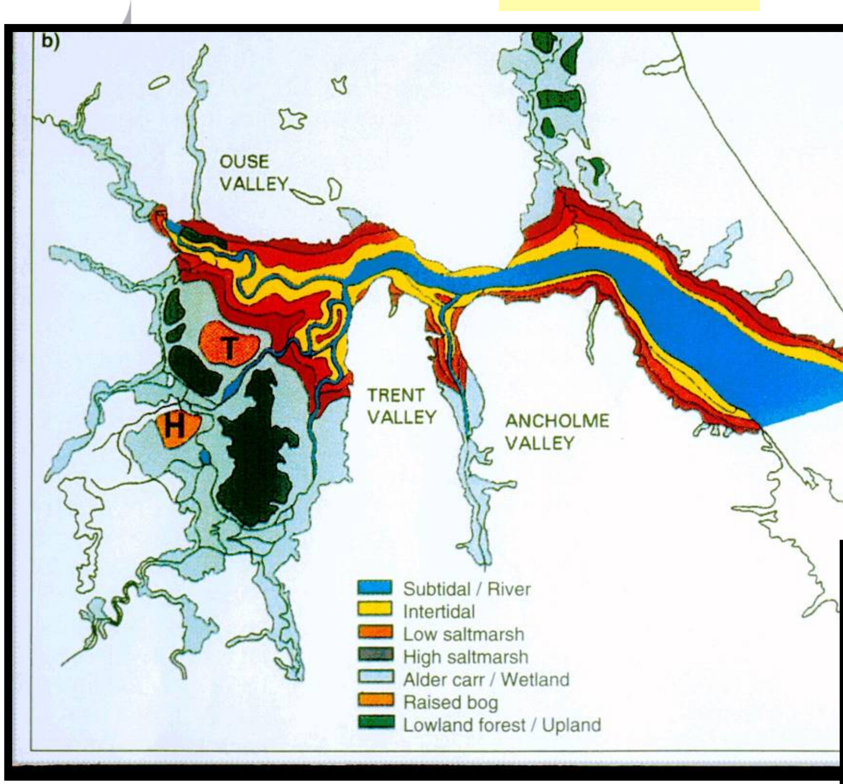
- **Conservation**
  - Protection of at risk wetlands
  - Improved water management on drained wetlands
  - Sediment recharge to coastal wetlands
  - Space for migrating wetlands

- **Restoration / creation**
  - Lowering of water levels on impounded wetlands
  - Raising soil surfaces with dredged material
  - Increasing sediment supply by removing dams
  - Restoring salinity conditions
  - Improving water quality
  - Revegetation
  - Combinations of the above

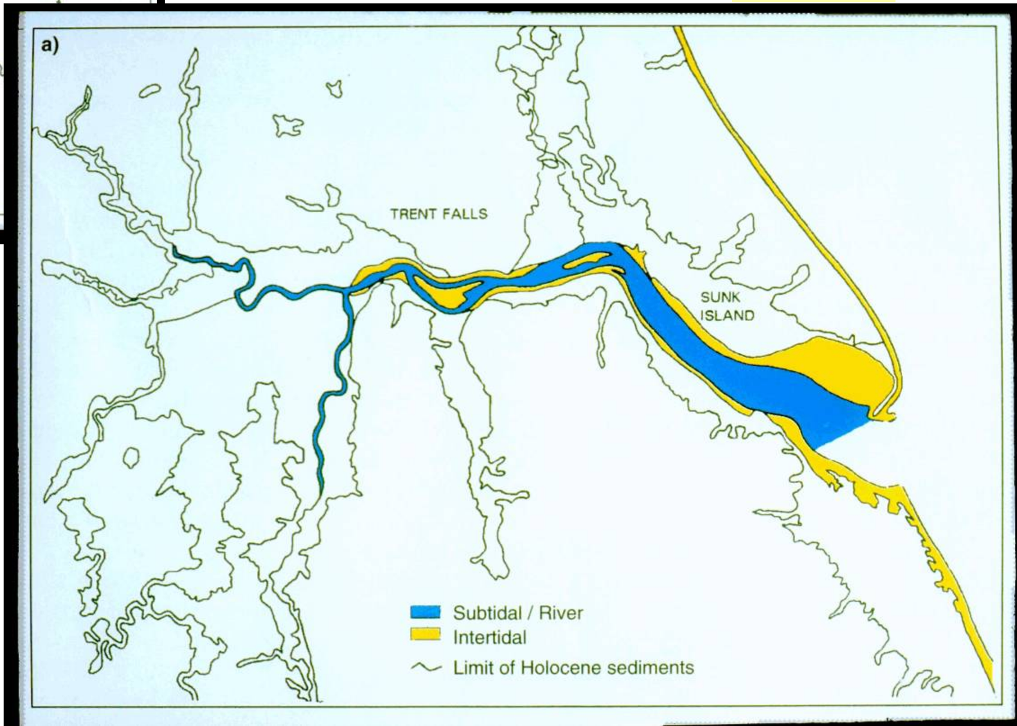
The Humber Estuary

405 km of levees
870 km^2 of drained wetlands

Historic



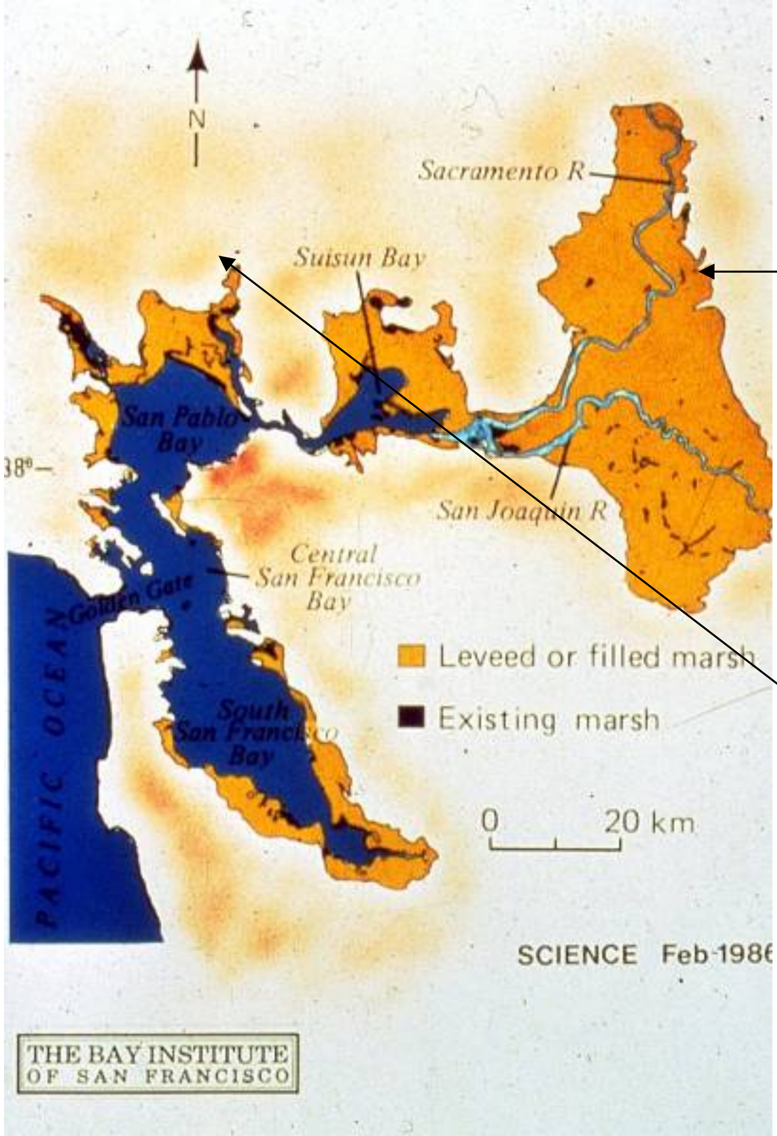
Now



Loss of biomes and carbon stocks.

Ongoing emissions

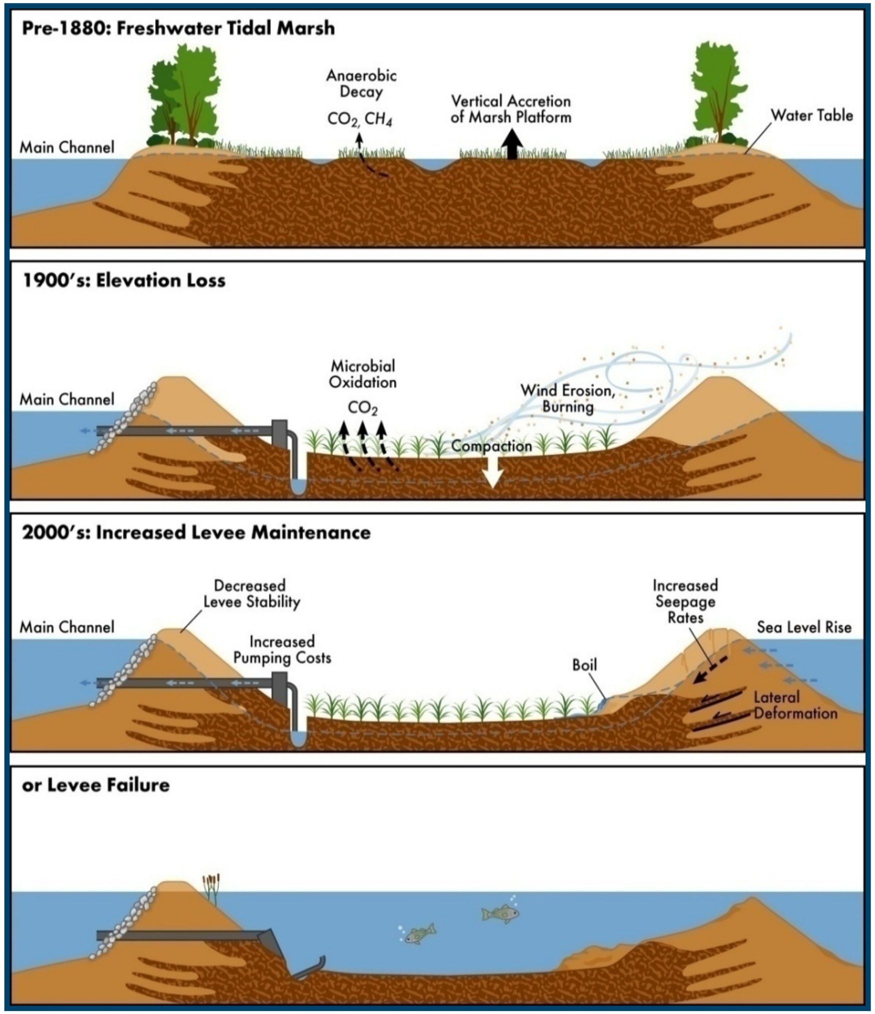
Examples from San Francisco Estuary



300,000 acres lost

200,000 acres lost

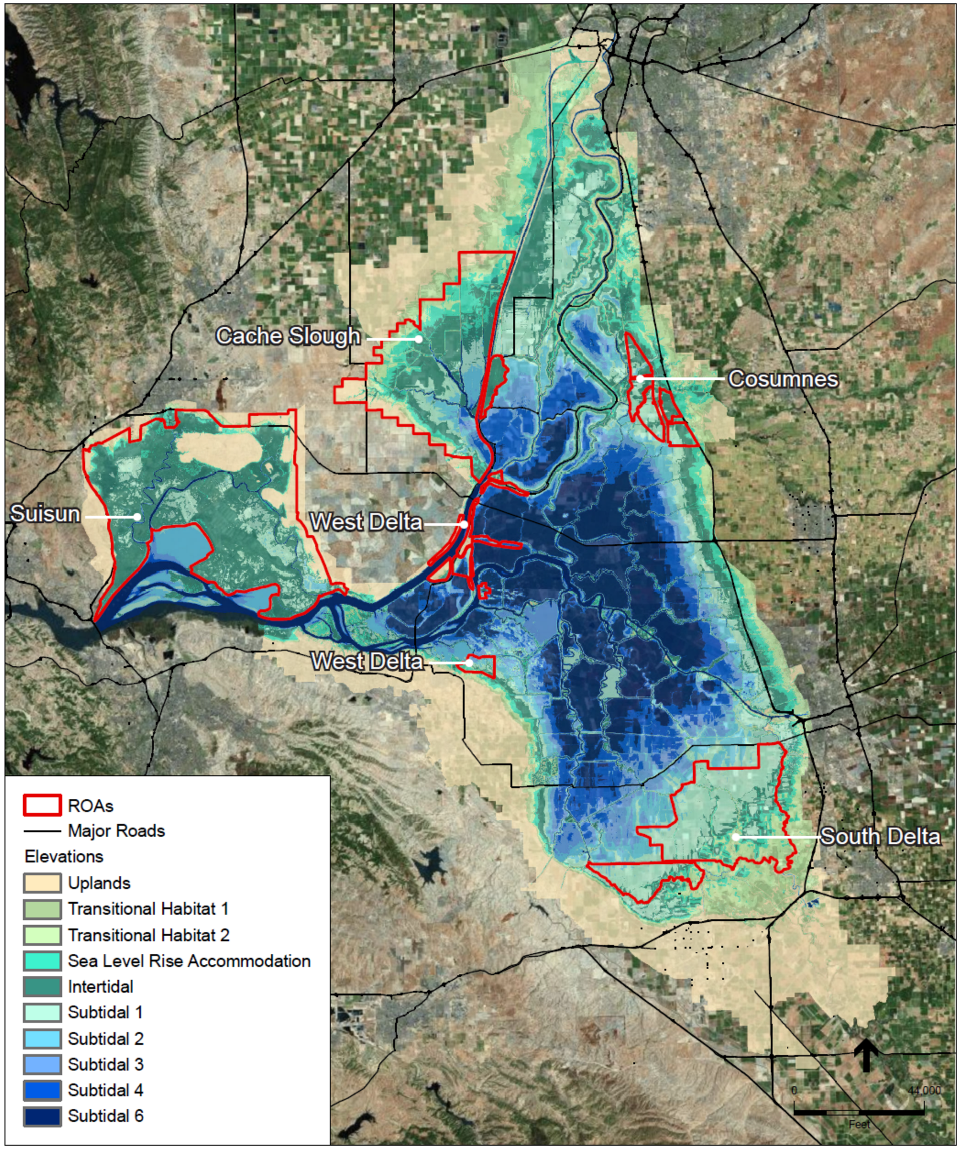
ESA PWA


Pre-1880: Freshwater Tidal Marsh

1900's: Elevation Loss

2000's: Increased Levee Maintenance

or Levee Failure



SOURCE:

DWR 2007 LiDAR; ESA-PWA 2012

Bay Delta Science Conference.

Figure 1

Elevations and ROAs of Delta-Suisun Marsh Planning Area

ESA PWA

Emissions from One Drained Wetland: Sacramento-San Joaquin Delta

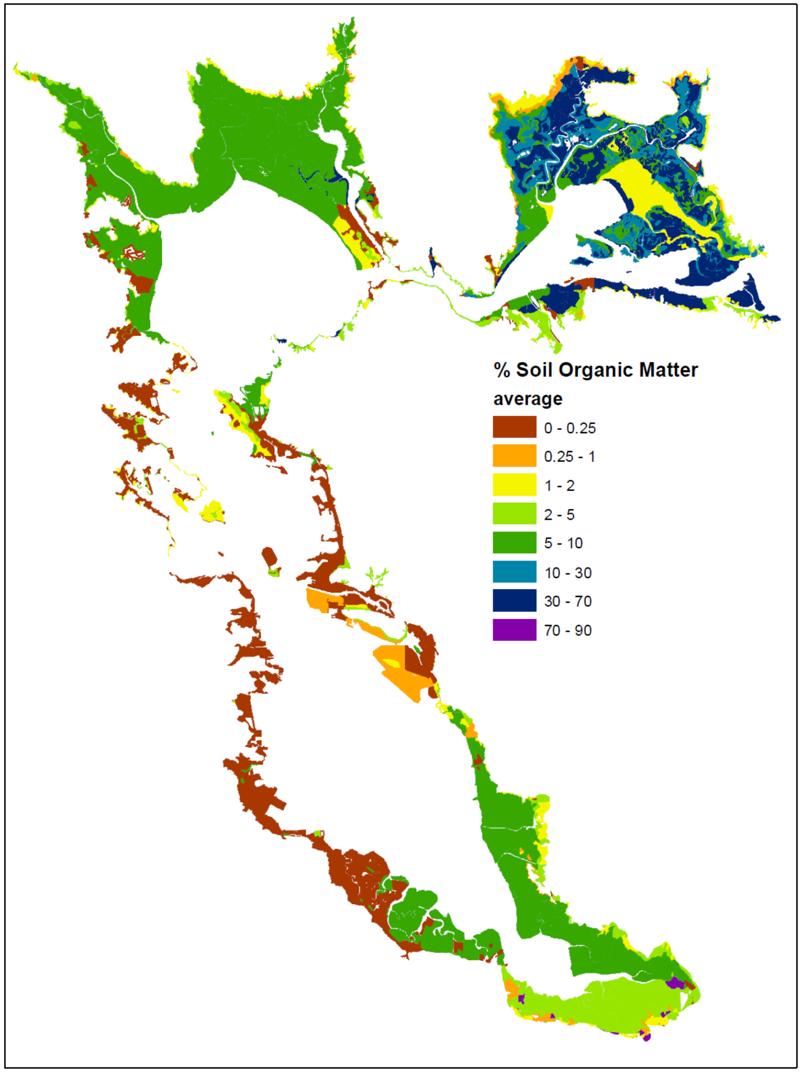
Area under agriculture	**180,000 ha**
Rate of subsidence (in)	1 inch

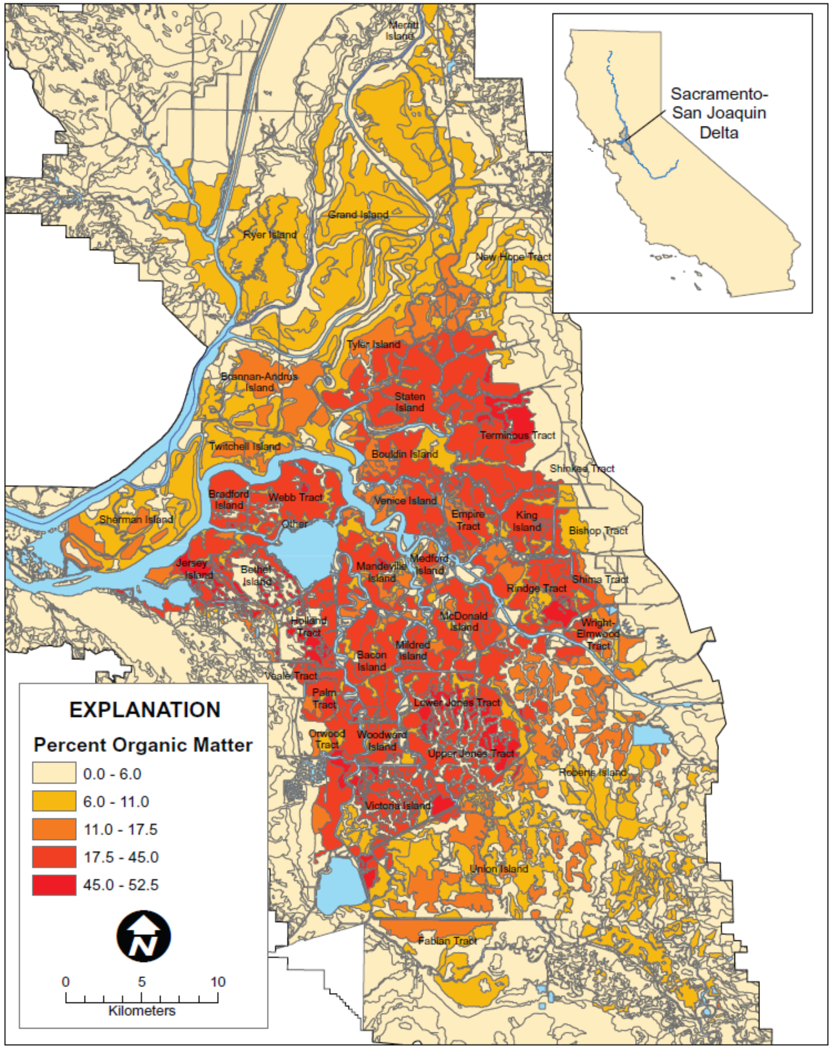
3 million tCO_2/ yr
released from Delta

1 $GtCO_2$ release in c.150 years
4000 years of carbon emitted
Equiv. carbon held in 25% of
California's forests

Accommodation space: 3 billion m^3

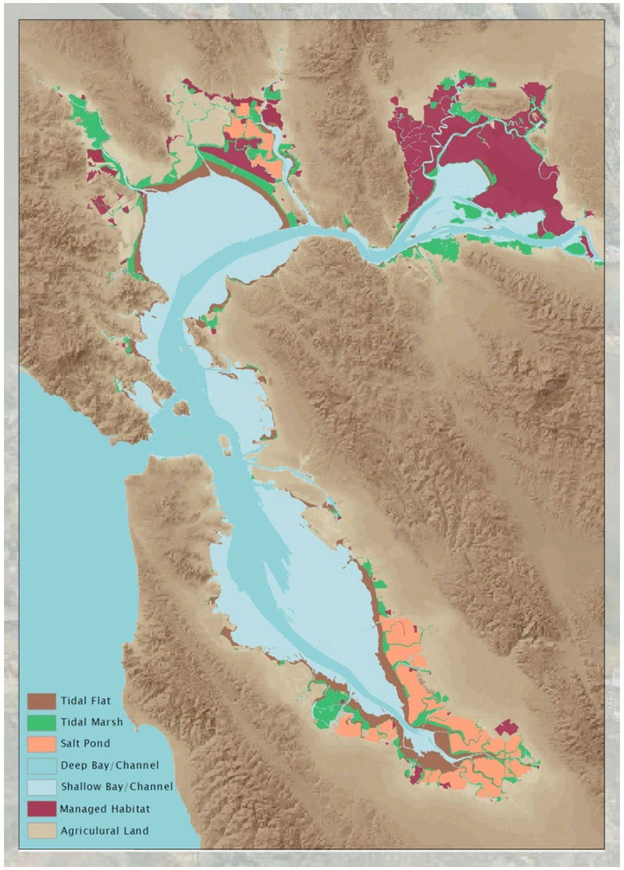
Baseline emissions

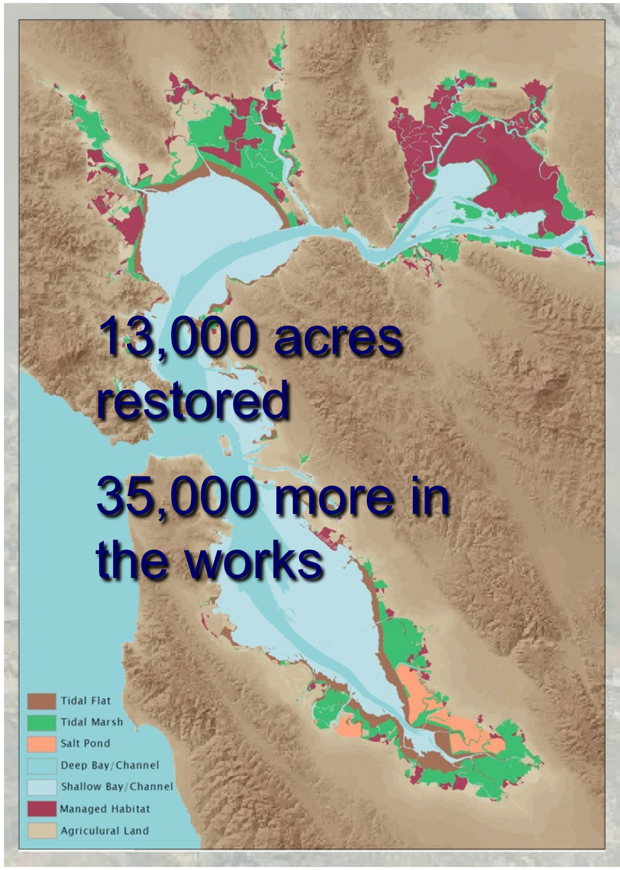




ESA PWA

Wetland Loss and Restoration





13,000 acres restored

35,000 more in the works

Past (~1850)

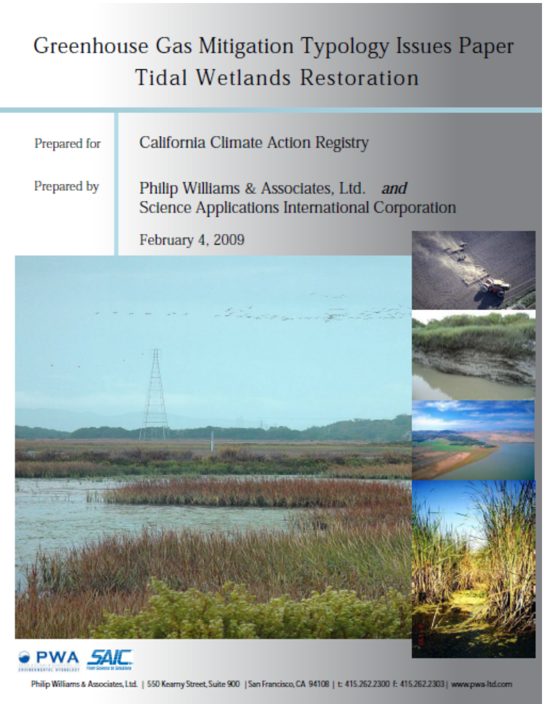
Present (~2000)

Future (~2030)

Todays Landscape

Future Landscape

Restoration projects take time to reinitiate carbon sequestration. Lost stocks may not be rebuilt.



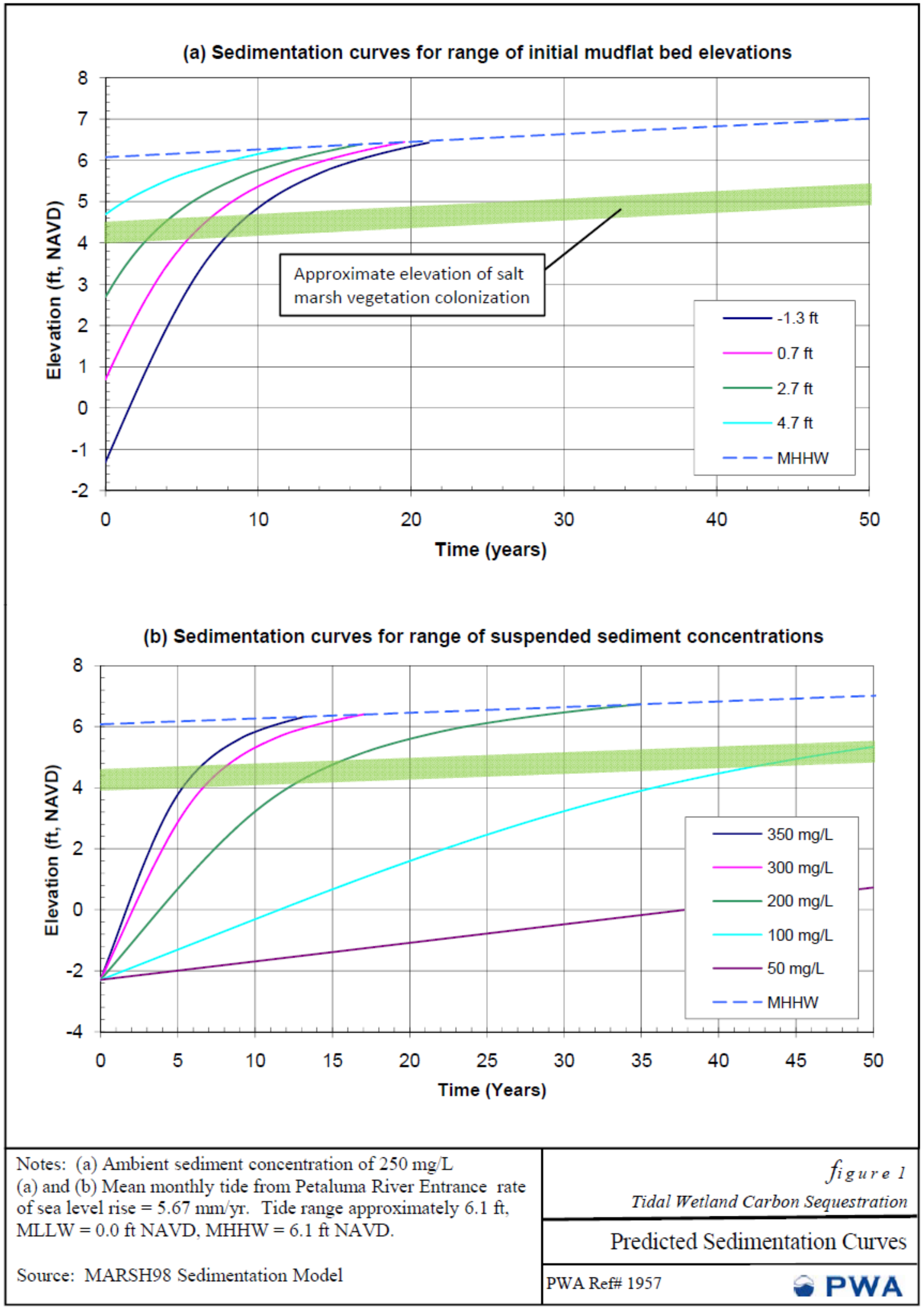
Greenhouse Gas Mitigation Typology Issues Paper
Tidal Wetlands Restoration

Prepared for California Climate Action Registry

Prepared by Philip Williams & Associates, Ltd. *and*
Science Applications International Corporation

February 4, 2009

Philip Williams & Associates, Ltd. | 550 Kearny Street, Suite 900 | San Francisco, CA 94108 | t: 415.262.2300 f: 415.262.2303 | www.pwa-ltd.com



(a) Sedimentation curves for range of initial mudflat bed elevations

(b) Sedimentation curves for range of suspended sediment concentrations

Notes: (a) Ambient sediment concentration of 250 mg/L
(a) and (b) Mean monthly tide from Petaluma River Entrance rate of sea level rise = 5.67 mm/yr. Tide range approximately 6.1 ft, MLLW = 0.0 ft NAVD, MHHW = 6.1 ft NAVD.

Source: MARSH98 Sedimentation Model

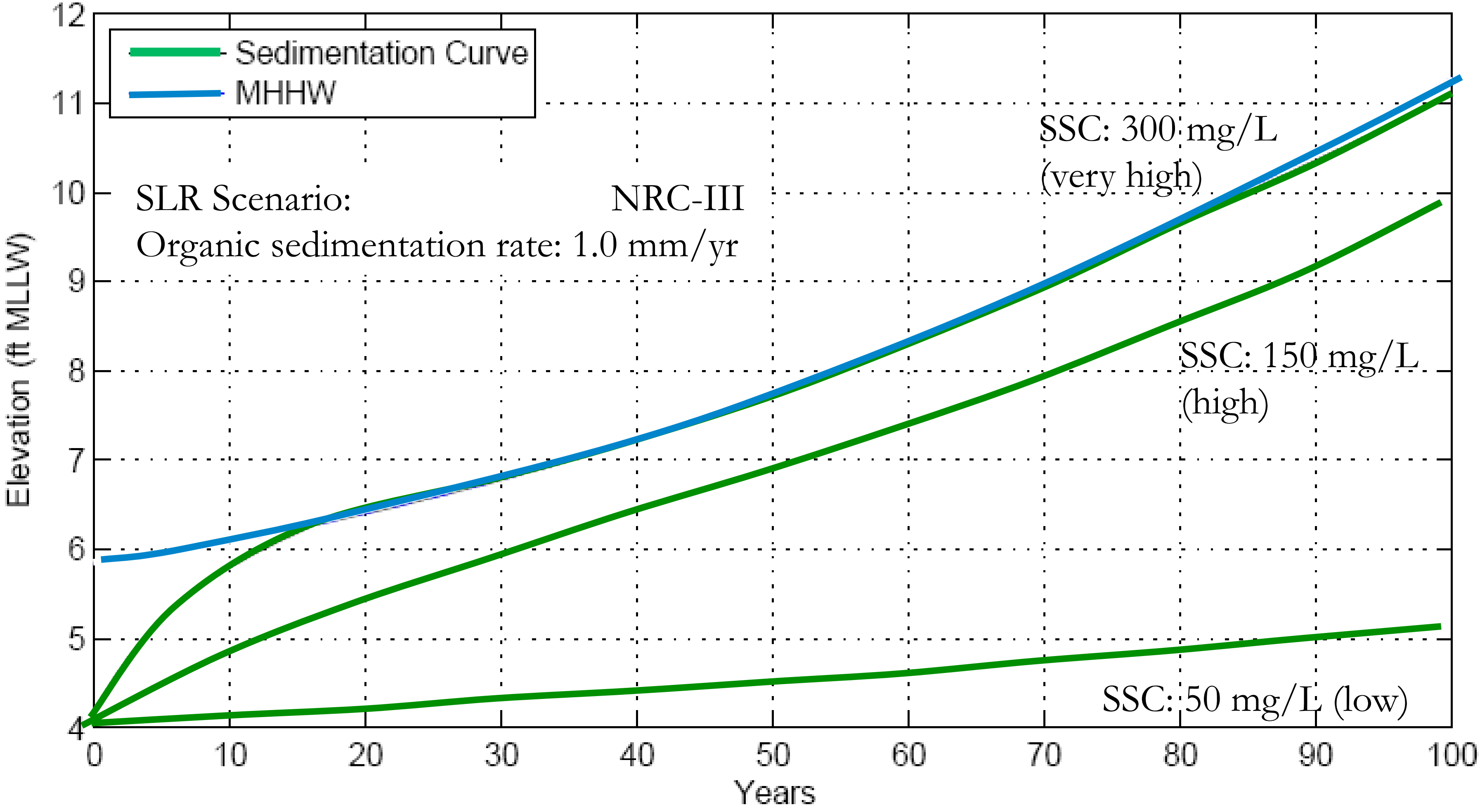
figure 1
Tidal Wetland Carbon Sequestration

Predicted Sedimentation Curves

PWA Ref# 1957

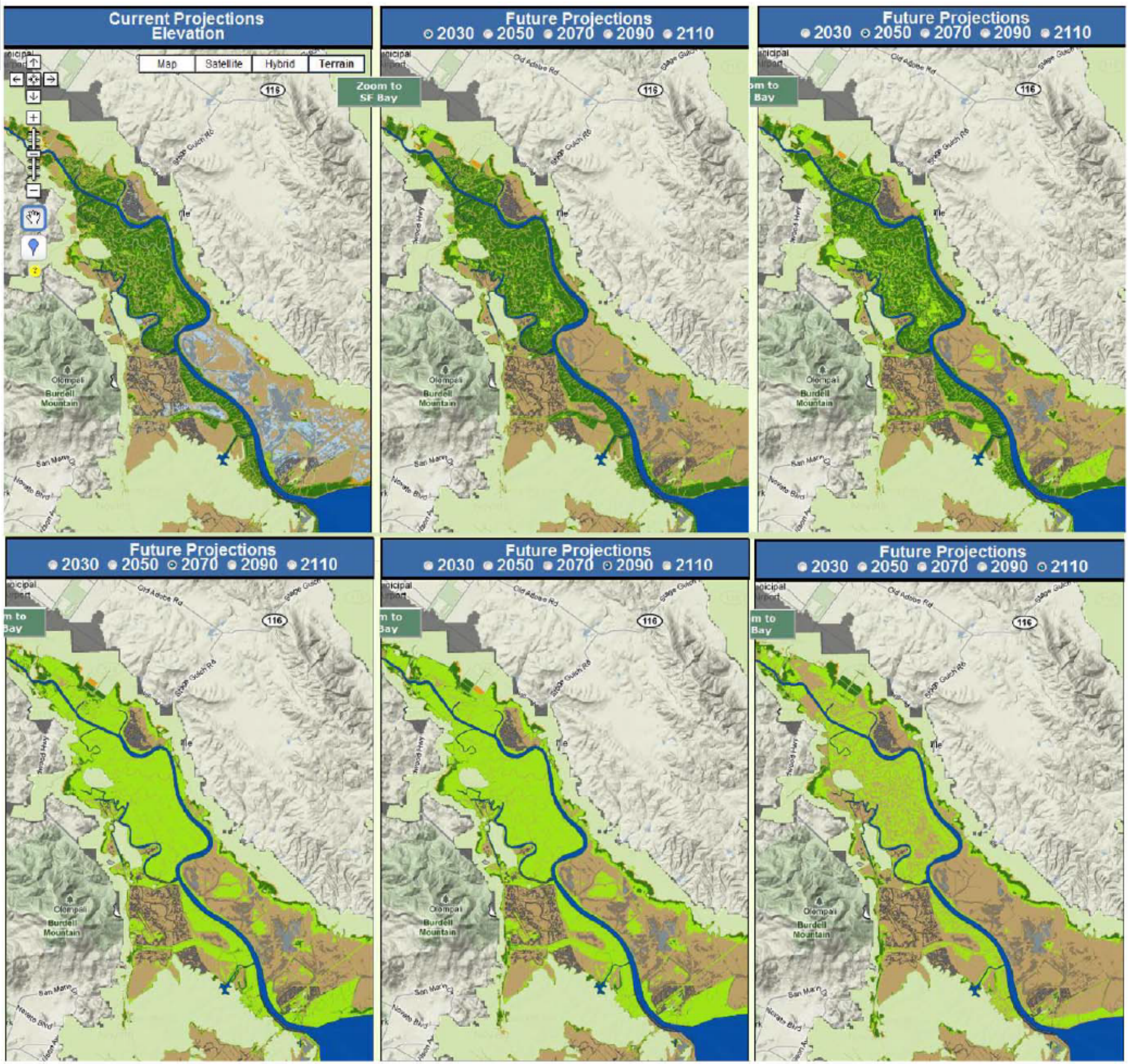
ESA PWA

Develop With Project Scenario



Modeled with Marsh98

ESA PWA



Stralsburg et al. 2011

The Sacramento – San Joaquin Delta

High organic sedimentation
Low mineral sedimentation

Once established marshplain is insensitive to mineral sedimentation

Former natural morphology reflected processes set in motion 6000 years ago

Carbon Capture Wetland Farm Bio-Sequestration

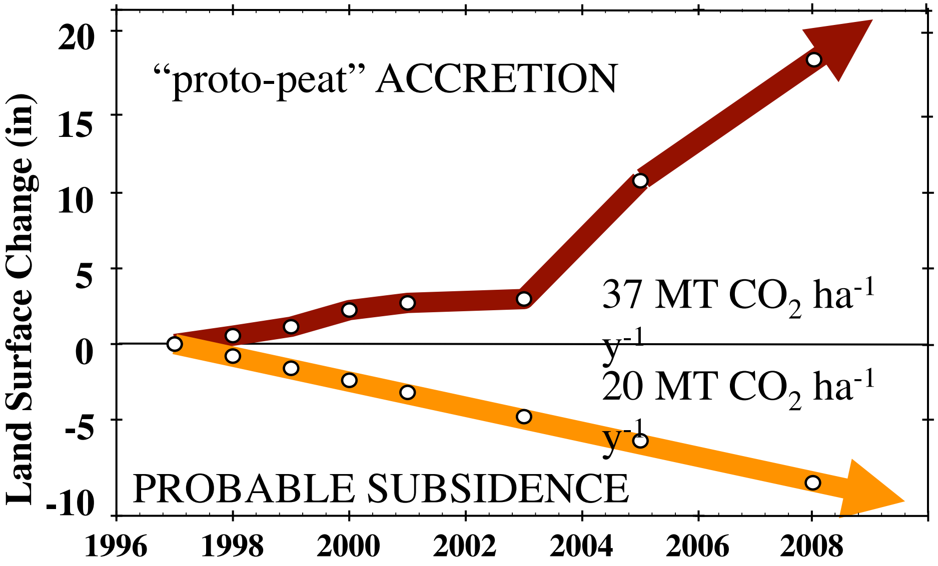
Stops peat oxidation and accretes “proto-peat” rapidly

Continuously submerged about 1 ft

Low oxygen conditions

Balance between plant growth and reduced decomposition

Average annual soil sequestration:
1 kg C m^{-2} yr^{-1} in soil



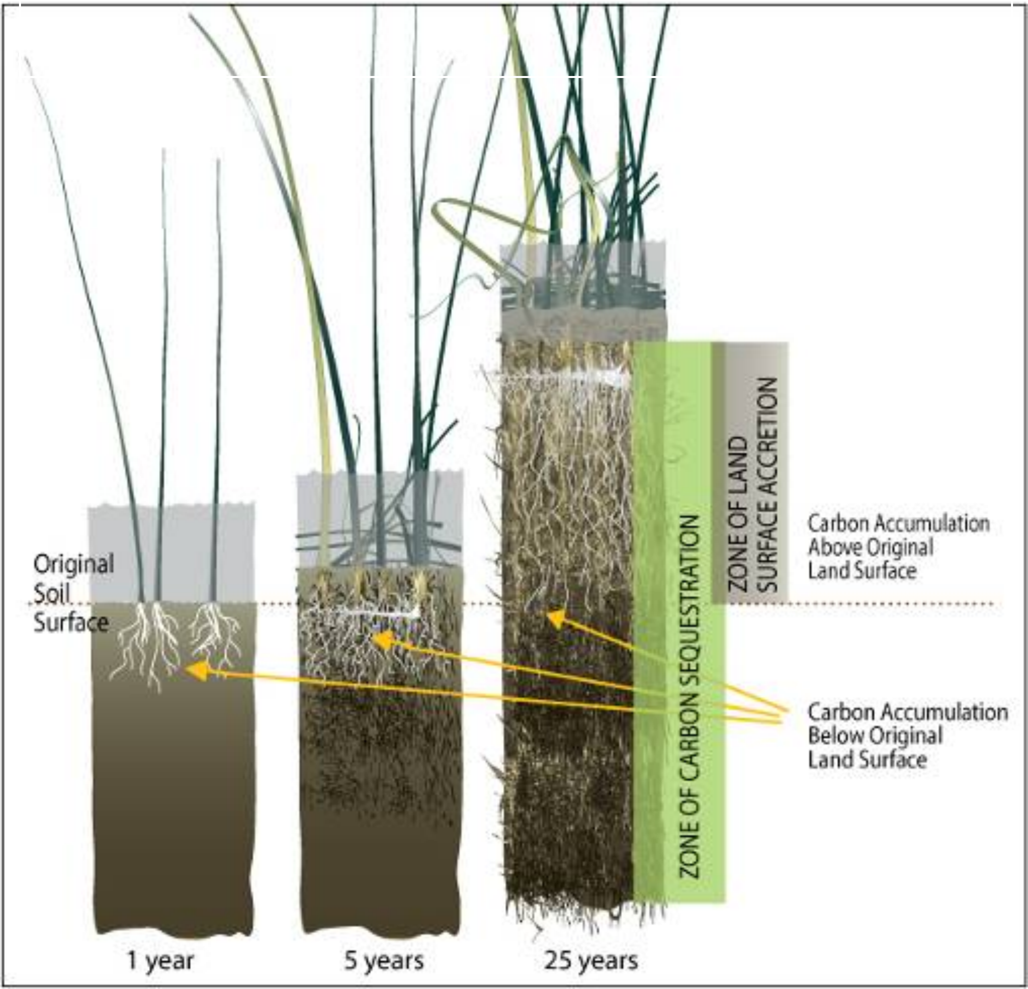
U.S. Department of the Interior
U.S. Geological Survey

Miller et al. 2008, SFEWS

Carbon is being stored in “peat” at an average of 1kg m^{-2} yr^{-1}

- 1MT C in 1000 m^{-2}, or 4MT C acre $^{-1}$ = 15 MT CO_2 + 10 MT CO_2 peat preservation

=25 MT CO_2 acre^{-1}



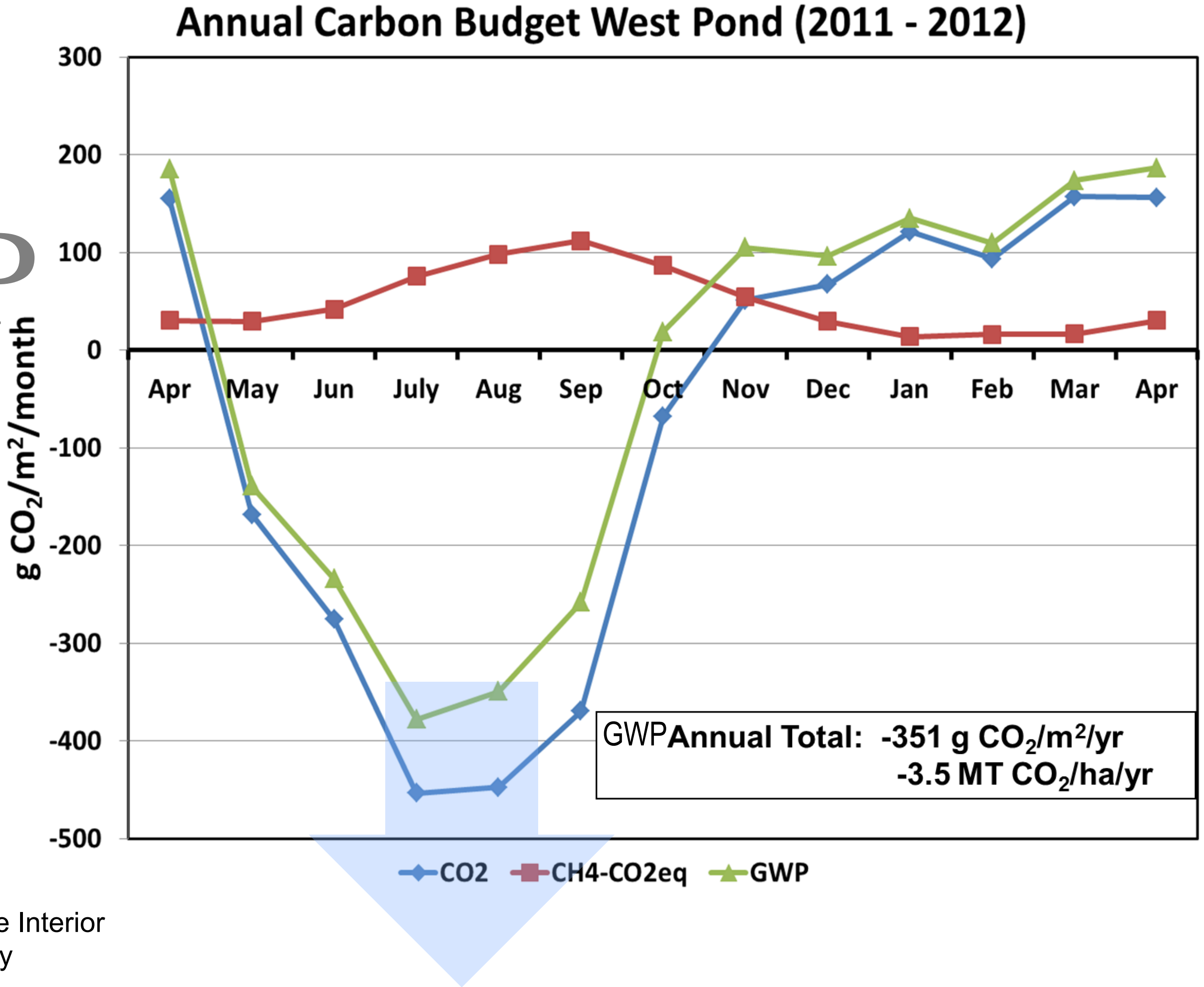
Net GWP Fluxes (from Eddy Covariance April 2011-2012)

2011 EC-based GWP for land use conversion:

MT CO_2eq ha^{-1} y^{-1} = -10 + 6.5 + 0 – (25 + 2.5) = **-31**

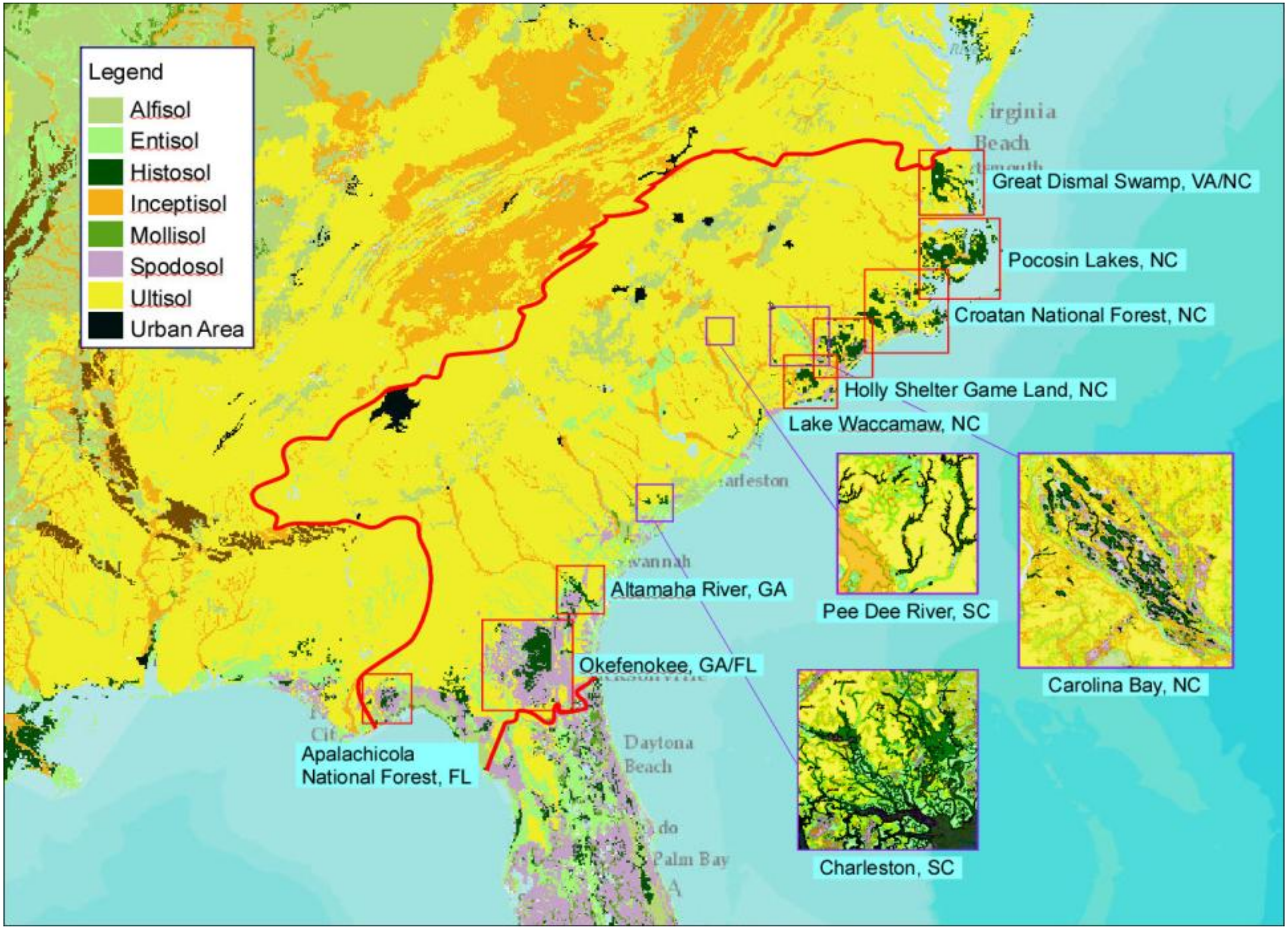
CO_2 CH_4 N_2O CO_2 N_2O

GWP



GWP**Annual Total: -351 g CO_2/m^2/yr**
-3.5 MT CO_2/ha/yr

Landscape Scale Look at Peatlands



Map Credit: C. Richardson

COASTAL BLUE CARBON OPPORTUNITY ASSESSMENT
FOR THE SNOHOMISH ESTUARY
THE CLIMATE BENEFITS OF ESTUARY RESTORATION

- 4749 ha of drained wetlands
- 29% of wetland loss in Puget Sound
- 1353 ha of restoration planned.

RESTORE AMERICA'S ESTUARIES ESA WESTERN WASHINGTON UNIVERSITY EARTH CORPS WILDLIFE FOREVER FUND BOEING NOAA

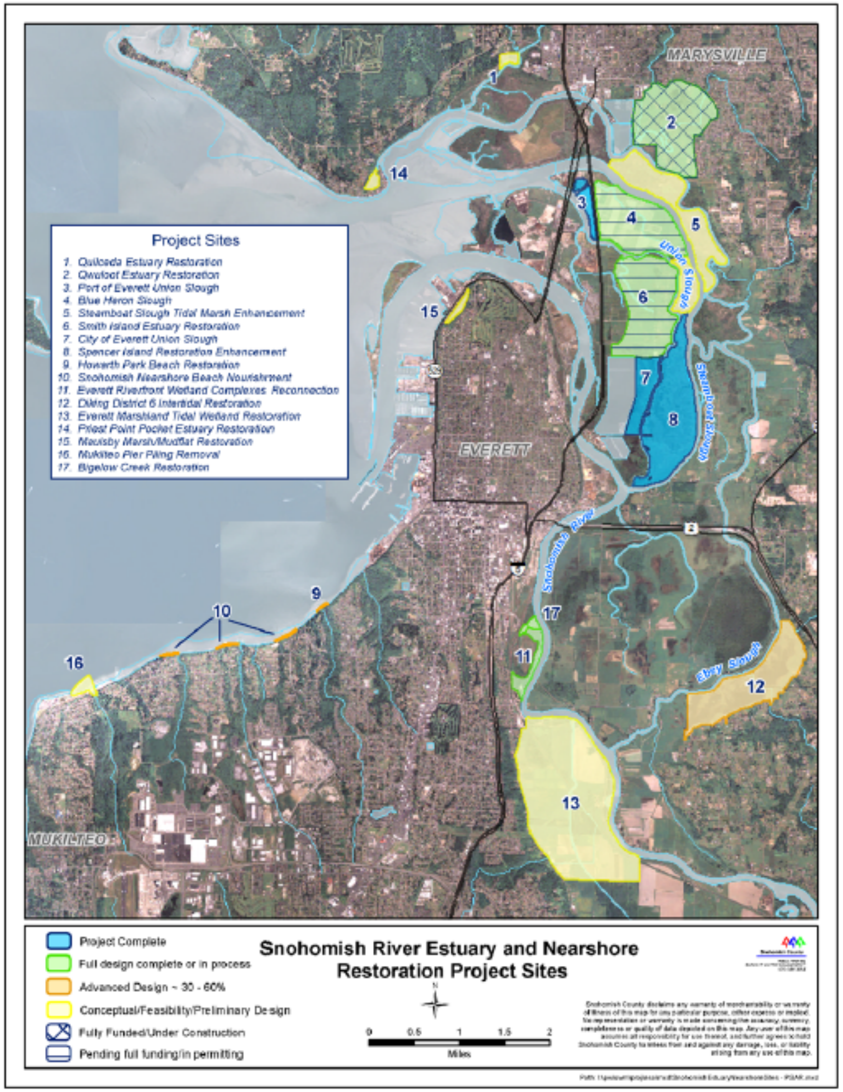


Figure 2 Snohomish Estuary nearshore restoration sites (Snohomish County, 2013).

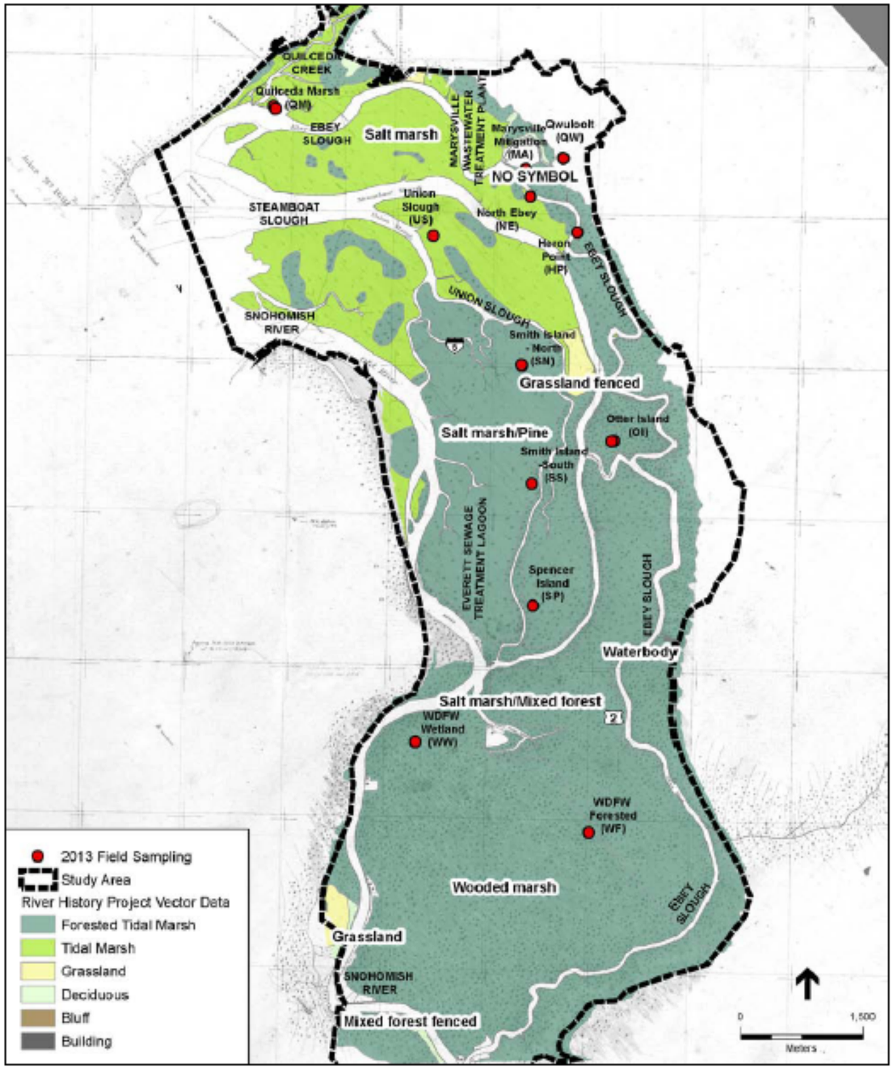


Figure 8 Historic habitats of the Lower Snohomish Estuary based on River History Project (Geomorphological Research Group, Quaternary Research Center, 2005) and Haas and Collins (2001) and 2013 soil core and vegetation plot locations.

NATURAL AREAS

Quilceda Marsh (QM)

Heron Point (HP)

Otter Island (OI)

Figure 3 Photos of natural areas where soil cores and vegetation plots were taken, June-July 2013. Photo Credit: D. Devier, with aerial support from LightHawk.

POTENTIAL RESTORATION AREAS

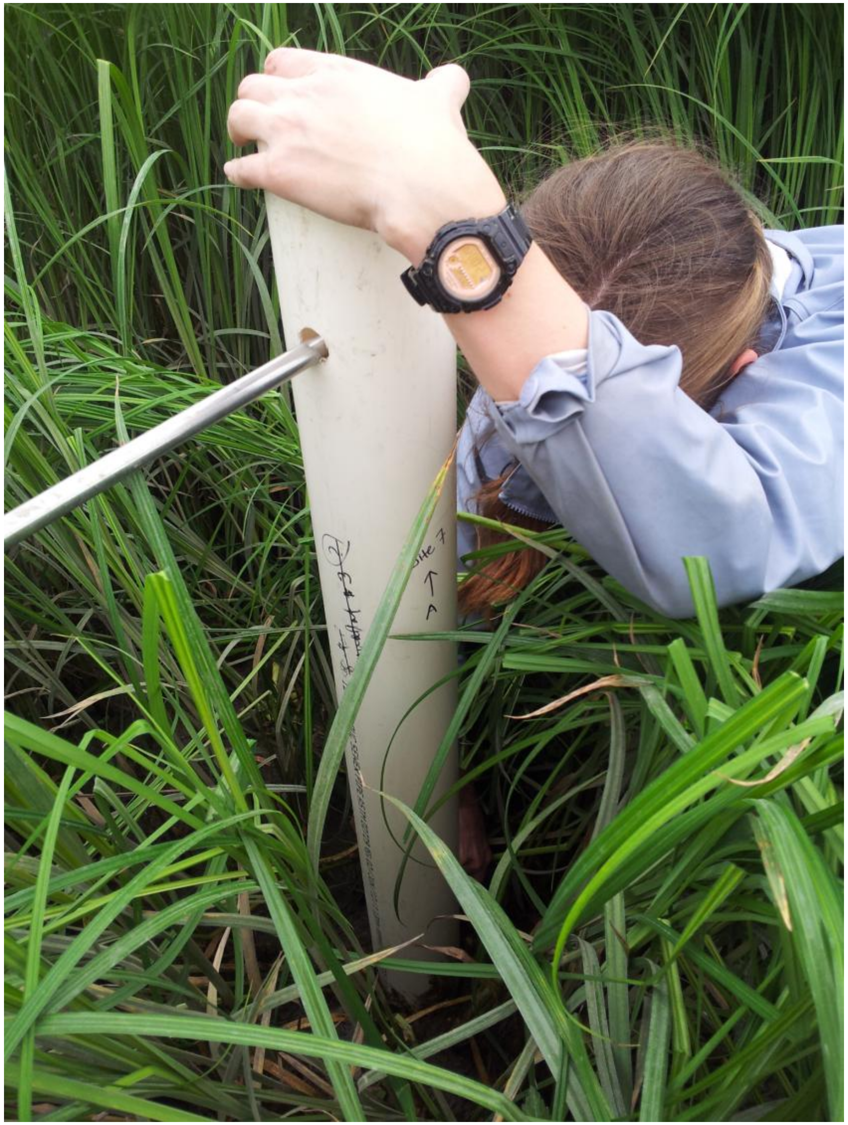
Qwuloolt (QW)

WDFW Forest (WF)

Smith Island North (SN)

WDFW Wetland (WW)

Figure 5 Photos of areas to be restored where soil cores and vegetation plots were taken, June-July 2013. Photo Credit: D. Devier, with aerial support from LightHawk.



Field and Laboratory Analysis

Soil carbon stock quantification:

- 3 Natural sites
- 5 Restoring sites
- 4 Restoration potential sites

Accretion rates:

- 5 sites

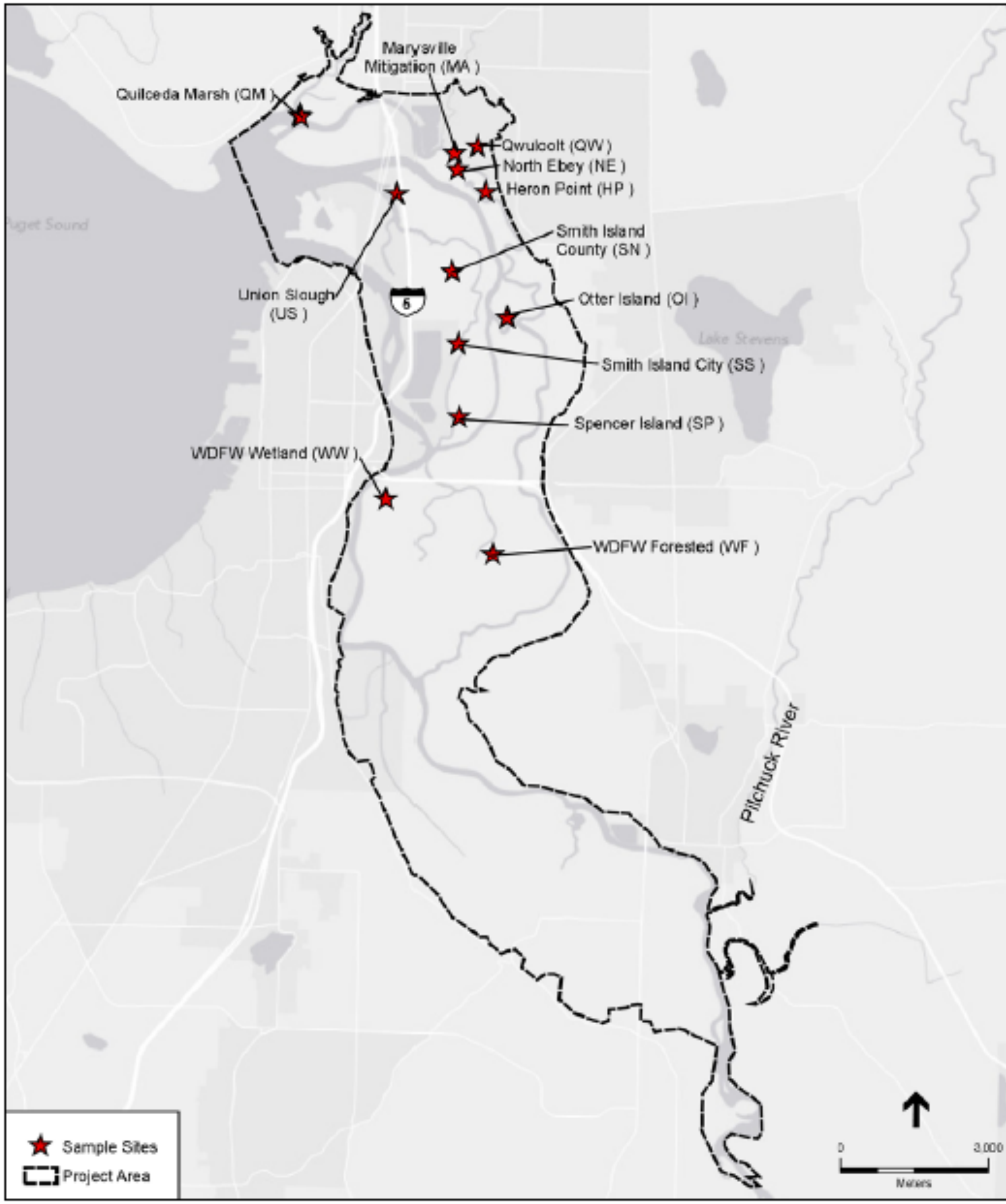


Figure 6 Study Area (dashed black line) and 2013 field sampling sites (red star).

Restoration and carbon sequestration potential

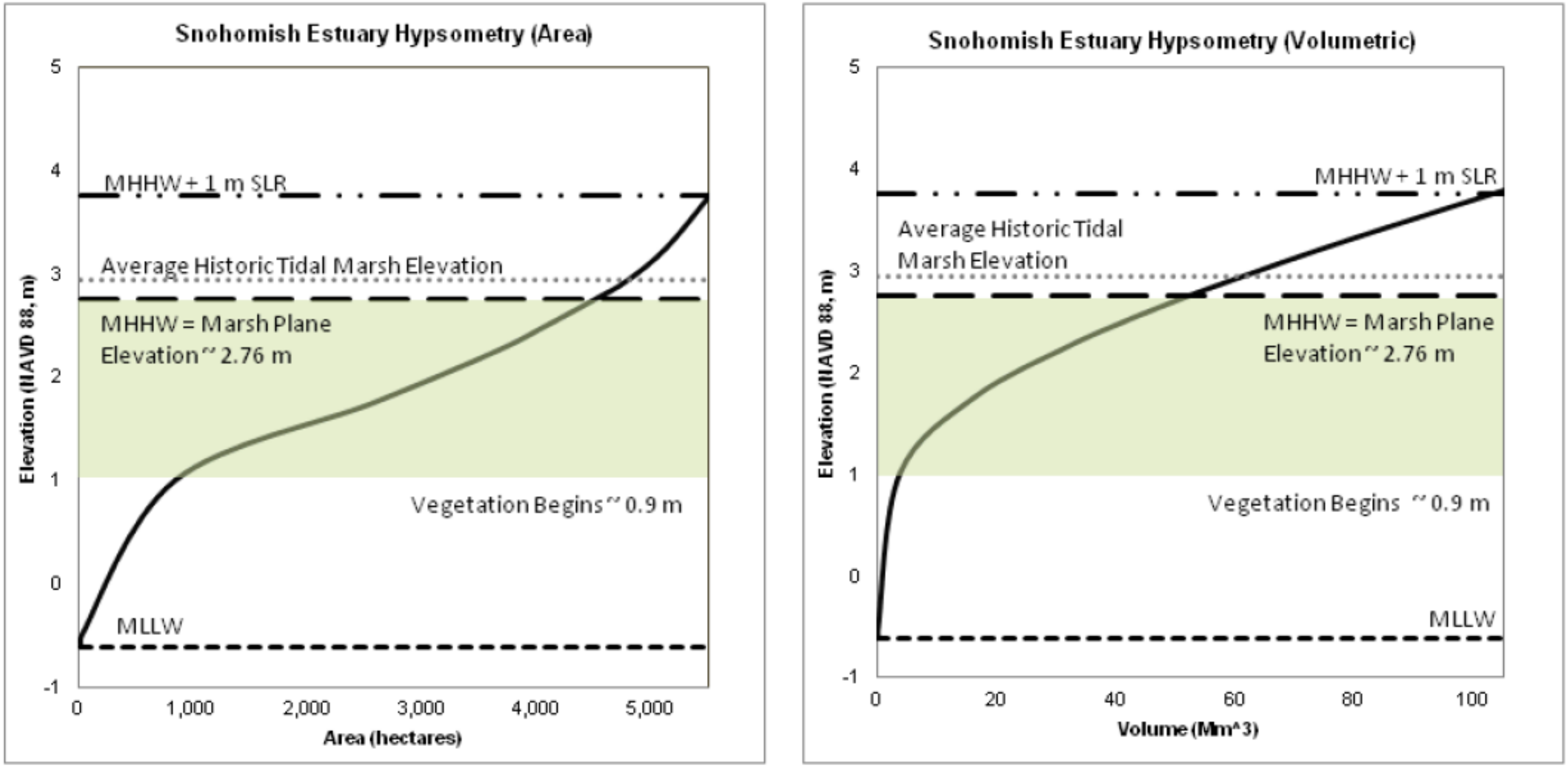
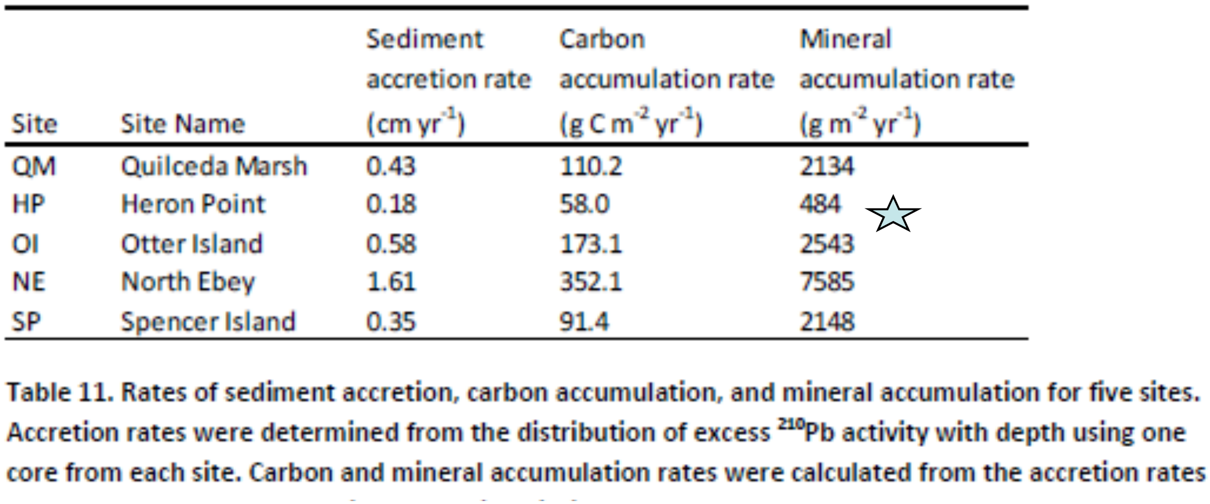


Figure 18 Hypsometric analysis of entire project area (ha).



Site	Site Name	Sediment accretion rate (cm yr^{-1})	Carbon accumulation rate (g C m^{-2} yr^{-1})	Mineral accumulation rate (g m^{-2} yr^{-1})
QM	Quilceda Marsh	0.43	110.2	2134
HP	Heron Point	0.18	58.0	484 ☆
OI	Otter Island	0.58	173.1	2543
NE	North Ebey	1.61	352.1	7585
SP	Spencer Island	0.35	91.4	2148

Table 11. Rates of sediment accretion, carbon accumulation, and mineral accumulation for five sites. Accretion rates were determined from the distribution of excess ^{210}Pb activity with depth using one core from each site. Carbon and mineral accumulation rates were calculated from the accretion rates

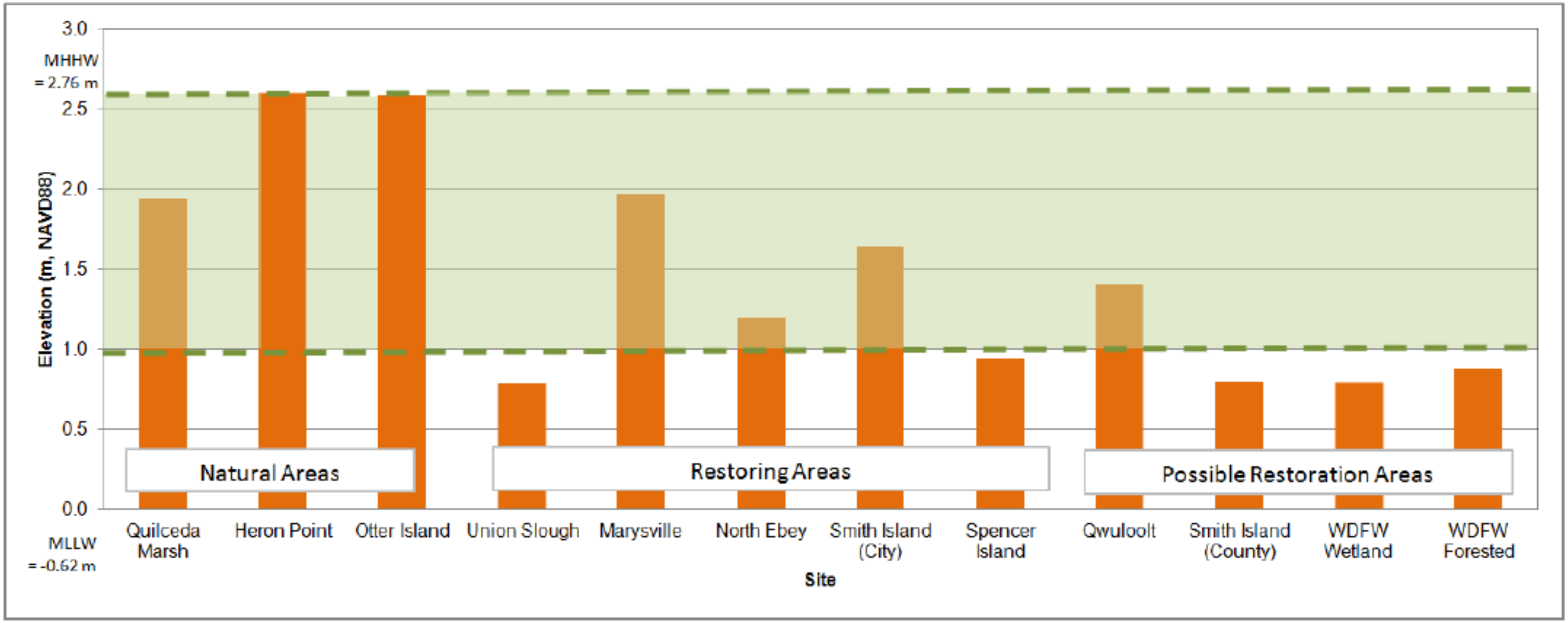
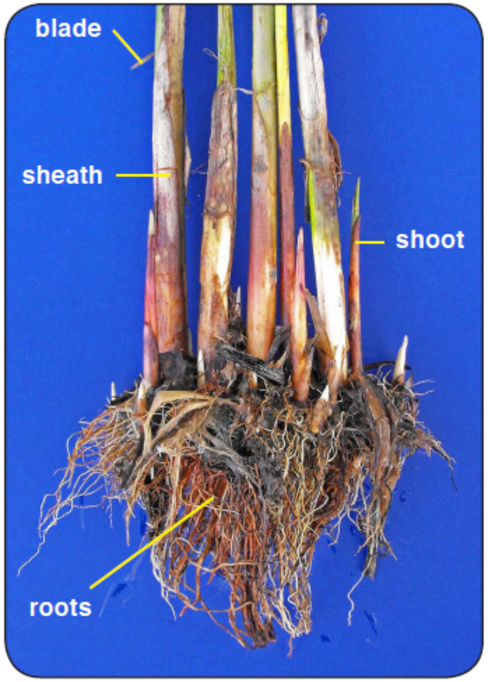


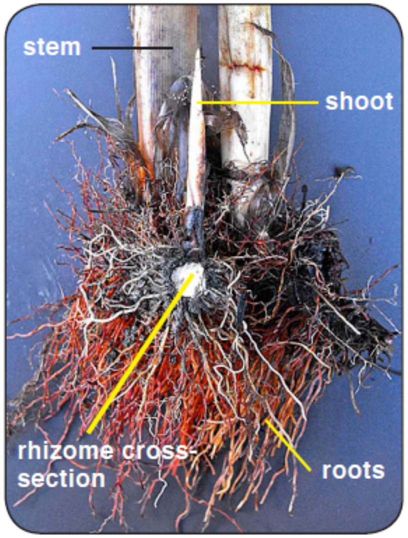
Figure 19 Existing and approximate targeted restoration elevations by site as of 2013. Units are in meters (m), NAVD88.

Site	Site Name	Total carbon mass in top 30 cm ($kg\ C\ m^{-2}$)	Average carbon density in top 30 cm ($g\ C\ cm^{-3}$)	Total mineral mass in top 30 cm ($kg\ m^{-2}$)	Average mineral density in top 30 cm ($g\ cm^{-3}$)
Natural sites					
QM	Quilceda Marsh	7.17 (0.67)	0.024 (0.00)	148.02	0.493
HP	Heron Point	9.85 (0.07)	0.033 (0.00)	82.71	0.276
OI	Otter Island	7.81 (1.72)	0.026 (0.01)	132.66	0.442
Transitional restored sites					
NE	North Ebey	6.48 (0.12)	0.022 (0.00)	141.38	0.471
SP	Spencer Island	8.29 (0.73)	0.028 (0.00)	182.69	0.609
MA	Marysville Site	9.74 (0.09)	0.032 (0.00)	246.63	0.822
SS	Smith Is. - City	6.11 (2.17)	0.020 (0.01)	331.08	1.104
US	Union Slough	5.37 (0.15)	0.018 (0.00)	236.98	0.790
Future restoration sites					
QW	Qwuloolt	11.31 (0.03)	0.038 (0.00)	188.45	0.725
SN	Smith Is. - County	18.52 (1.59)	0.062 (0.01)	163.15	0.544
WW	WDFW Wetland	23.36 (1.79)	0.078 (0.01)	87.34	0.291
WF	WDFW Forested	15.34 (0.29)	0.051 (0.00)	75.61	0.252

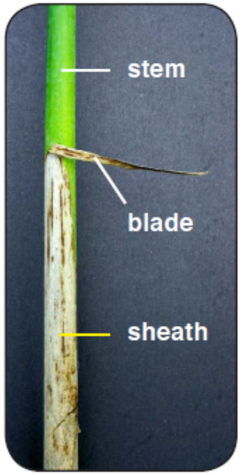
Table 10. Total carbon mass and average carbon density in the top 30 cm of cores, with averages (± standard deviation) reported for each site (n = 2). Mineral mass and mineral density were determined using one core from each site.



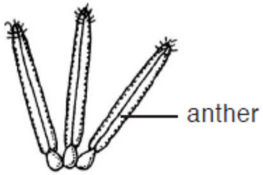
Great Bulrush stems, roots and new shoots in autumn



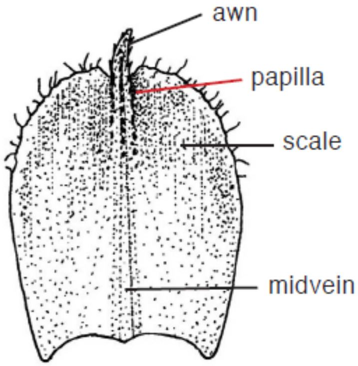
Cross-section of rhizome 7 mm thick with roots and new white shoot 5 cm tall



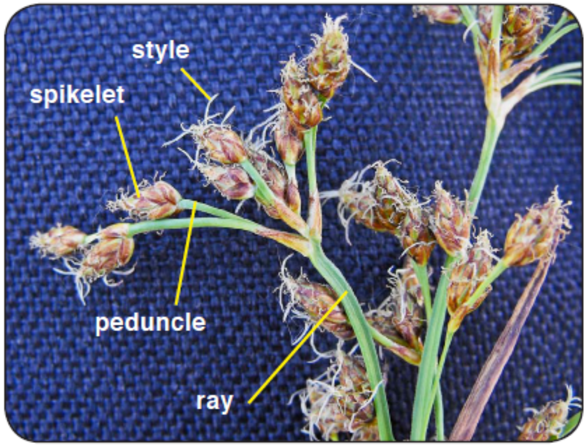
Lower stem 12 mm wide with leaf blade shorter than sheath



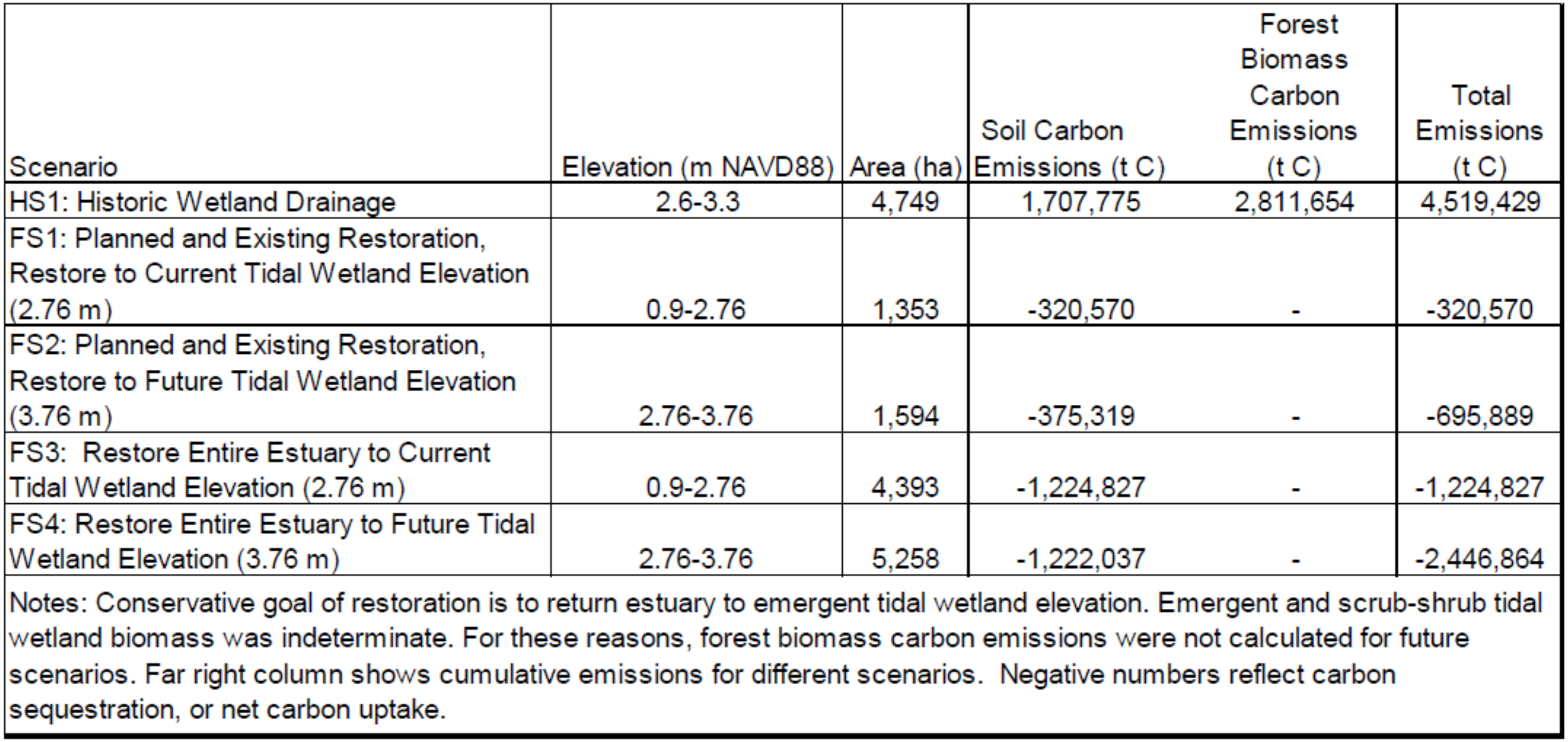
Young stamens x10; each c. 2 mm long



Fertile scale x15; dorsal side



Inflorescence with green rays, peduncles and brown spikelets c. 8 mm long with exserted styles



Scenario	Elevation (m NAVD88)	Area (ha)	Soil Carbon Emissions (t C)	Forest Biomass Carbon Emissions (t C)	Total Emissions (t C)
HS1: Historic Wetland Drainage	2.6-3.3	4,749	1,707,775	2,811,654	4,519,429
FS1: Planned and Existing Restoration, Restore to Current Tidal Wetland Elevation (2.76 m)	0.9-2.76	1,353	-320,570	-	-320,570
FS2: Planned and Existing Restoration, Restore to Future Tidal Wetland Elevation (3.76 m)	2.76-3.76	1,594	-375,319	-	-695,889
FS3: Restore Entire Estuary to Current Tidal Wetland Elevation (2.76 m)	0.9-2.76	4,393	-1,224,827	-	-1,224,827
FS4: Restore Entire Estuary to Future Tidal Wetland Elevation (3.76 m)	2.76-3.76	5,258	-1,222,037	-	-2,446,864

Notes: Conservative goal of restoration is to return estuary to emergent tidal wetland elevation. Emergent and scrub-shrub tidal wetland biomass was indeterminate. For these reasons, forest biomass carbon emissions were not calculated for future scenarios. Far right column shows cumulative emissions for different scenarios. Negative numbers reflect carbon sequestration, or net carbon uptake.

Table 13 Summary of carbon emissions due to subsidence by site and state of restoration. The historic scenario (HS1) is the only scenario that includes forested tidal wetland biomass losses. Future restoration scenarios conservatively estimate carbon emissions with recovery of emergent tidal wetlands only.

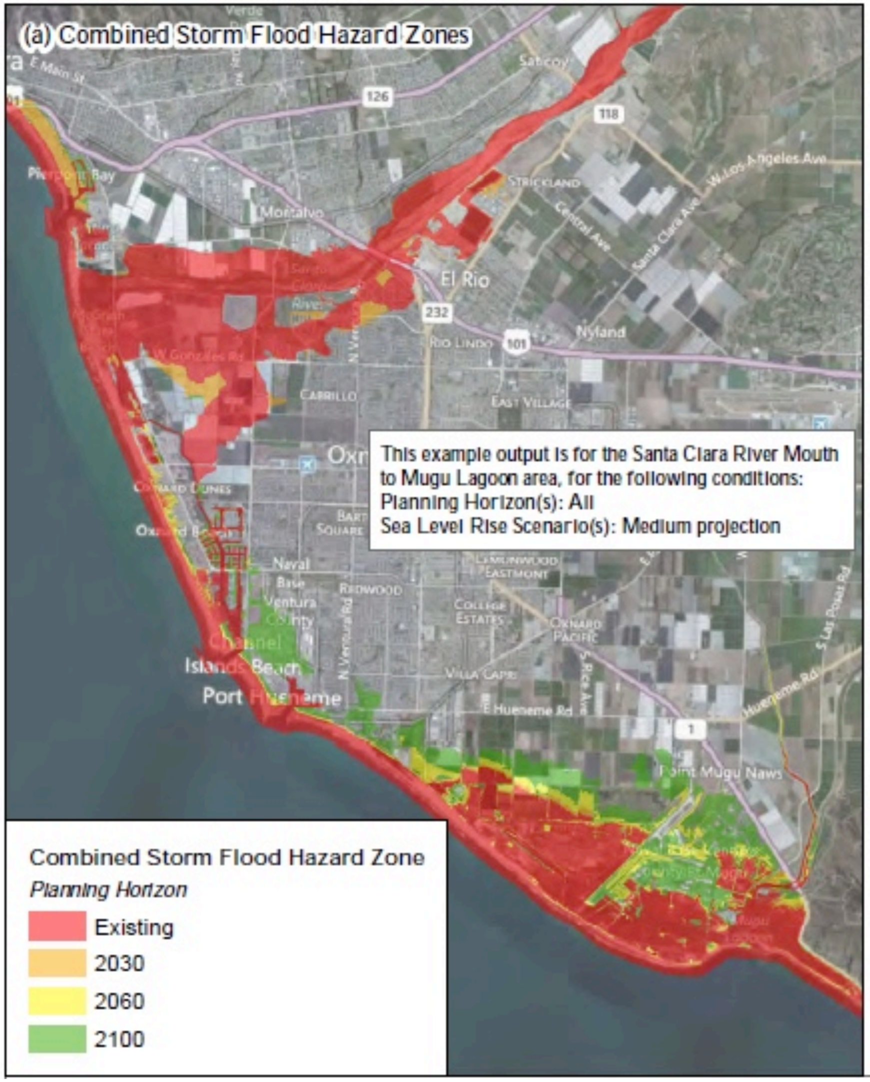
Key Results – Existing Projects

1. *Planned* restoration of 1,353 ha would yield 1,176,000 tons CO_2 sequestration at current sea level
2. Planned restoration would yield additional 1,377,000 tons CO_2 sequestration to future sea level
3. Total CO_2 sequestration of 2,553,000 tons
4. This is equivalent to the emissions from 500,000 cars in one year, or 5,000 cars/year for 100 years

Key Results – Expanded Restoration

1. *Full* restoration of 4,393 ha would yield 4,495,000 tons CO_2 sequestration at current sea level
2. Full restoration would yield additional 4,485,000 tons CO_2 sequestration to future sea level
3. Total CO_2 sequestration of 8,980,000 tons
4. This is equivalent to the emissions from 1.76 million cars in one year, or 17,600 cars/year for 100 years

Ventura Coastal Resilience Project



This example output is for the Santa Clara River Mouth to Mugu Lagoon area, for the following conditions:
Planning Horizon(s): All
Sea Level Rise Scenario(s): Medium projection

figure 6

Ventura County Climate Change Vulnerability Study

Example of Combined Storm Flood Hazard Zones

ESA PWA Ref# D211452.00

ESA PWA

Expected outcomes:

Current and future SLR hazards and impacts mapped

The Nature Conservancy
Protecting nature. Preserving life.

Source: Imagery from NAIP 2012

12/5/2013

N

0 0.5 1 Miles

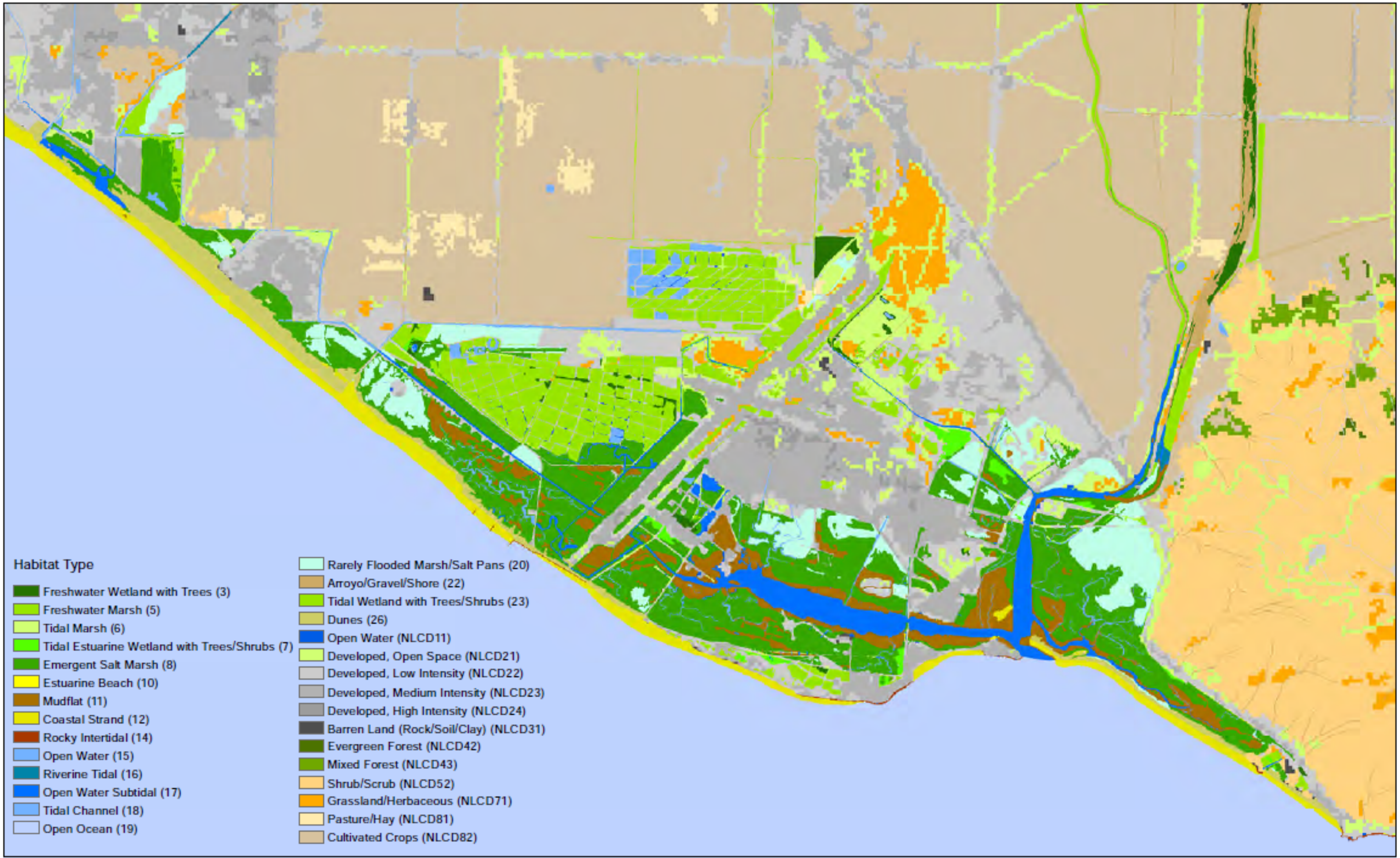
figure 3

Ventura County Climate Change Vulnerability Study

Buffered Region for Greenhouse Gas Analysis

ESA PWA Ref# - D211452

ESA PWA



This layer combines the SLAMM wetland habitats map with upland habitats from the National Land Cover Database (2006).

12/20/2013

N

0 0.5 1 Miles

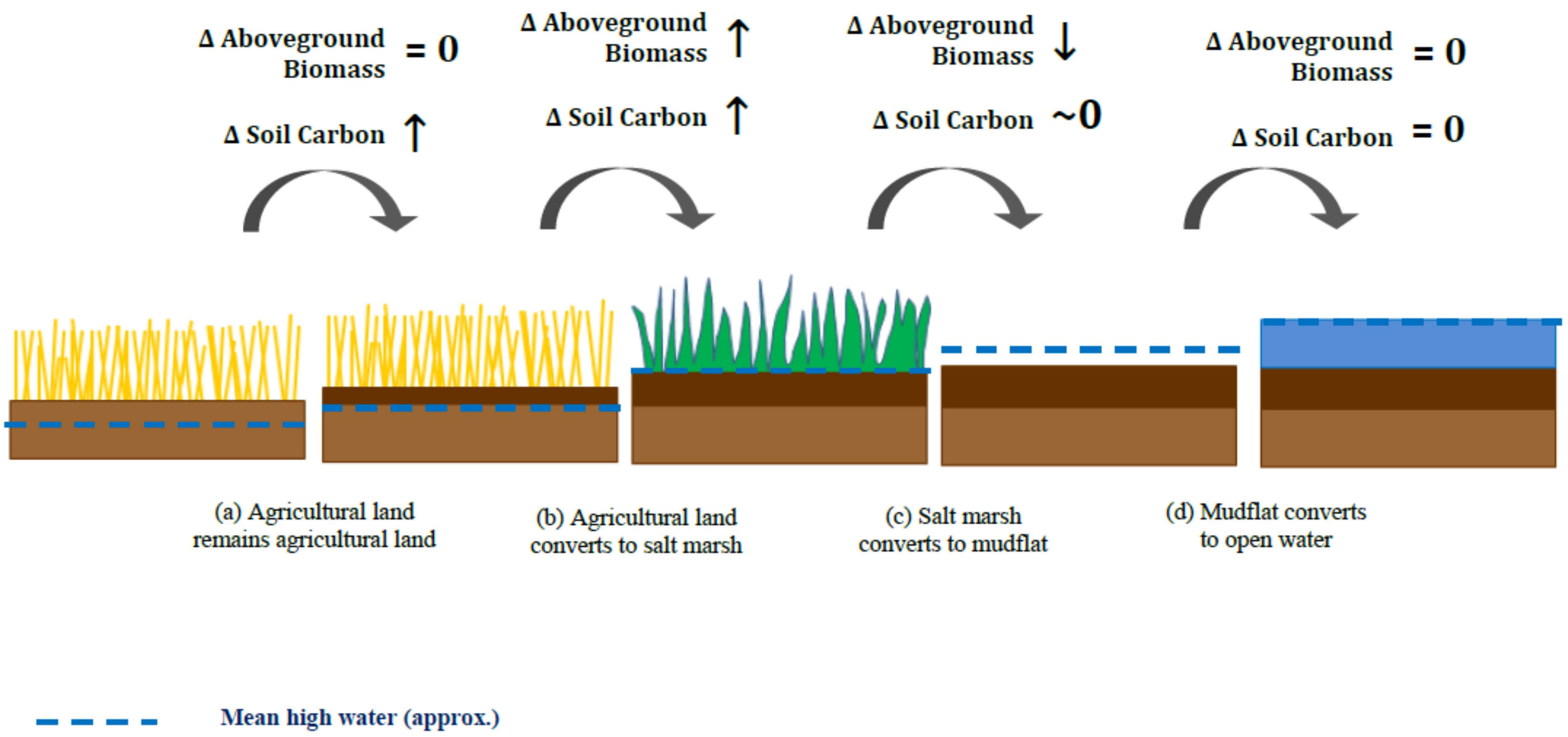
figure 5

Ventura County Climate Change Vulnerability Study

Aggregated Land Cover Map

ESA PWA Ref# - D211452

ESA PWA



(a) Agricultural land remains agricultural land

(b) Agricultural land converts to salt marsh

(c) Salt marsh converts to mudflat

(d) Mudflat converts to open water

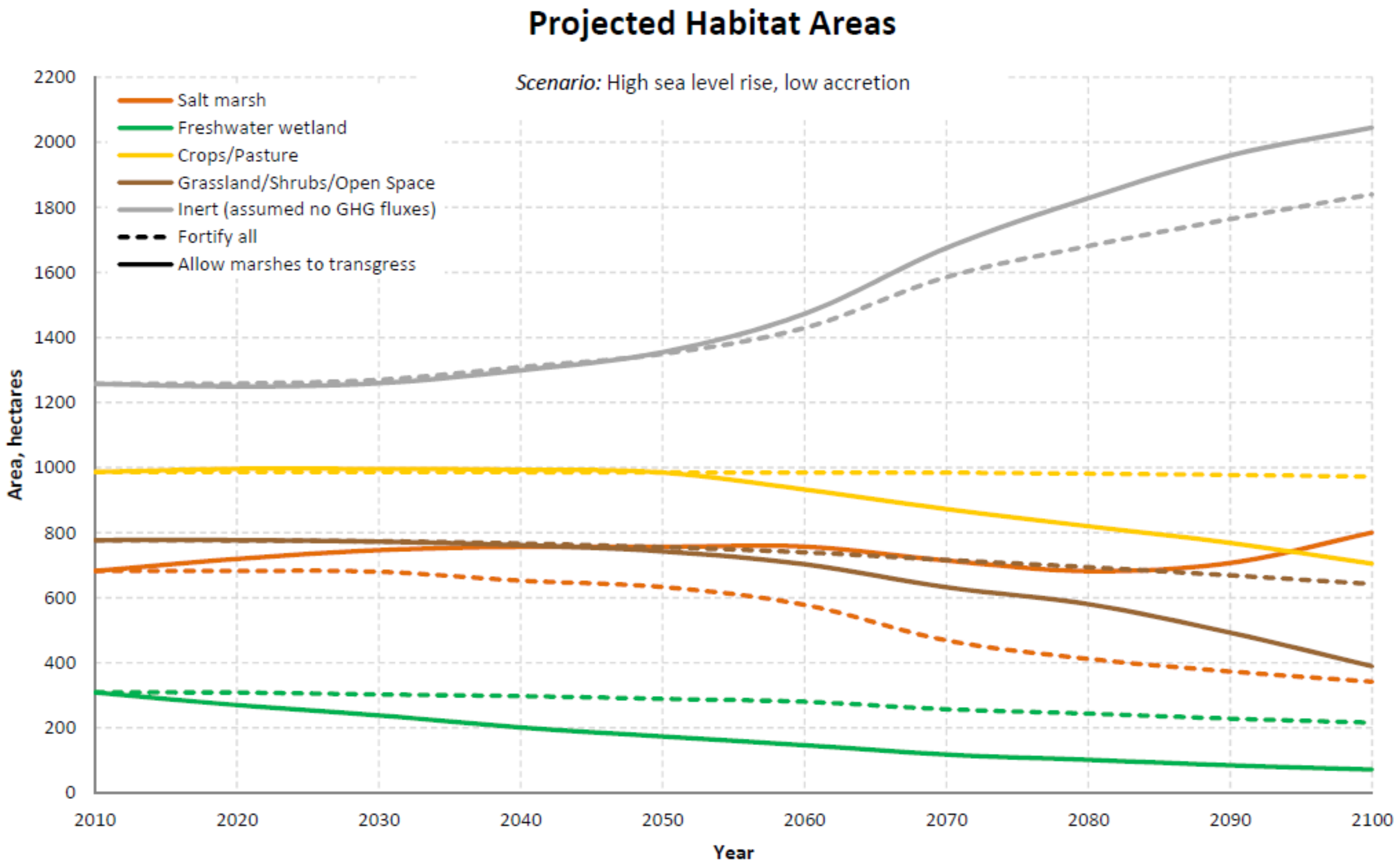
Note: This is an example and does not show all possible habitat conversions.

Mean sea level shown for reference only. Time between transitions is not specified and depends on land elevations, rate of sea level rise, and accretion rate.

figure 4
Ventura County Climate Change Vulnerability Assessment

Conceptual Model of Accounting Framework

ESA PWA Ref# D211452.04



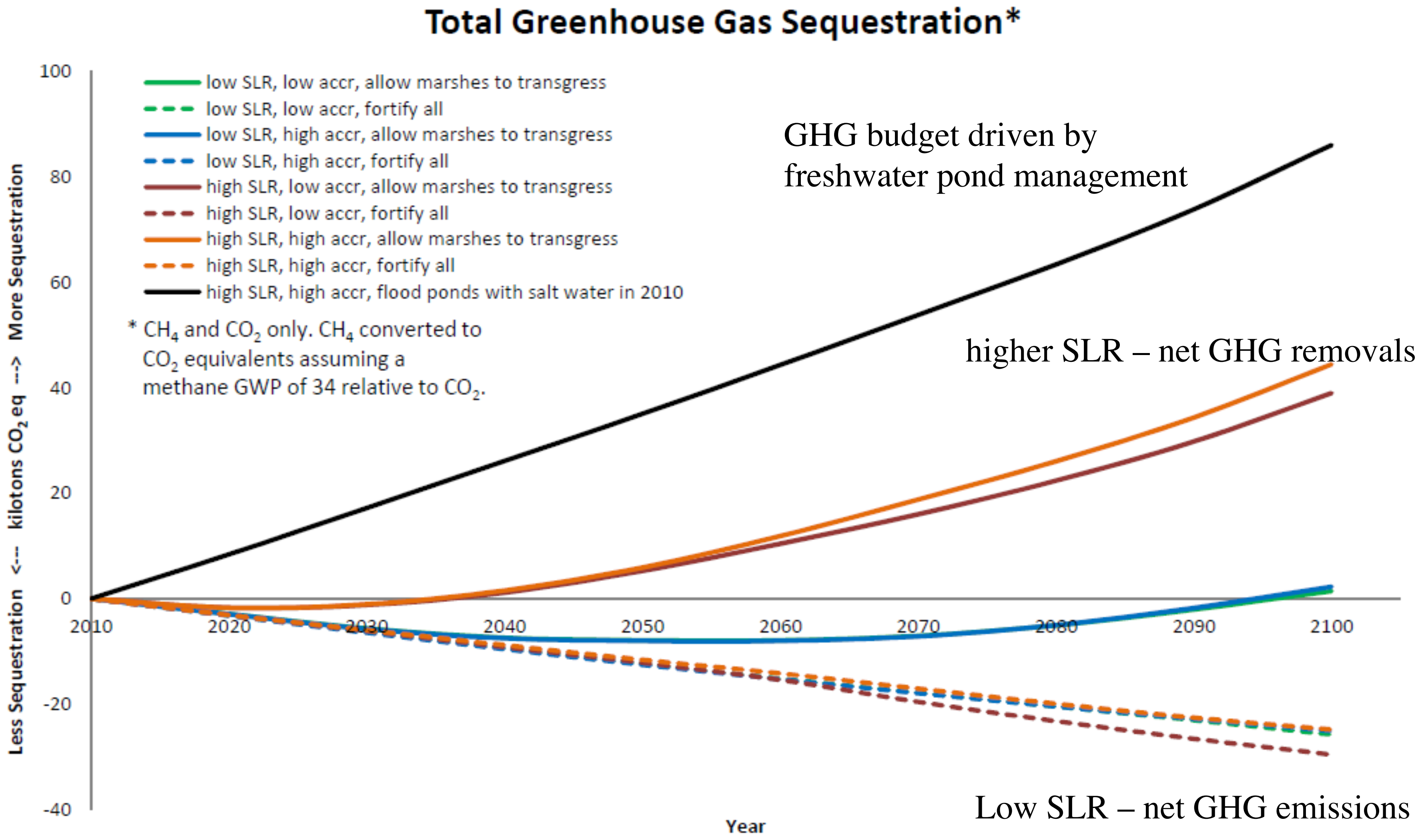
Source: Modified from ESA PWA 2013b.

figure ***6c***

Ventura County Climate Change Vulnerability Assessment

Projected Habitat Areas for High SLR and Low Accretion

ESA PWA Ref# D211452.00



Total Greenhouse Gas Sequestration*

* CH_4 and CO_2 only. CH_4 converted to CO_2 equivalents assuming a methane GWP of 34 relative to CO_2.

GHG budget driven by freshwater pond management

higher SLR – net GHG removals

Low SLR – net GHG emissions

Normally, GHG accounting results are presented in tonnes or megatons. In this case, the size of the Mugu Lagoon and Ormond Beach study area lends itself to kilotons, a less typical unit of analysis.

figure **12b**

Ventura County Climate Change Vulnerability Assessment

Total GHG Sequestration (Methane 100-yr GWP of 34)

ESA PWA Ref# D211452.00

ESA PWA

Tampa Bay Blue Carbon Assessment

- Build on *Potential Impacts and Management Implications of Climate Change on Tampa Bay Estuary Critical Coastal Habitats*. E. Sherwood & H. Greening, 2014. Environmental Management 53(2): 401-415

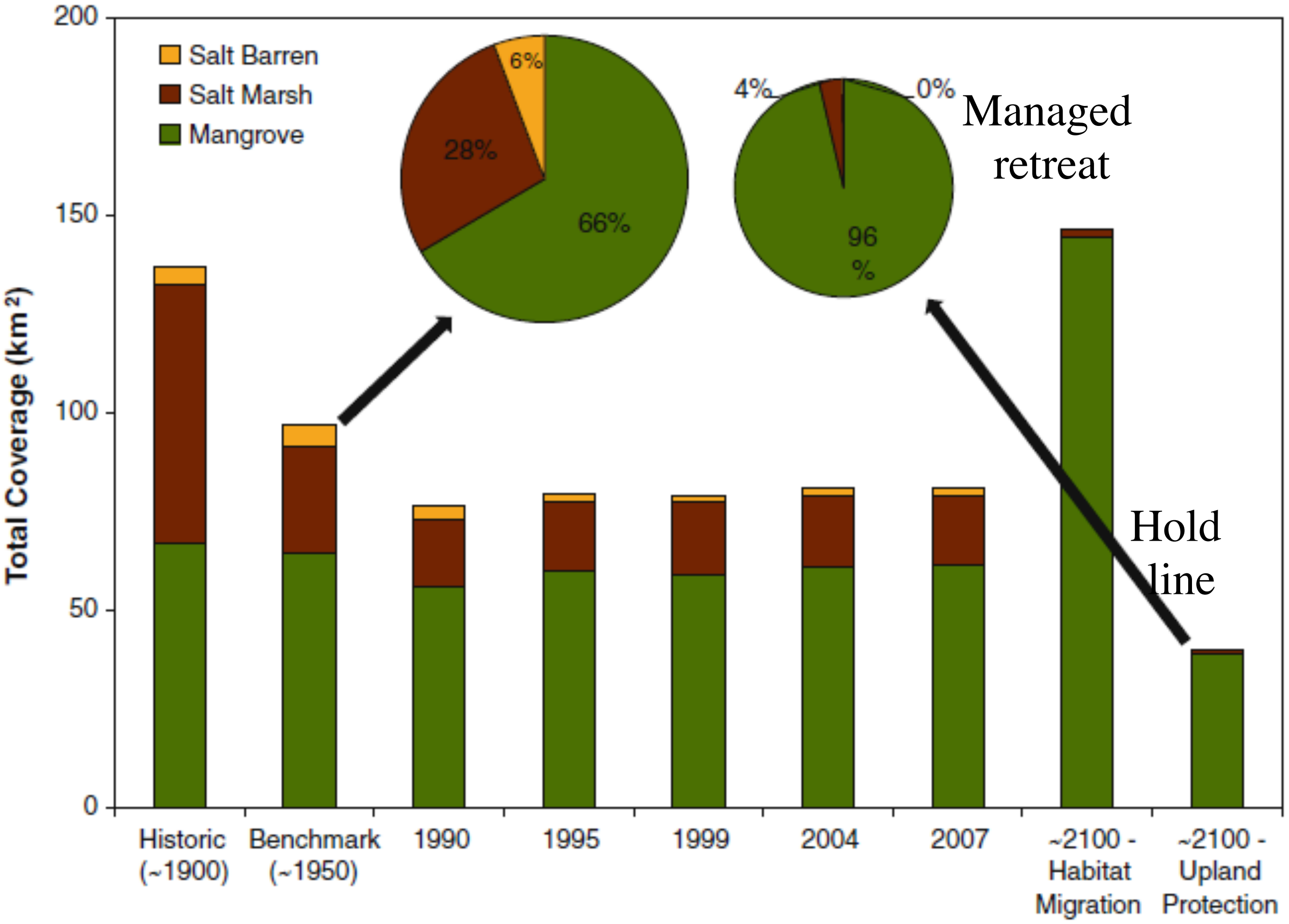
ENVIRONMENTAL MANAGEMENT

Springer

- Enhance the existing Tampa Bay SLAMM model to address seagrass and coastal uplands

- Update land acquisition priorities to accommodate sea level rise

Assessing the Blue Carbon Benefits of Habitat Restoration in Tampa Bay



From Sherwood and Greening, 2013

Characteristics of carbon projects

Priorities for site selection

- Economies of scale
  - Typically forestry projects are 10,000 ha+ in size
  - Some fixed costs irrespective of size but returns scale dependant
  - Capacity to plan at landscape scale and allow for change
  - Potential for aggregation of “like” smaller projects

Priorities for site selection

- High relative net GHG benefits
  - Avoided emissions: $C0_2$, N_2O, CH_4
  - High C sequestration: e.g., forested tidal wetlands, subsidence reversal

Priorities for site selection

- Financial fitness
  - Funding for planning, design and construction
  - Stacking of credits?
    - Carbon
    - Nitrogen?
    - Conservation?
    - Water?
    - Flood?

Priorities for site selection

- Low complexity/ low risk
  - Clear GHG reductions
  - High sea level resilience
  - Community support

Priorities for site selection

- Improved adaptation
  - Plan for long-term landscape change
  - Avoid conflicting locations for mitigation projects

Priorities for site selection

- Workable timeline
  - Near term results, or
  - Capacity to wait for return.

Project Planning Process

1. Project idea and preliminary assessment
2. Project design and planning
3. Develop a project design document
4. Review project activities and develop a project implementation strategy
5. Finalize financing and investment arrangements
6. Approvals, validation and registration
7. Implementation and monitoring
8. Verification and Issuance.

Stephen Crooks
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VCS | VERIFIED CARBON STANDARD

A Global Benchmark for Carbon

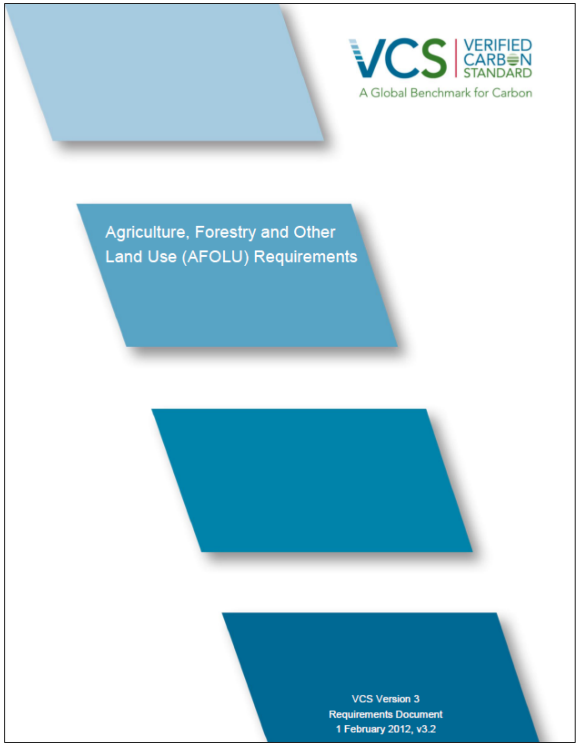
Wetlands Restoration and Conservation (WRC)

Adopted into Standard Oct 4, 2012

http://v-c-s.org/wetlands_restoration_conservation

Other Categories:

- Afforestation, Reforestation, Revegetation (ARR)
- Agricultural Land Management (ALM)
- Improved Forest Management IFM)
- Reduced Emissions from Deforestation and Degradation (REDD)



VCS VERIFIED CARBON STANDARD

A Global Benchmark for Carbon

Agriculture, Forestry and Other Land Use (AFOLU) Requirements

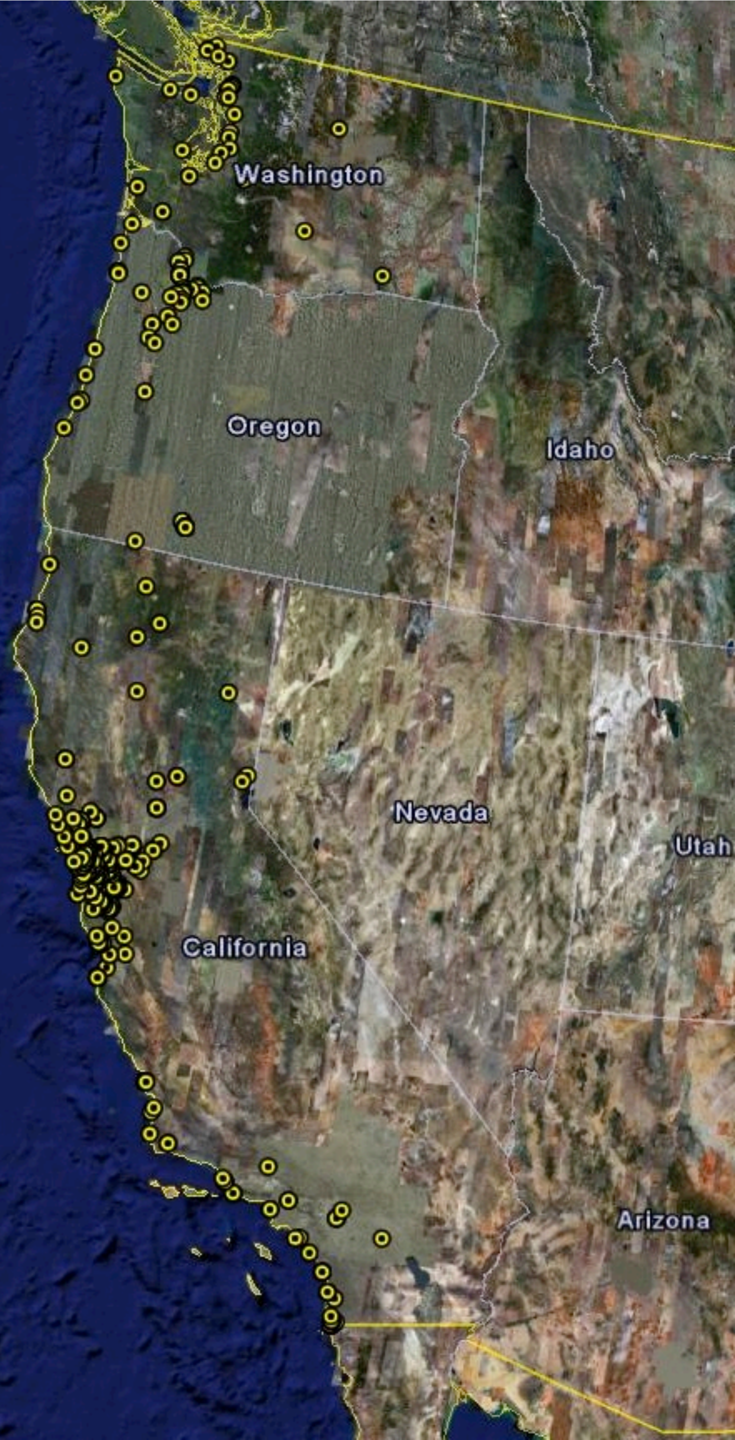
VCS Version 3
Requirements Document
1 February 2012, v3.2

RESTORE AMERICA'S ESTUARIES

Recent Activity

- **IUCN and UNEP Reports on Blue Carbon** (2009)
- **Climate Action Reserve - Tidal Wetlands Issues Paper** (PWA and SAIC 2009)
- **RAE Blue Ribbon Panel and Action Plan** US focused 2010
- **NCEAS Working Group –** tidal wetlands carbon model
- **International Blue Carbon Working Groups (**2011-onwards)
    - Science
    - Economics and Policy
- **Reports** (2011)
    - **World Bank, IUCN, ESA PWA –** Global estimates and policy implications
    - **Duke University – Economic Potential**
    - **Climate Focus – international Policy**
- **IPCC Wetlands Supplement for National GHG Accounting** (2011-2013)
- **Voluntary Carbon Standards**
- Recognizes wetlands activities
- *Methodology for Tidal Wetlands and Seagrass Restoration* in review
- **Working Groups**
    - US Federal Agency Blue Carbon Group
    - World Bank Blue Carbon Working Group
    - National groups / programs – Indonesia, Australia, Abu Dhabi, Costa Rica, Oregon,
- **Guidelines for Coastal Wetland Carbon Projects** – in progress

ESA PWA



40 years of restoration experience

1400 wetlands projects

Plans developed for most major Estuaries on west US coast

Implemented Coastal Wetland Restorations

Wetland Restoration Project	Year Constructed	Acres Restored
Hamilton Army Airfield Restoration	2013	500
Qwuloolt Estuary Restoration	2013	360
Sauvie Island Wetland Enhancement	2013	120
Colewort Creek Tidal Wetland Restoration	2012	50
Miami River Wetlands Enhancement (OR)	2011	55
Eden Landing Marsh Restoration Ponds 8 & 9	2011	730
South Bay Salt Ponds - Alviso Pond 6	2010	330
South Bay Salt Ponds - Alviso Ponds 5, 7 & 8	2010	1400
South Bay Salt Ponds – Pond SF2	2009	240
Crescent Bay Tidal Marsh Restoration	2009	300
Bahia Wetlands	2008	400
Bair Island Restoration	2007	900
Napa-Sonoma Marsh Restoration	2005	3000
Petaluma Marsh Expansion	2003	100
Cooley Landing Wetlands	2001	115
Charleston Slough	1996	120
Roberts Landing	1995	300
Sonoma Baylands	1993	320
TOTAL		**9,340**

- Includes
  - largest wetland restorations on the Pacific Coast
  - Oyster reefs and eelgrass
- Learning curve