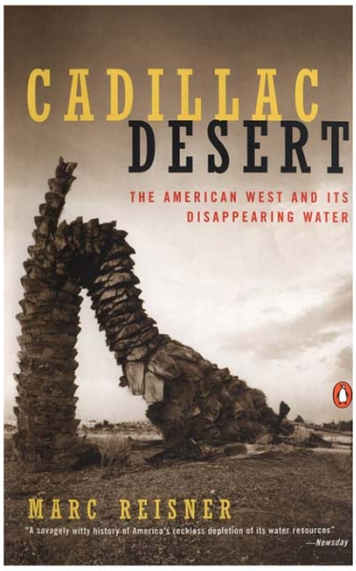
Water and California:
The Role of the Sacramento-San Joaquin Delta
ESPM 2, Fall 2013
Dennis Baldocchi

Case study on the Sacramento-San Joaquin Delta. A venue about 60 miles from Berkeley, conduit for much of the water transferred through the state, a disturbed and artificially-created landscape, it is home to productive agriculture and battleground for many environmental issues challenging the State of California relating to sustainable land management and land use, fish, water, agriculture, water quality and recreation.

Water is central to the functioning, intellectual spirit, economy, life style and rich cornucopia of fruits, vegetables and nuts that define California

Because California has a Mediterranean climate with long dry summers, it has the potential to have productive agriculture, given water can be transferred from the mountains and rivers to the farms, up and down the state. Our unique situation enables us to grow +90% of certain nuts and fruits like almonds, walnuts, apricots, pomegranates, as well as some of the best wine in the world.

An Environmental Classic



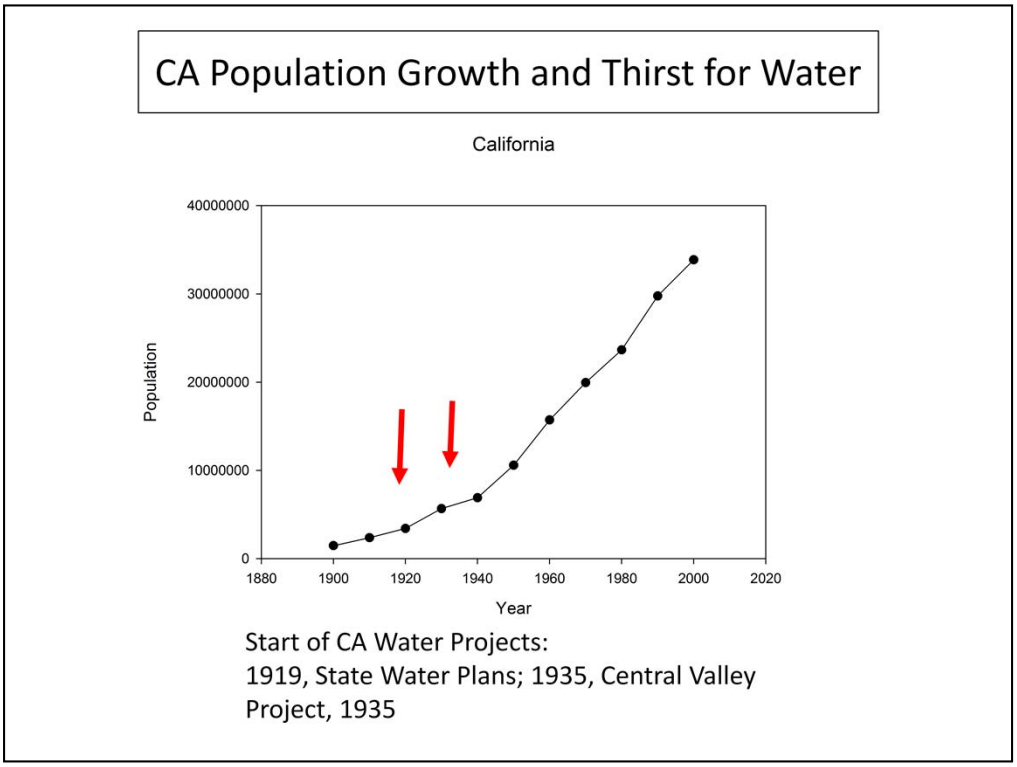
This is a must read book if you are interested in the development of water and water transfer systems in California. It tells of the heroes and villains and those sacrificed for the greater good.

California, Before the Water Projects

Sustained a Population Less than 3 Million

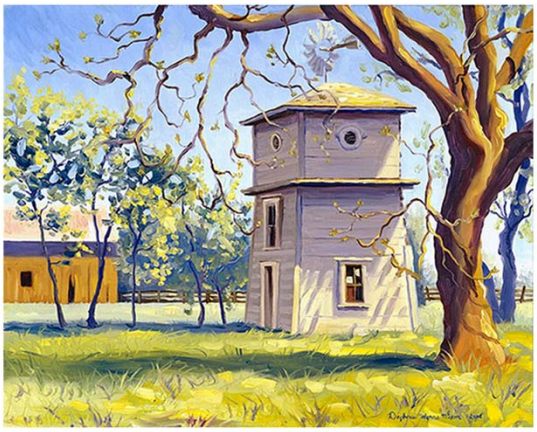
C. Satriani

Before the development of water projects, growth in California was limited by available water. Most farmers collected their water to sustain them through the year



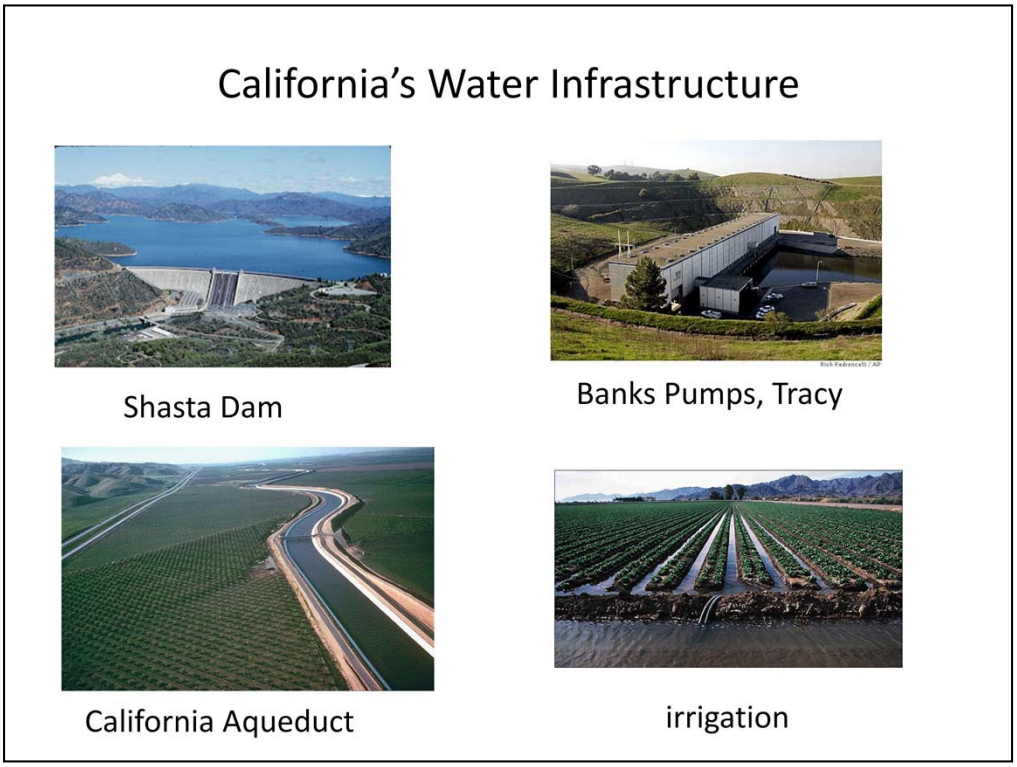
Growth in California is tied, if not highly dependent upon the state and federal water projects that created infrastructure for water storage and transport across the state.

Farm Tank house



For perspective, drive around the country side and notice and look at the old farmsteads. In essence they were self sustaining and due to the Mediterranean climate, with no summer rain, had to store their water. All these homes had iconic water towers. Sadly many are in disrepair.

http://winwithwynne.wordpress.com/oil-paintings-of-tank-houses-in-solano-county-ca/



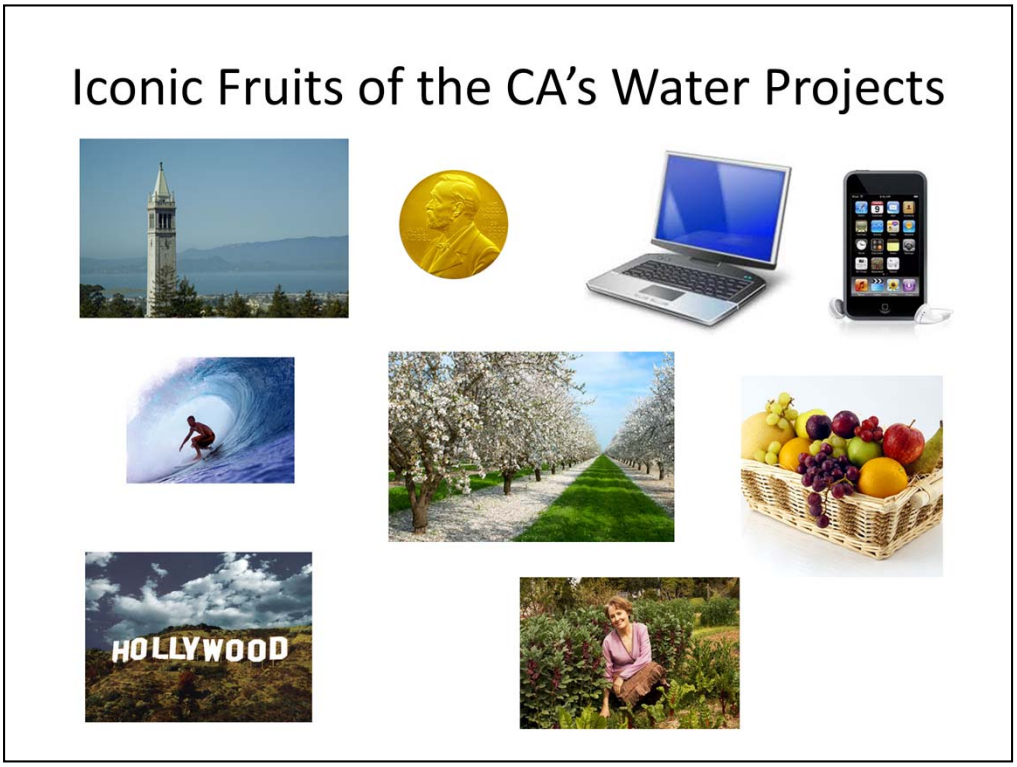
Snow in the Sierra Nevada runs off and is stored in many of our reservoirs (Shasta, Oroville, New Melones, Hetch Hetchy). Much of this water flows out to the sea and passes through the delta. Pumps near Tracy siphon this water into canals associated with the California Aqueduct and Delta Mendota canals. This water is pumped south and up hill to supply vast agriculture in the San Joaquin Valley and over the Tehachapi mountains to Los Angeles.

http://aquadoc.typepad.com/.a/6a00d8341bf80a53ef01156fc693be970b-800wi

Here are some of the major canals that transport water across California. The Hetch Hetchy brings water to San Francisco, gravity fed. Canals south of the delta must pump water Up Hill, against the direction of flow of the parallel and meager San Joaquin River

Moving Water Across the State Consumes up to 19% of its Energy

Not only is water pumped uphill from the Delta through the San Joaquin Valley, that which goes to Los Angeles must be pumped over 2000 feet, one of the highest lifts in the world.



Yet we can claim the costs are worth it. I claim much of what is California is possible by the fruits of the water projects, including UC system. Water enabled the population to grown, economy to foster. The fine weather we love is why we need water projects, as we don't get rain when we need it.

Sacramento-San Joaquin River Delta

Note: Web of Channels, Now Confined Artificially

This brings us to the story of the delta, the central pivot point of the California water transfer system

Background Reading

Delta Fact Sheet
Sacramento San Joaquin Delta
Ingebritsen and Ikehara, 1999
in Galloway, D.L., Jones, D.R., and Ingebritsen, S.E., eds.,
Land subsidence in the United States:
U.S. Geological Survey Circular 1182, p. 83-94.

State of the Bay-Delta Science, 2008
http://www.science.calwater.ca.gov/pdf/publications/sbds/sbds_final_update_122408.pdf

California's Sinking Delta
http://www.csmonitor.com/Environment/2009/1202/californias-sinking-delta

Impact of Delta on California

- Source of Irrigation water for 4.5 million acres of farmland
- Drinking water for +20 million (2/3rds) Californians

http://www.abag.ca.gov/bayarea/sfep/reports/fact/delta.html

Delta and Ca Rivers

- Drains: Sacramento, Feather, American, Consumnes, Mokelumne, Stanislaus, Tuolumne, Merced and San Joaquin Rivers into San Francisco Bay and the Pacific Ocean
- Receives 40% of State's Runoff;
- Provides 2/3 of State's Drinking Water

http://www.paddleguides.com/rivers/california/ca_map.jpg

Bay Area and Delta Watershed comprises 40% of the States area and 2/3 of the States drinking water. Intersection of Sacramento and San Joaquin Rivers

What is the Delta?

Legal Delta
~ 740,000 ac total
1156 sq miles

Primary Zone:
~ 490,000 ac
Secondary Zone:
~ 250,000 ac
…of which
Ag uses:
~ 530,000 ac
Urban:
~ 70,000 ac
Wetlands:
~ 40,000 ac
Waterways:
~ 60,000 ac

57 Islands

700 Miles of Rivers and Sloughs

1100 miles of levees

San Francisco Bay
(water/marshes/unfilled diked baylands):
± 375,000 acres

Chesapeak Watershed is 64,000 sq miles

Chesapeake watershed is 64000 sq miles

Delta and Multiple Stakeholders

- Cities, freshwater for drinking and households
- Agriculture, water for irrigation of field crops, fruits and vegetables
- Ecologists, water flows to support fish, water fowl, endangered species (delta smelt), native plants, and stymie invasive species
- Hydrologists, sufficient water flows to prevent salt water intrusion
- Fisherman, water flows to support juvenile salmon and other androgynous fish
- Recreation, fresh water for fishing, boating and water sports

The Delta is a great case study on environmental management and decision making. It has multiple stakeholders, each with contrasting desires and needs for its water

Ecological Importance/Environmental Issues/Conflicts

- Largest Estuary of the Pacific Americas
- Major Water Source for California
  - Wetland/Ecosystem vs Agriculture vs Urban Consumption vs Fish
- Water Quality/Exportation
  - Salt Water Barrier for Ag and Urban Freshwater Supplies
  - Maintains Conduit of water flows for fish
  - Water Law and Riparian Rights
  - Methyl Mercury
- Land subsidence
  - 10 m of peat soil has been lost over last 150 years
- Levee stability and maintenance
  - State vs Private Cost Sharing
  - Vulnerability of levee system to hydrologic pressure from subsidence, sea level rise and earthquakes
- Invasive Species in water ways
- Migratory Birds/ Wetland Habitat
- Societal Conflict/Engineering Solutions/Societal Decisions
  - Subject of State Bonds and Water Bills, ++$11 Billion SB 7X 1
  - Single vs Multiple Uses
  - Habitat Restoration
  - Peripheral Canal
  - Pricing and Metering Water Use
  - Carbon Farming
  - Bolster Levees/Reclaim Flooded islands??
  - Status Quo is NOT an OPTION

Use of the Delta has led to environmental problems and sources of conflict among various stakeholders

Deltas are Under Threat World-Wide

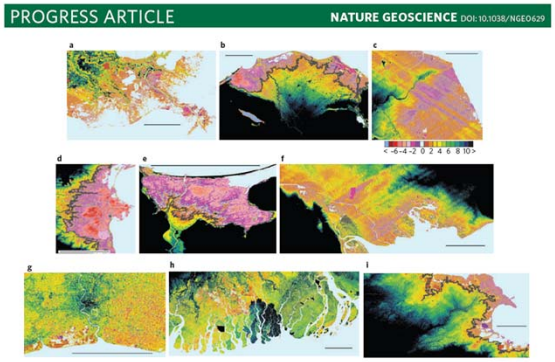


Figure 1 | Topography of representative deltas. SRTM altimetry is binned at 1-m vertical intervals, starting at sea level (light blue), to a height of 10 m, then black. Topography below mean sea level is in shades of pink. **a**, Mississippi, USA; **b**, Nile, Egypt; **c**, old abandoned Yellow, China; **d**, Po, Italy; **e**, Vistula, Poland; **f**, Shatt al Arab, Iraq; **g**, Chao Phraya, Thailand; **h**, Ganges-Brahmaputra, Bangladesh; and **i**, modern (since 1855) Yellow, China. Scale bar on images represents 50 km. For **b**, **d**, **e** and **i** examples, the 2-m best-fit isoline is provided as a grey line.

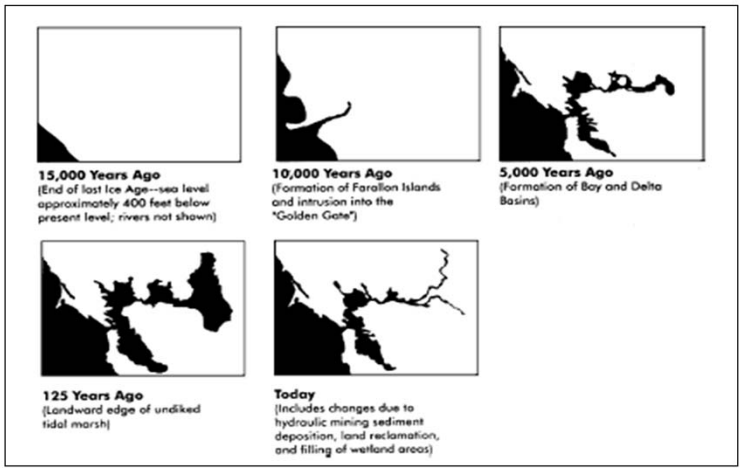
Pros: Home to 0.5 Billion People, Rich Habitat, Flood Control, Buffers Land from Storms

Cons: Sinking, Vulnerable to Flooding, Reduced Sediment Loads and Channel, Susceptible of Land Conversion to Ocean

The delta is a case study for other deltas in the world who are facing problems from overuse.

Home to 0.5 Billion people; 85% of deltas experiences severe flooding; Pink below sea level

Geological History



Peatlands Accreted Organic and Mineral Soils in Lock-Step with Sea-Level Rise, ~ 5mm/y

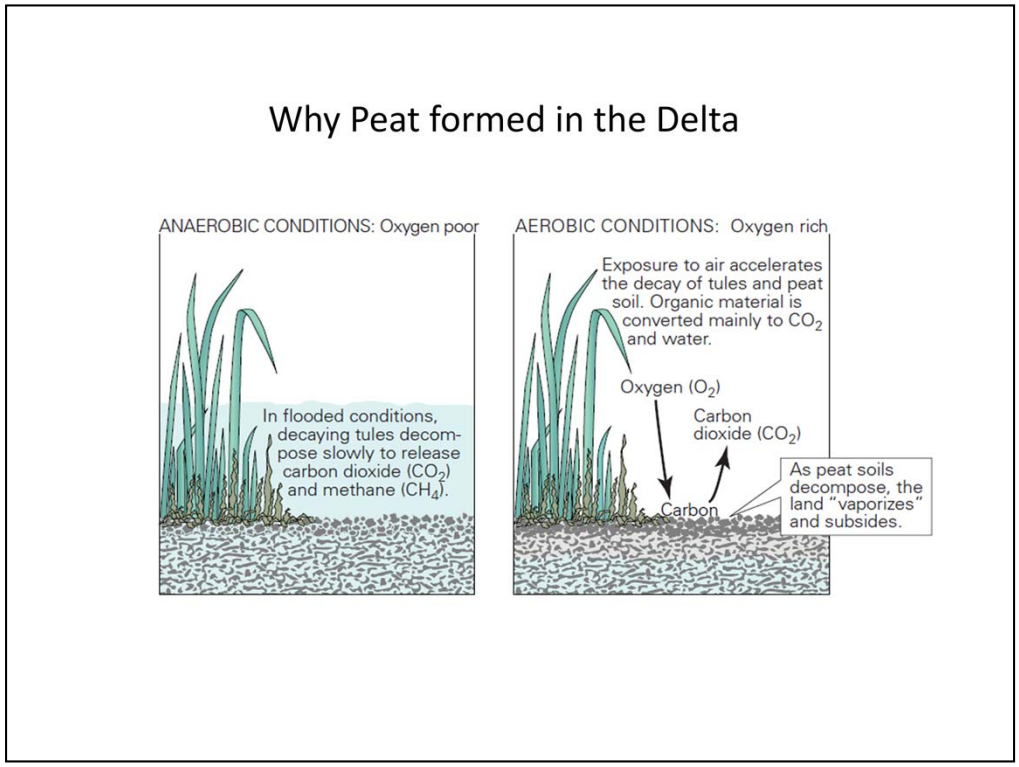
Simenstad et al. 2000; Ingram et al

The Geological history is quite recent, past 10,000 years or so since the end of the ice age. Sea level rose about 120 m over this time. The delta is at the confluence of two rivers on a former inland sea, so the land is basically flat. Historically this land was flooded and vegetated by wetland plants. Flooding inhibits decay, so as the plants died peat would form. The peat could accumulate as the sea slowly rose. Over time about 10+ m of peat formed.

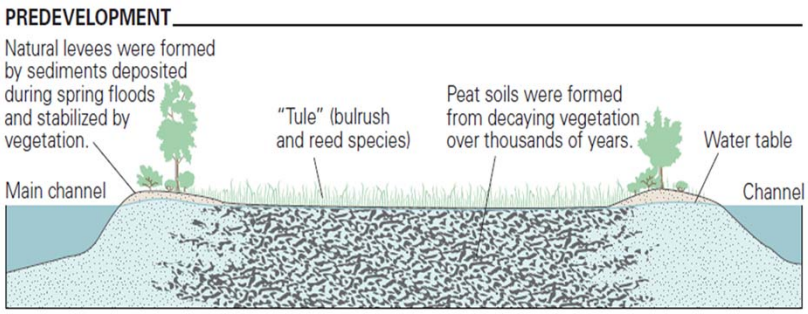
Highly Productive Tule/Cattail Tidal Ecosystem

- Long Growing Season
- Ample Sunlight
- Unlimited Access to Water
- Nutrients in Runoff

This ecosystem is highly productive for the reasons noted above.



Example of peat formation. Flooding inhibits decomposition



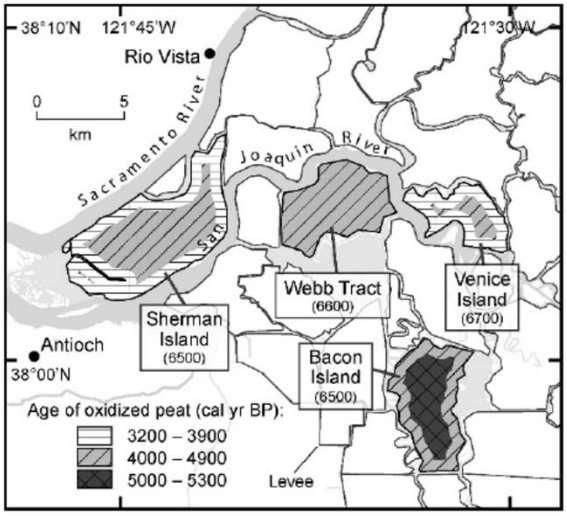
Example of cross section of land prior to development. River channels were bounded with large tule wetlands.

Peat Cores

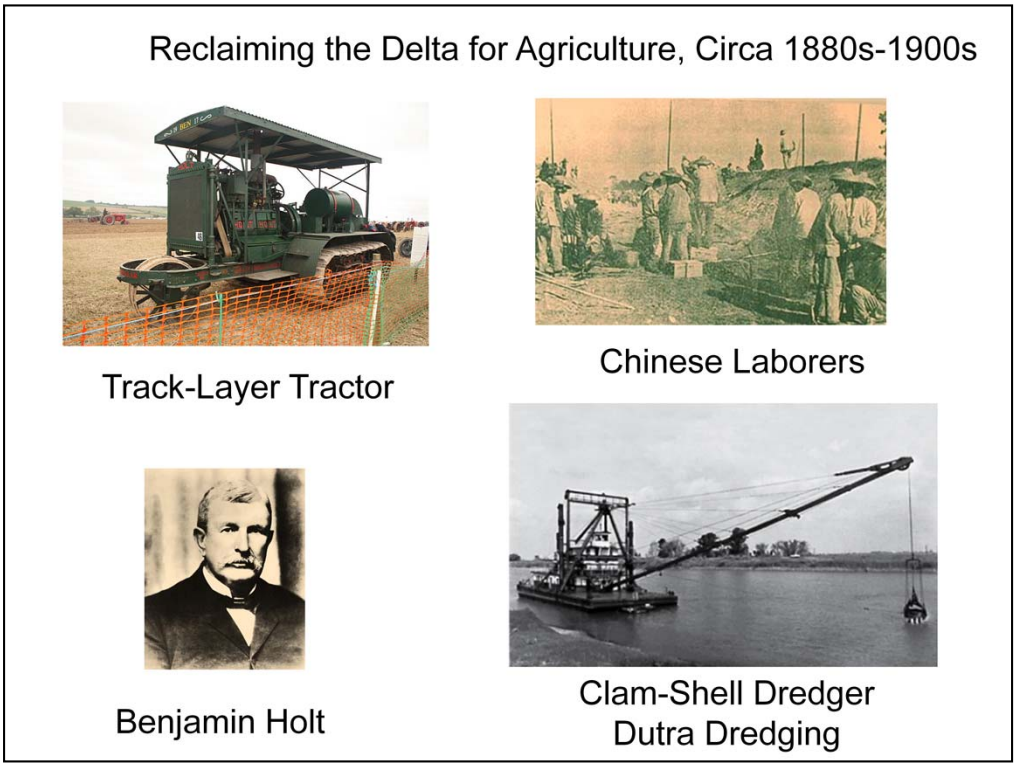
Today, you can dig a hole and near the water table find un-decomposed tule corms and peat that is thousands of years old

Age of the Peat:

3 to 5k years

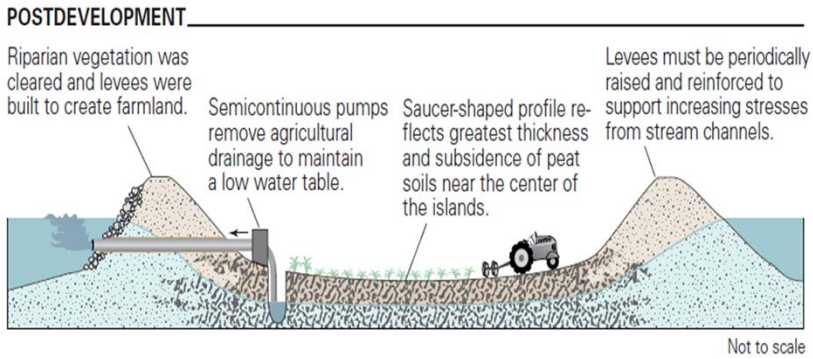


Mapping of peat age with 14C determines it to be 3000 to 5000+ years old



Technology and history led to the development of the delta. The gold rush brought new numbers of settlers to California. Most passed through the Delta on their way from the port in San Francisco to the foothills of the gold country. Many did not find fortune and many had farming backgrounds. The more visionary knew the delta could be drained and yield rich productive soils. The first developments depended on manual labor. This come on the backs and hands of Chinese laborers who first came to California to build the trans national railroad. These manual levees readily failed. So the next innovation was the clam shell dredger. Finally, new generation of tractors needed to be developed to cultivate the land. Benjamin Holt developed the track layer tractor, which helped reclaim much of these lands. This technology led to military applications in World War I in the form of tanks.

There is no Free Lunch;
the act of draining the Delta is causing us
to Mine the Delta



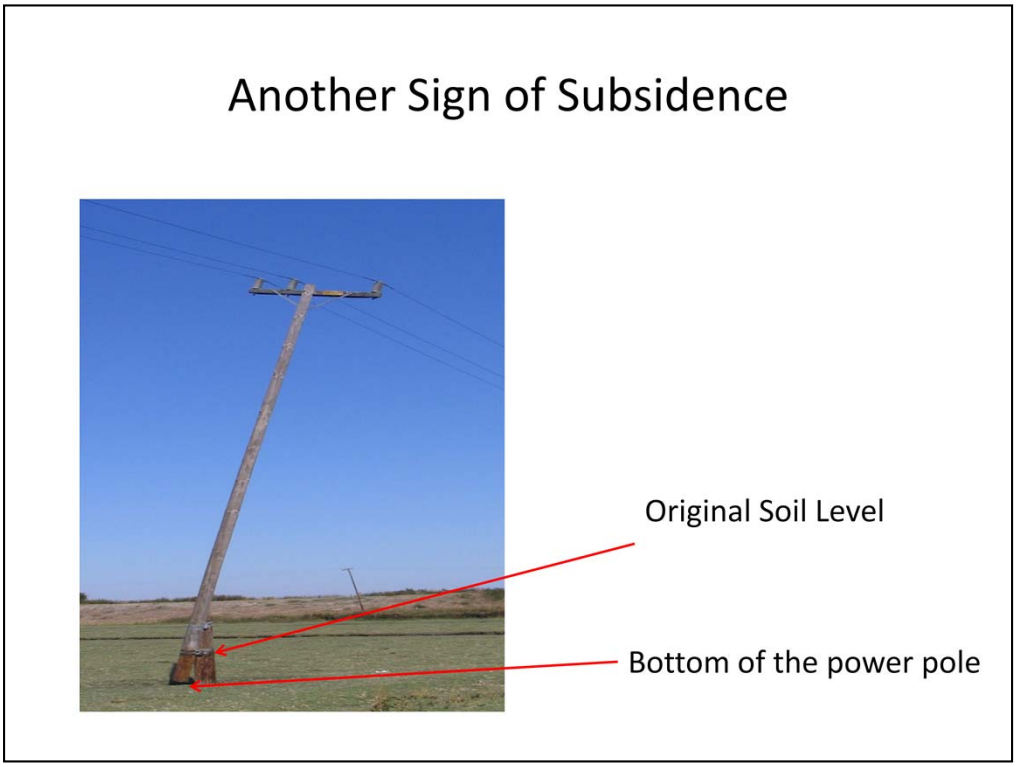
Exposure of peat soils to air is causing rapid decomposition and subsidence

Degraded and Subsided Peatland, > 10 m below Sea-Level

View from the Antioch bridge. See how the water of the San Joaquin river is much higher than the land on Sherman Island

Exposure of Base of Power Poles, a measure of subsidence over the past Century

Evidence of subsidence can be shown looking at the base of the power transmission lines that were built in 1910

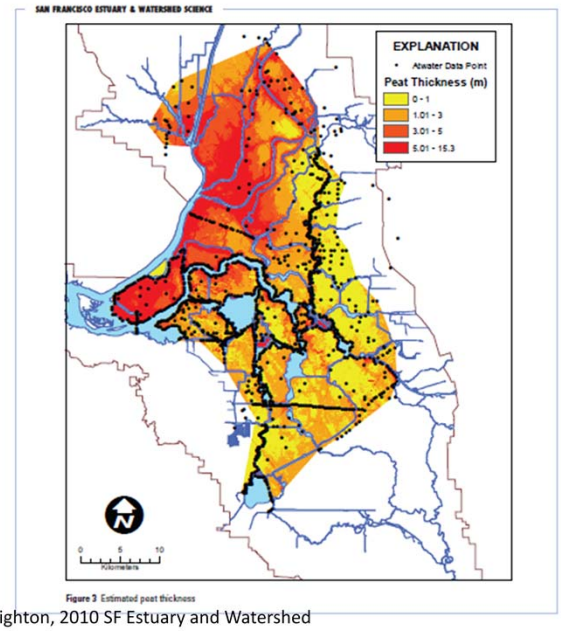


This is the power line that supports my methane sensor. In this case they had to support the pole with a brace.

Now Do you Believe the Land has Subsided?:
Boats don't Fly

It is amazing to see freighters fly by when you are out in the field. This is a very dramatic view and proof of wholesale soil subsidence

Thickness of Peat



Deverel and Leighton, 2010 SF Estuary and Watershed

These soils are rich because they have high organic matter and supply nutrients to plants as the organic matter mineralizes. We find we don't have to fertilize our rice because the soils are so rich.

Peat is up to 15 m deep on the western side of the delta.

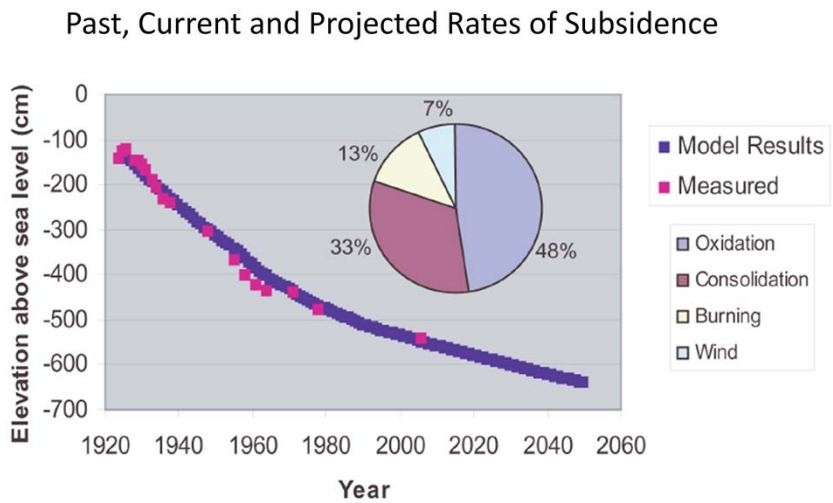


Figure 6 Average measured and model-estimated elevation change on Bacon Island. Pie chart shows the model-estimated causes of subsidence.

Deverel and Leighton 2010

The rate of subsidence has decelerated with time. When the delta was first drained, the most labile peat decomposed first and fastest. In early years we lost several inches of soil per year. Most of the subsidence is due to oxidation (decomposition). Other sources are wind erosion, compaction and fire.

Rates of Subsidence of Delta Peat Islands

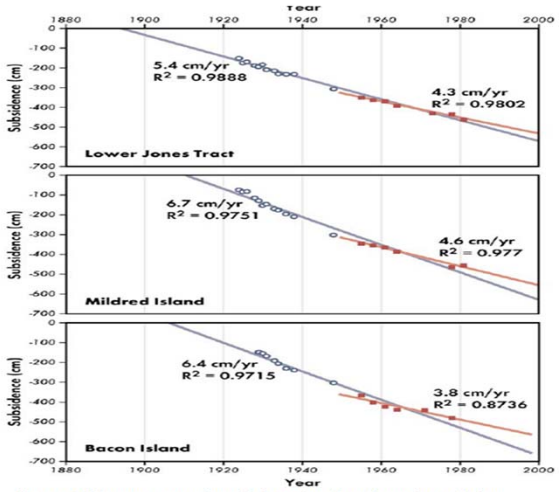


Figure 3. Linear regression of elevation data from three Delta islands to assess changes in rates of subsidence. Blue line depicts best fit for subsidence data from 1925-1981; red line represents post-1950 data. See text for discussion. Data from Deverel (1998; personal communication, S. Deverel, 2004).

2.2 m of Subsidence in My Lifetime

Data on subsidence at different islands

Towards Meeting California's Goals to Offset Carbon Emissions:

Restoring the Delta to a Tidal Wetland, An Effective Carbon Sink

San Joaquin Delta Land Reclamation Photographs, ca. 1904-1907, Bancroft Library Online Archive of California

One thing we want to do is to try and solve environmental problems, rather than be Cassandras who only cry about problems everywhere. One plausible solution is to restore wetlands. Here is an historical picture of the Delta from 1907. My Italian immigrant grandfather and step-grandfather came to California during this time and started farming in this region.

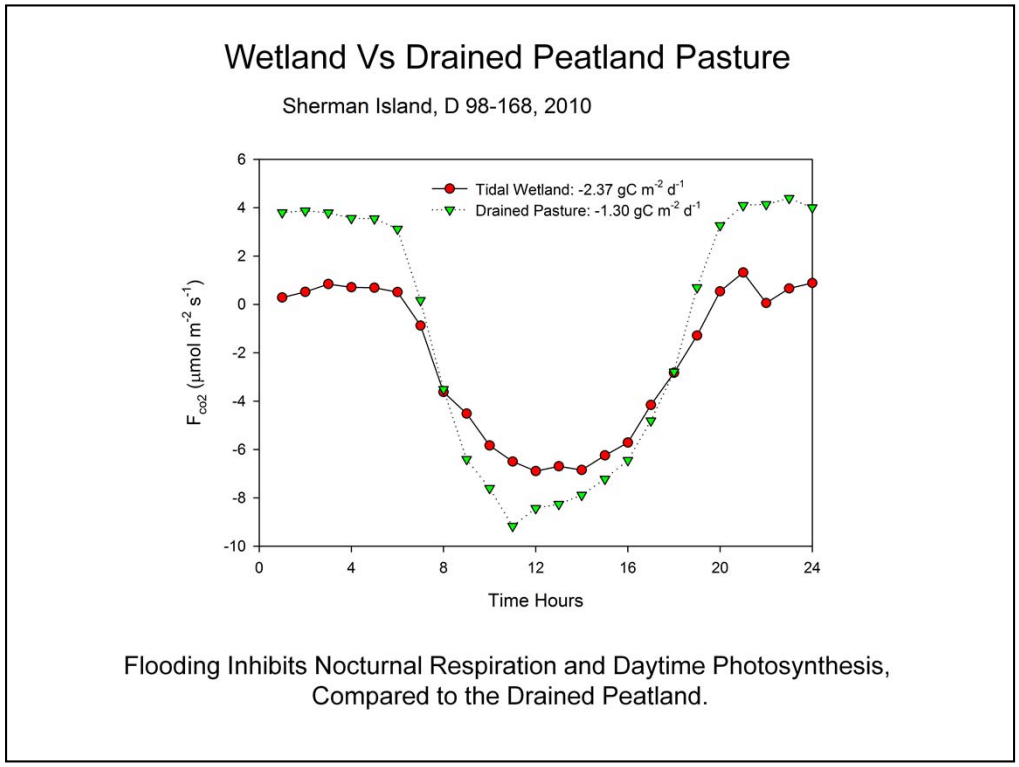
C Flux Measurements on Tidal Wetland

What were conditions like before the Delta was developed?

We've been making carbon dioxide and methane flux measurements over the delta. From a levee on Sherman Island we can sniff the primordial wetlands of Sherman lake. Granted they may not be like the interior delta because they are built on sediments that have flowed down the Sacramento and San Joaquin rivers. Never the less they remain and undisturbed wetlands and merit study.

Native Tules on Sherman Lake

We conducted a commando raid a few years ago to measure methane emissions from these tules. The area is highly tidal and the water level can go up and down a meter or so, draining and inundating the land and vegetation.



Our data over the wetland was spotty because our instruments were stolen. But you can see the wetland respires little at night, while the respiration of the drained peatland is quite large.

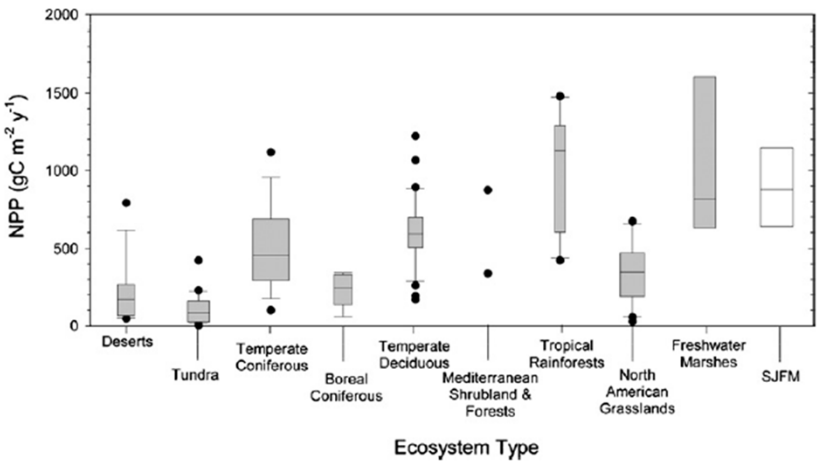
Pro and Cons of Ecological Restoration

Pros: Stop or Reverse Soil Subsidence by Restoring Wetlands, Stabilizes Levees, Reduces Pumping Costs, Increases Biodiversity, Habitat for Juvenile fish and Migratory Water Fowl, Protect California's Water Conveyance System, $$$$$ if we do nothing

Cons: Matter of Scale, $$$$$ to Implement, Rates of Accretion are Slow (100 years), Flooding will lead to production of Methane, reduce water quality by promoting production of Methyl Mercury and DOC, and Serve as Habitat for Mosquitoes, vectors for West Nile Virus

In this class we need to understand how to become good environmental stewards. We need to be aware of the scope and causes of environmental problems, to be aware our health and happiness are tied to the state of the environment, not to take it for granted, be aware of possible solutions and be aware of the unanticipated consequences of solutions.

Marshes Maintain High (>1000) Net Primary Productivity (gC m^{-2} y^{-1})



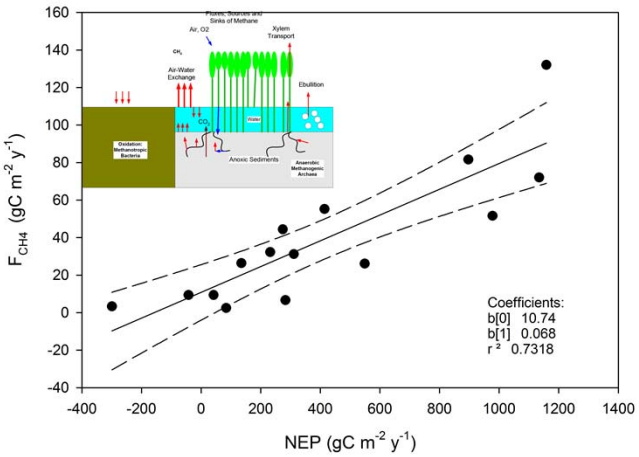
Rocha and Goulden 2009 AgForMet

NPP of water column is 90 gC m^{-2} y^{-1}: Jassby et al 2002

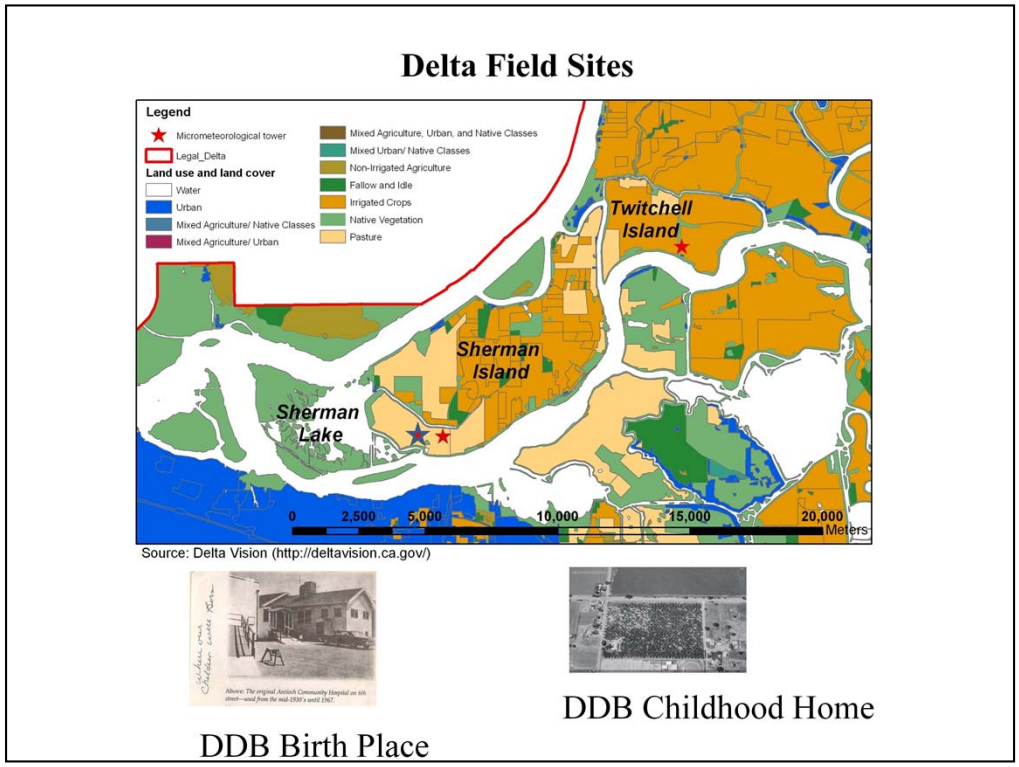
Comparison of different wetlands and ecosystems as sinks for carbon. Freshwater marshes are much greater sinks that iconic forests and ag lands

- **Wetlands in California Provide Huge Potential to Sequester Carbon**
  - **Long Growing Season & Ample Sunlight Promotes Photosynthesis**
    - **Flooding Retards Respiration**

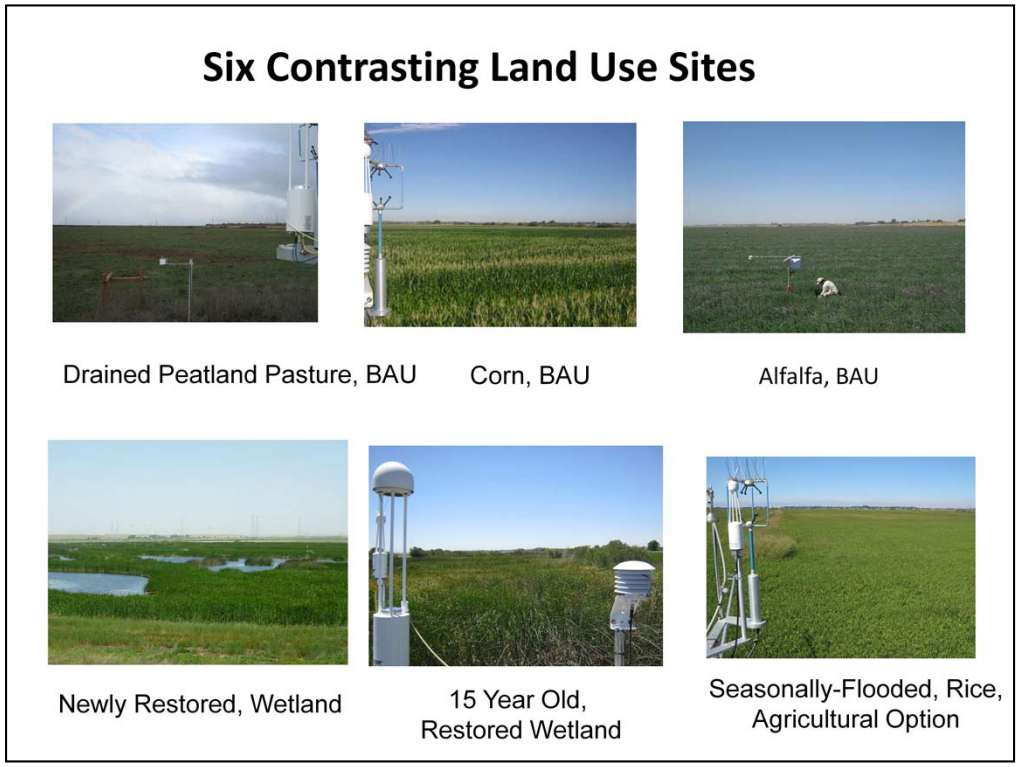
- **At What Cost?**
- **Annual Methane Emission Scales with Net Primary Productivity of Wetlands, Natural and Managed**



Wetland ecosystems with a great potential to sequester carbon have the potential to be large sources of methane..



We are trying to study the impacts of ecological restoration and business as usual land practices. The delta is a special place for me. I grew up on the edges of the delta and my family farmed on Sherman and Liberty Islands.



We are studying 3 landscapes that are business as usual, pasture, corn and alfalfa, and 3 flooded options, a newly restored wetland, an old pilot project and rice.

Sherman Island, Drained, Grazed, Peatland Pasture

The pasture raises interesting challenges towards flux measurements. On one hand it is the most perfect site I have ever worked on. Table top flat, strong, steady winds from the west, huge fetch for the air and land to come into equilibrium over fairly uniform vegetation. But for microbially-generated trace gases it is quite heterogeneous. We have cows walking around the paddock burbing methane. And at night the atmosphere becomes stable, the flux footprint extends beyond the drier portions of the paddock and senses wet patches, rich in methane producing microbes and organic sediments. All make the measurements more variable in time.

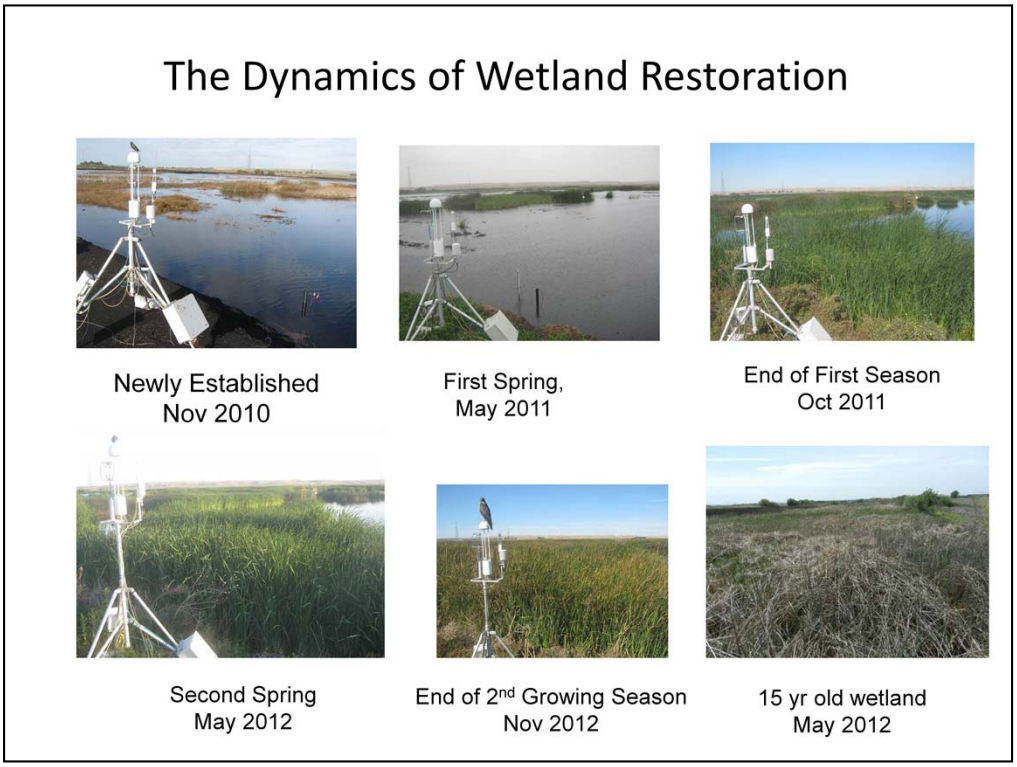
Agriculture in the Delta, Rice

Since much of the delta is privately owned we are looking for solutions that benefit both the farmers and the citizens of California. One idea is to plant rice, a wetland crop. The hope is flooding will stymie excessive respiration by the soils. Prior to the 1990s rice could not be cultivated in California, as the delta was perceived to be too cool at nice to promote flowering of the grass; In Agronomy 100 in 1976 I learned ‘you could not grow rice south of I 80’. Our colleagues at UC rice experiment station developed a new variety M104 that could withstand cooler temperatures and thrive in the Delta..

Side note, when my grandfather came to California from Italy he first settled in the Sutter basin and tried to farm rice. The lack of dams, upstream, led to several floods and crop failures

Wetland Restoration At Mayberry Slough

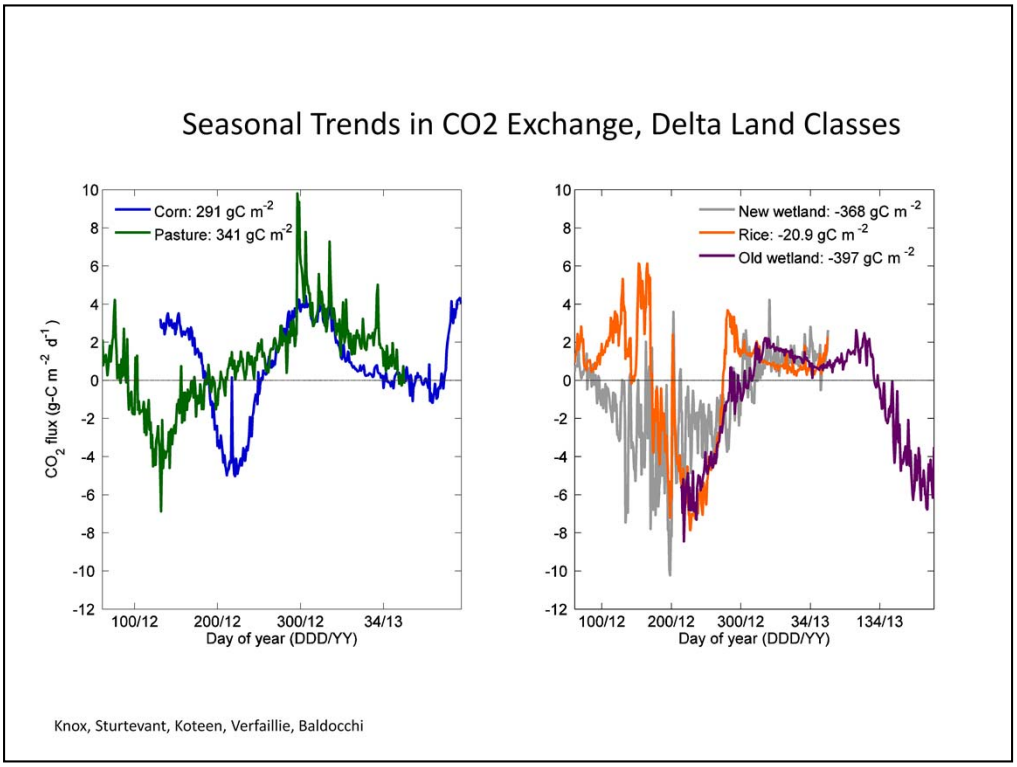
The other option is to restore wetlands. The California Dept of Water Resources has bought large swaths of Sherman Island and Twitchell Island, and through state water bonds have the resources to restore wetlands at large field scales. This restored wetland on Sherman Island is several hundred acres in scale and started in 2010. We have been measuring carbon and methane fluxes since Nov 2010 and are tracking its development.



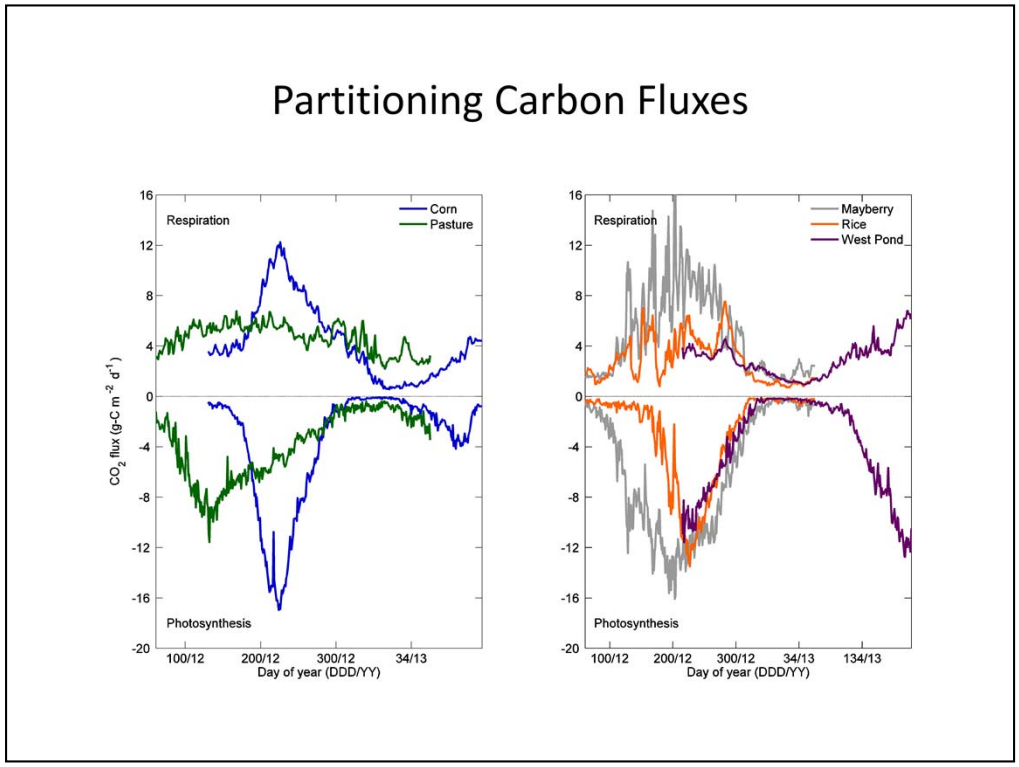
Things we learn about studying the biosphere is that each year is different and as ecosystems grow and mature their ability to metabolize changes. Here the system started out with large areas of open water. By the next spring new tules and cattails started to emerge and expand. In the early years most of the landscape was dominate by green vegetation. But these reeds are deciduous. They die each fall, and they are not immediately incorporated into the water column and soil sediments. It takes several years for the stems to rot and the dead reeds to fall over. Hence in following years there is competition between dead stems and live stems for light. This has repercussions on subsequent respiration, photosynthesis and methane production.

Delta is part of the Pacific Fly-way
and is winter home for many migrating water fowl

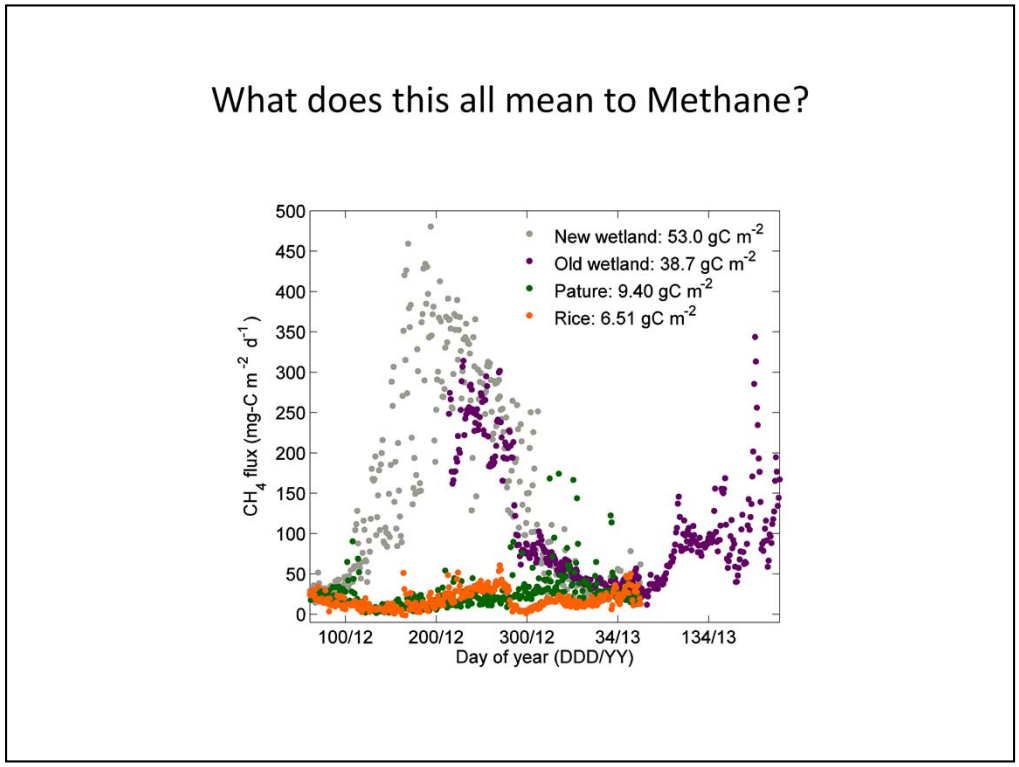
Flooding lands during the winter can be a win-win strategy. Flooding can inhibit respiration, it promotes resident water fowl (ducks, geese, swans, sand hill crane), and these birds can provide ecosystem services by incorporating straw into the soil.



New data. Unpublished, just produced. No one has seen yet. Comparison of net carbon fluxes from business as usual land use types (pasture and corn) and wet systems (wetlands and rice). Planted crops like corn and rice experience short seasons of carbon uptake, compared to perennial pastures and tules. Winter rains promote high rates of carbon loss from the pasture and corn fields, compared to the flooded wetlands that remain flooded for water fowl



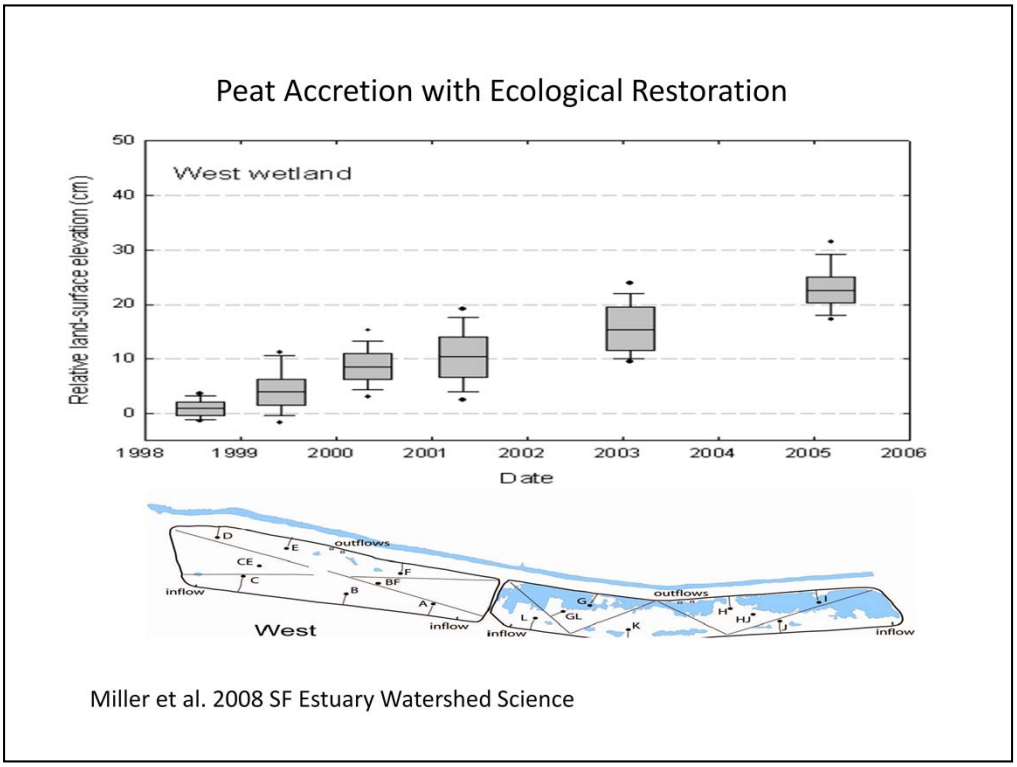
More new data. Partitioning net carbon fluxes into ecosystem respiration and photosynthesis lets us look under the hood. The aerobic soils of the drained corn and pastures enable large respiration rates to occur year round, that lead to much of the long term subsidence. The story is more messy with the wetlands. To some degree flooding inhibits respiration. But our new measuremetns are also revealing the fact that respiration scales with photosynthesis. Hence the newly formed wetland is achieving high rates of photosynthesis at the cost of high rates of respiration. The more decadent older wetland has lots of woody biomass competing for photons so its photosynthesis rates are lower as are its respiration rates



And a third set of new and novel data on greenhouse gas fluxes from the delta. The wetland restoration projects are gianormous, humongous emitters of methane

Biosphere Services:
Twitchell Island Tule Pilot Project

In 1997 USGS developed a pilot project on Twitchell Island to see how much peat a tule wetland can accrete over a decade or so.



Published data on the pilot wetland study

Fate of Water in the Delta

In this next section we'll focus on water transfer and budgets

Typical Delta Water Balance, 1000 acre-feet

10 THE STATE OF BAY-DELTA SCIENCE, 2008

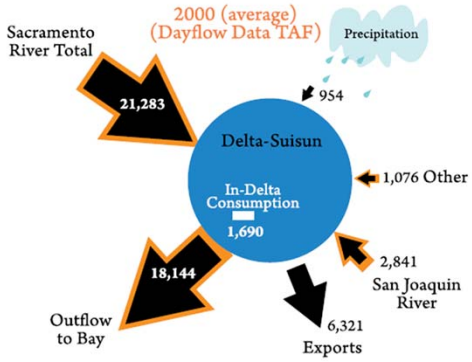
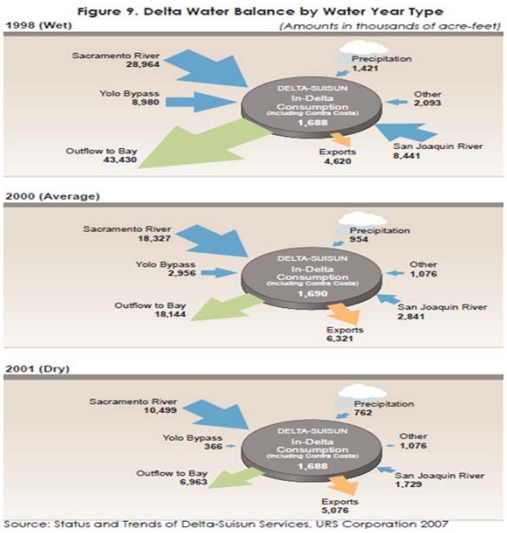


Figure I.3. Delta Water Balance showing inflows and outflows during an average water year, in thousand acre-feet. (Source: URS Corporation 2007)

Internal Consumption > Precipitation
Exports to San Joaquin Farms and LA

Water Flows through the Delta. Key numbers 6 million acre feet of water are exported south. A critical amount of water must flow out to the bay to keep the water in the delta fresh, not saline. Year to year variation in rain and runoff makes this task challenging

Perturbed Water Balance, 1000 acre-feet, Ranges Widely



Flow to Bay
43,000k (wet) – 6,900k (dry)

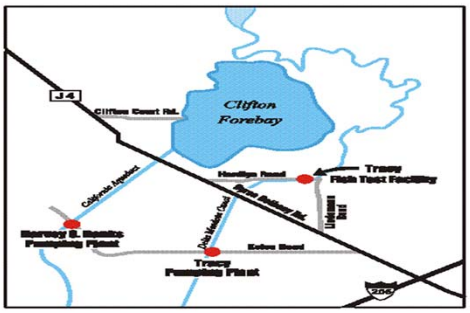
Export to South
4,600k (wet) – 6,300k (ave)

Water Mgt MUST Consider Low and High Flow Years

We should not manage water flows and allocations for average conditions. We must consider the range of conditions

Storage + Conveyance

- Clifton Court ForeBay
- County
  - Contra Costa Canal
- State
  - California Aqueduct
  - Harvey O Banks Pumps
- Federal
  - Delta Mendota Canal
  - Tracy Pumping Plant



•Water Flows to South Delta and is Pumped UPHILL to Southern California

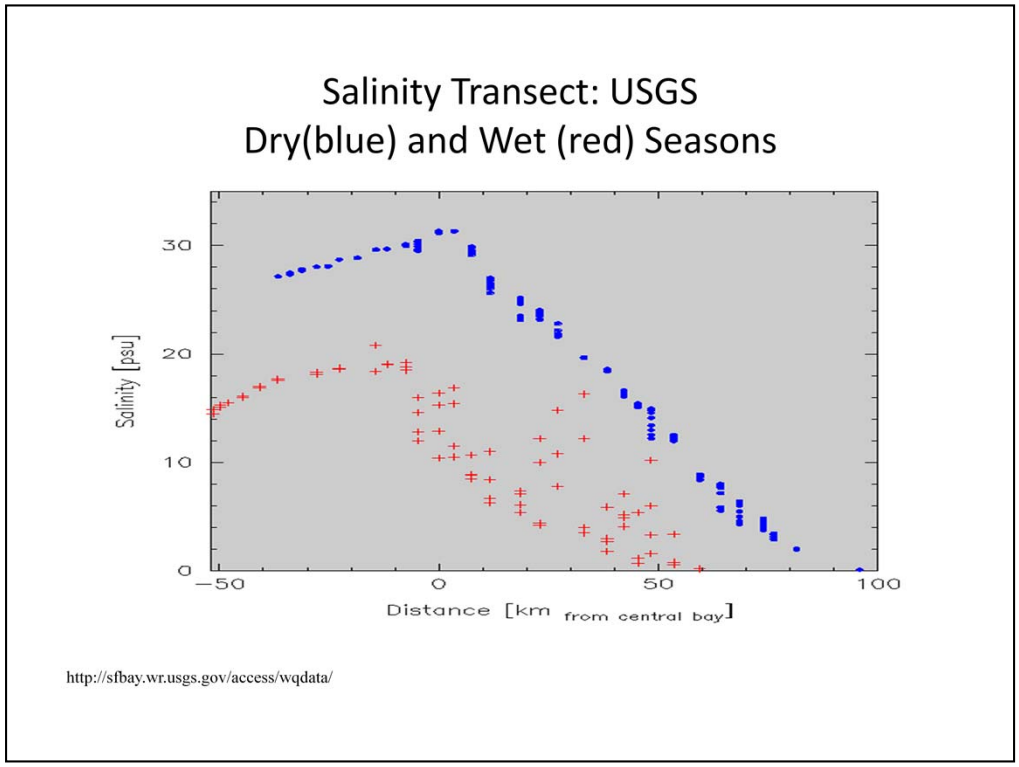
•Pumps Cause High Morality to endangers fish species, eg Delta smelt

Temporary water storage occurs at Clifton Court fore bay, before being shipped south at the Tracy pumps. Big issues on mortality of endangered species like the delta smelt

Water Quality

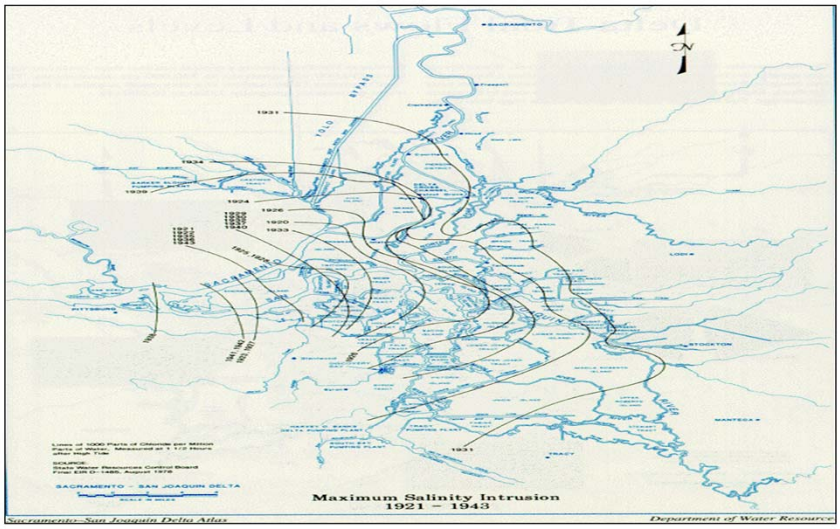
- Salinity/Tides/Inflow
- Herbicides
- Insecticides
- Selenium
- Suspended Sediments and Organic Matter
- Mercury
- Fertilizer
- Urban runoff, oil/grease
- Water diversion
- Irrigation runoff
- Boating/Recreation

Proper flows of water through the delta are paramount for maintaining water quality for a broad spectrum of consumers. This list give examples of factors degrading water quality



We are at the mouth of an estuary and this means there is connection to the sea, tides and salt. Here we see the gradient of salt during the wet and dry seasons. Salt intrusion comes way into the estuary during the summer

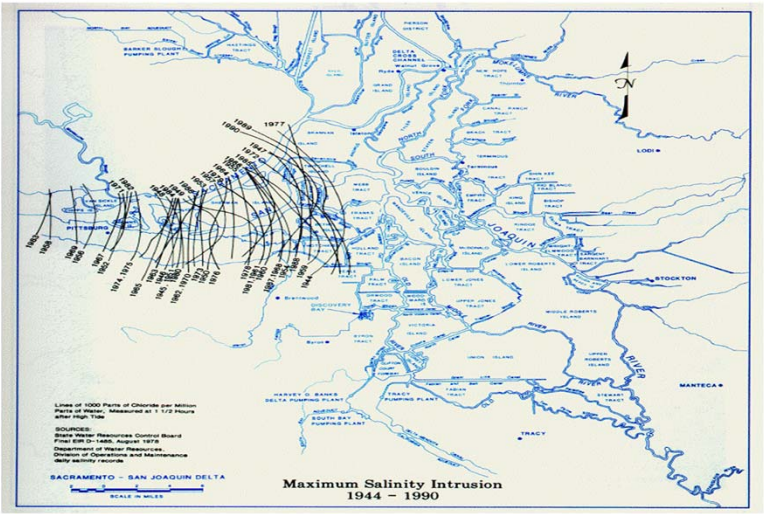
Water Quality:
Salinity Intrusion (1000 ppm, Cl) before Shasta Dam



Sacramento-SanJoaquin Delta Atlas

Historically this ecosystem experienced wide swings in salt. Before Shasta Dam there were incursions of high saline water (1000ppm Cl) up to Sacramento..Salt is not good for irrigation. It reduces the osmotic water potential and stresses plants.

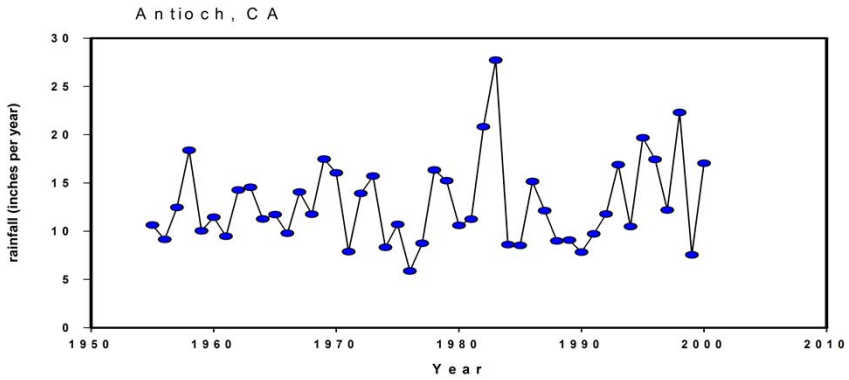
Salinity (1000 ppm, Cl) after Shasta Dam



Sacramento-SanJoaquin Delta Atlas

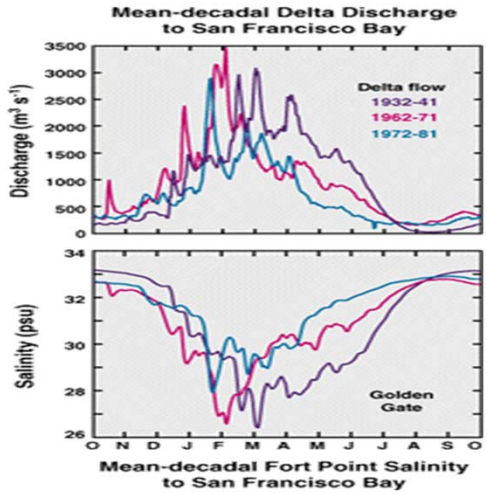
The Shasta dam has helped reduced the variability of the salt isopleths. Nevertheless salt can be high in the west delta during dry years

Region is Effectively a Desert, with NO Growing Season Precipitation



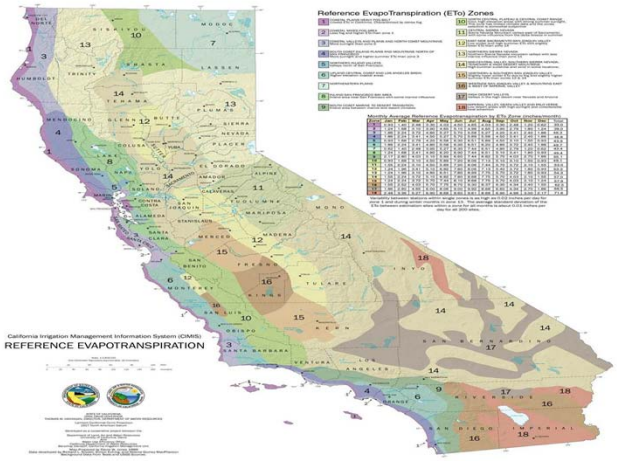
Inter-annual Rain Variability
mean: 12.8 in/yr (325 mm a^{-1})
range: 5 to 30 in/yr
Summer Rain: ~0

Spring Discharge and Salinity



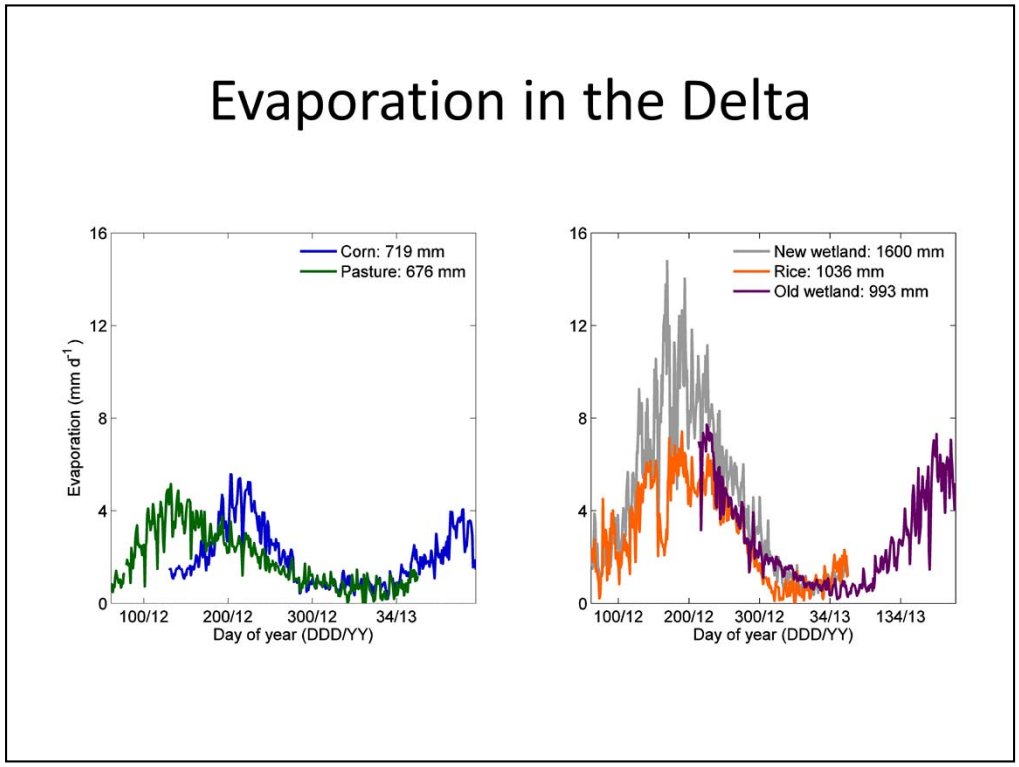
http://sfbay.wr.usgs.gov/access/Peterson/spring.html

Evaporation and California



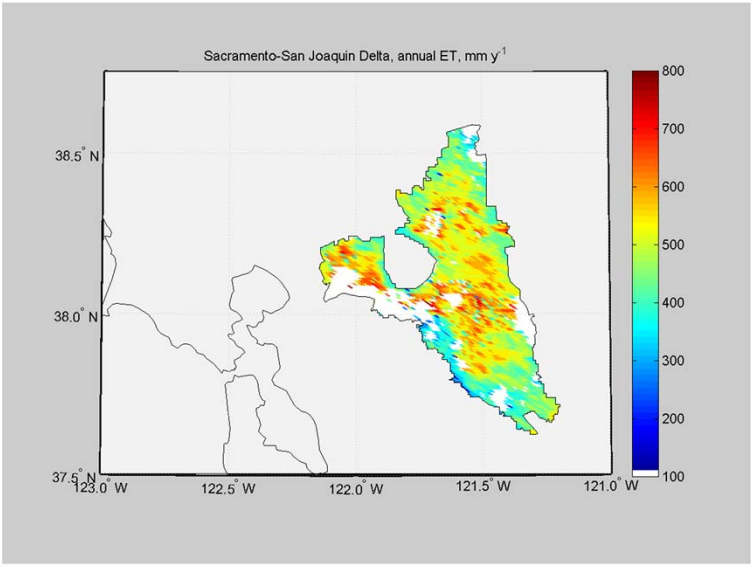
Potential ET in Delta is 57 inches or 1448 mm

The Delta is in a desert so its potential evaporation is huge, especially with irrigated vegetation which will evaporate at potential rates.



Examples of evaporation for crops and native wetlands. Wetlands and rice evaporate more than a meter of water. Nearly world record rates (>12 mm/d) of evaporation occurs during the summer over the tule wetland. So there is a water cost to restoring wetlands, too..

Annual Evaporation from Legal Delta at 1 km Resolution



Annual ET = 1.37 million acre-ft = 1.69 10^9 m^3/y

Map and Model: Y Ryu and D. Baldocchi

One of our tasks is to use models and remote sensing to upscale our evaporation measurements. Here is our budget of water use by the Delta.

Levees and Sustainability of the Delta

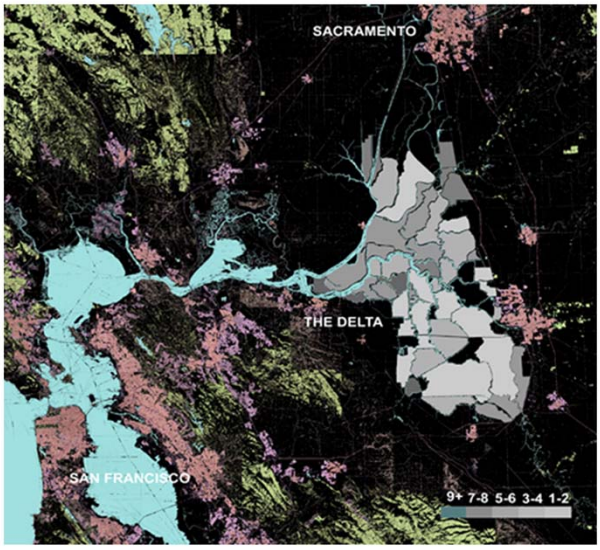
(California Department of Water Resources)

The Delta has a long history of failed levees

Jones Tract Flood
June 3, 2004

Jones tract failed on a calm summer day. It is not only storms, earthquakes and critters that cause levees to fail. Levess are starting to suffer from the fact that subsidence is cause water to channel under the levees and cause boils and wet spots on the islands.

Incidents of Flooded Islands



Nearly All Islands Have Flooded, Many up to 8x

Many of the islands have failed at least once, and many multiple times. In my lifetime I have seen Sherman, Brannan and Jones tract fail

Levees

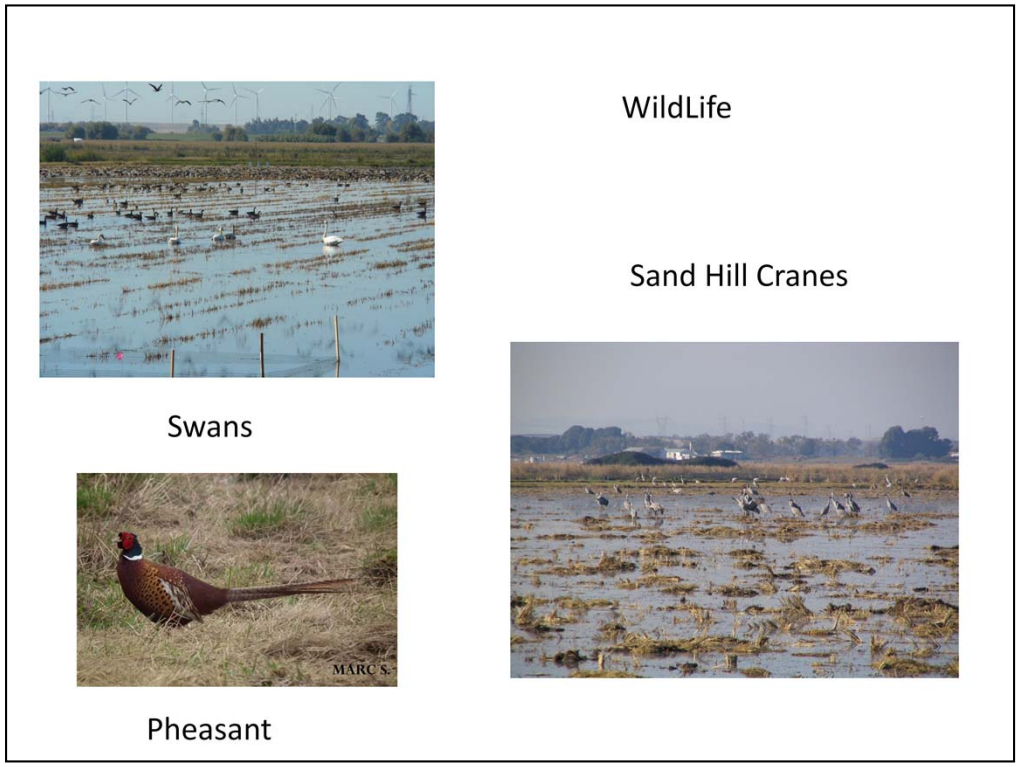
- Expensive: Maintenance $10k to $100k per mile!
  - $100 Billion to Reinforce and reclaim Delta
- Poor Construction material: Peat
- Vulnerable: Erosion Pressures by River Flow, winter rains/Tides, Burrowing animals, Earthquakes
- Who should be responsible for Maintenance?
  - Public/Private?

Levees are expense to maintain, but they need to be protected to keep salt water from intruding and disrupting the water transport/delivery system

Reasons to Maintain Levees

- Transportation corridor
- Water Quality and water flow
- Agricultural Protection
- Recreation
- Infrastructure, route for gas and electric transmission
- It will be impossible to reclaim wetlands on Flooded Islands, Water column will be too deep

Reasons to maintain the levees



Wildlife. One of the reasons I love the delta

Winter Quarters for Pacific Coast Migratory Flyway

- 400k to 650k water fowl and migratory birds use the Delta annually
- Bird Population has decreased 75% since 1900.

http://www.abag.ca.gov/bayarea/sfep/reports/fact/delta.html

Major fly way

Wildlife

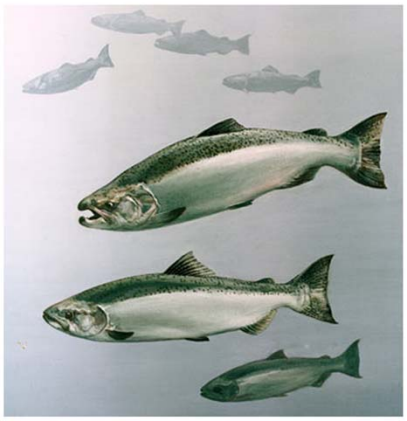
- Birds: 230 species
- Mammals: 45 species
- Fish: 52 species
- Flowering Plants: 150 sp
- Reptiles/Amphibians 25 sp
-
- Historic
- Tule elk, Bear

Endangered Fisheries

Fish

Winter-run Chinook Salmon, *Oncorhynchus tshawytscha* (SE,FT)
Sacramento Splittail, *Pogonichthys macrolepidotus* (FC)
Delta Smelt, *Hypomesus transpaciJicus* (FT, 4/93)
Green Sturgeon, *Acipenser medirostris*
Sacramento Perch (native population), *Archoplites inrerrup- tus*
Sacramento Blackfish, *Orthodon microlepidotus*
Hardhead, *Mylopharodon conocephalus*
Longfin Smelt, *Spirinchus thaleichthys*

Chinook Salmon



- Conditions in Waterways where Salmon Spawn
- Conditions in Delta where they Rear and Migrate
- Amount and Timing of Water Releases
- Loss of Habitat
- Water Diversions and Pumps
- Mine Drainage
- Ag Pollution
- Ocean Conditions
- Fishing Pressure

Low point 189 salmon 1994The precipitious drop in fall run Chinook salmon returns despite the unprecdented shut-down of the commerical fishing industry and improved ocean conditions strongly suggest that conditions in Central Valley waterways (where the salmon spawn) and the Delta (where they rear and migrate) play a major role in the population decline.

Invasive Species

Water Hyacinth, Clogs waterways

FIGURE 73. Patch of *E. crassipes* along the marsh fringe.

Trends in Invasive Species

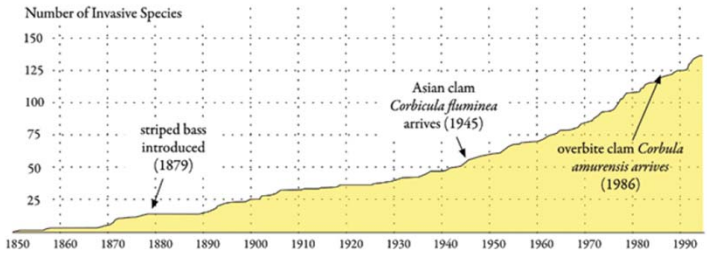


Figure I.1. The estimated number of invasive species in the San Francisco Estuary from 1850 to 1995. (Source: Adapted from Cohen and Carlton 1998)

State of Bay Delta Science, 2008

Range of Pepperweed

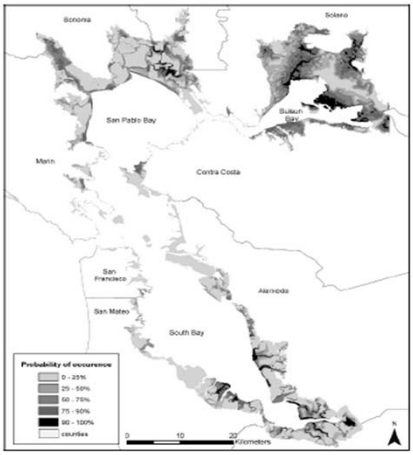


Figure 2. Probability of occurrence of perennial pepperweed within spatial extent I, San Francisco Bay, California.

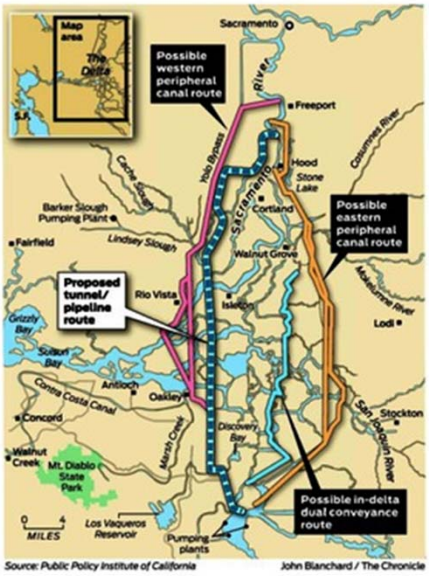
Vanderhoof et al 2009 Invasive Plant Sci Mgt

Managing the Delta

- Business as Usual
  - Agricultural is unsustainable as peat continues to oxidize
- Re-Enforce Levees
  - Encourages encroachment by Urbanization
  - Expensive and Levee Collapse is inevitable
- Isolate the Delta
  - Re-consider the Peripheral Canal; Use Conditionally; Bank Water during Surplus Flow
  - Ensures water quality, but does not solve other problems
- Abandon the Delta
  - Salt intrusion may stem invasive species.

What are we to do? Here are ideas being discussed

The Future?
A Delta Conveyance Tunnel, Peripheral Canal,
or Through Delta Routing?



Here is where it is important for you to become environmentally educated citizens. You will have to vote on issues that relate to projects like this Delta tunnel or canal. The peripheral canal was on the ballot in 1980 and failed. A form will be introduced again. Can we afford to let the delta become a septic pond if it is installed, or can we not afford to do anything and risk the health of the state and our economy if the Delta fails. These are the hard choices that are politically charged. I don't know the answer. My heart says no, my head says yes, toward installing a conveyance system.

Science Perspectives

- Delta is continually changing and subject to uncontrollable drivers
- We cannot predict all outcomes of management solutions
- Neither desirable or possible to ‘freeze’ Delta in its present state
- The capacity of the water system is at its limit
- Doing Nothing is Not an Option, as BAU Will Lead to a Collapse of the Delta and California’s Water Supply

These are some of the hard choices we face.

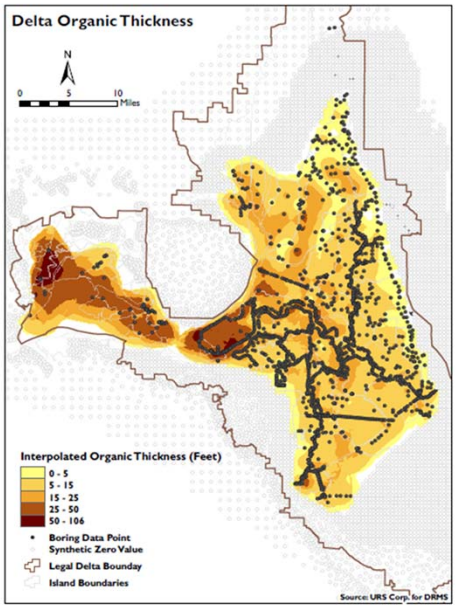
The Health of the Delta and SF Bay are Connected

SUMMARY OF BAY HEALTH, 2011	STATUS	TREND	DETAILS
WATER			
Safe for aquatic life	Fair	Improving	Bay water quality is better than 40 years ago, but the rate of improvement has slowed. Mercury, exotic species, toxic sediments, and trash are still problems, with improvement expected for exotics and trash. Many potentially harmful chemicals have yet to be assessed.
Fish safe to eat	Fair	No change	Limited consumption of most popular Bay fish species is advised due to contamination from legacy pollutants. No signs of improvement since 1994.
Safe for swimming	Good	No change	Most Bay beaches are safe for swimming in summer, but bacterial contamination is still a problem at most beaches in wet weather.
Freshwater inflow	Poor	No change	Amounts and variability of freshwater inflows have been reduced, resulting in chronic drought conditions for the Estuary. Flow conditions have been predominantly poor for the last 10 years, with the Freshwater Inflow Index at a record low level in 2010.
HABITAT			
Estuarine open water	Fair to poor	Deteriorating	Quantity and quality of springtime habitat is declining. Since the 1980s, habitat conditions have generally been poor in all but wet years.
Baylands	Fair	Improving	Historic decline has ended; gradual restoration underway; there is a long way to go.
Watersheds	Fair	No change	Watersheds are largely stabilizing after damage from historical land use changes; monitoring in more watersheds is needed to improve assessment of status.
LIVING RESOURCES			
Fish	Mixed, mostly fair	Deteriorating	Fish abundance and diversity are declining in all regions of the Bay except near the Golden Gate. The fish community is in poor condition in Suisun Bay.
Shrimp/Crab	Good	Improving	Most shrimp and crab populations are increasing, but ocean species dominate in the Bay. The abundance of Dungeness crab juveniles fluctuates widely, but Bay shrimp are generally stable.
Birds	Mixed, mostly fair	Trends mixed	Some populations are increasing, some are static, and some are declining, with some earlier increases recently reversed. Tidal marsh birds are below desired levels. Reproductive success is generally low or has decreased since 1993.
ECOLOGICAL PROCESSES			
Flood events	Poor	Deteriorating	Dams and water diversions have cut frequency and duration of floods by more than half, reducing freshwater inflow variability and transport of sediment and nutrients to the Bay.
Food web	Fair	Deteriorating	Declines in reproduction of fish-eating birds suggest that less food is available.
STEWARDSHIP			
Individual/Community action	Fair	Improving	Active stewardship could be greater, but regional efforts appear to be increasing. Bay Area citizens are using water more efficiently, and we are gradually expanding our use of recycled water.
Management action (example)	Good	Improving	In-Bay disposal of dredged material has been greatly reduced since the Comprehensive Conservation and Management for the Estuary was adopted in 1993.

THE STATE OF SAN FRANCISCO BAY 2011 • v

And the Delta is connected to the state of the Bay.

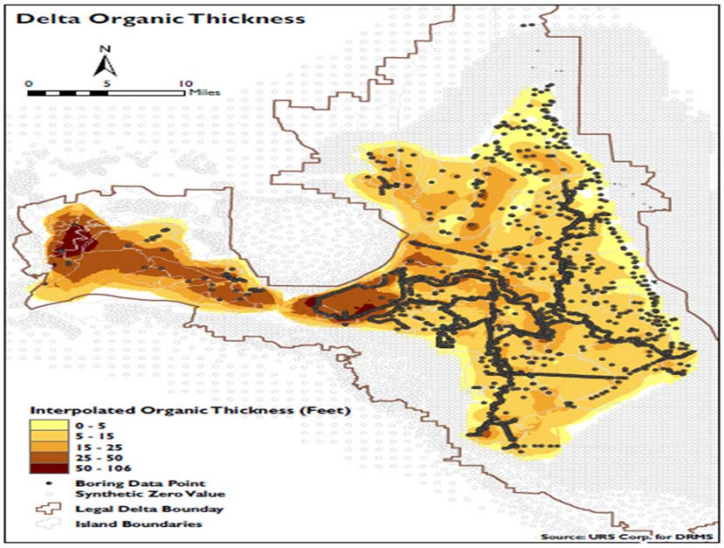
Potential C Sequestered or Lost in the Sacramento-San Joaquin delta over the Holocene
C = Area times Depth times bulk density times C content
Area Primary zone = 765 mi^2 = 1983 km^2 = 1.983 e9 m^2
Depth = 10 m (a conservative estimate given there may be or have been 30 to 50 m of peat in places)
Carbon Content ~ 50 to 70% based on cores by Drexler at Twitchell Island in 1993. For ball park assume 60%
Bulk Density of deeper peat 0.18 to 0.29 g cm^{-3} or 180 to 290 kg m^{-3}
C = 1.983 e9 m2 x 10 m x 0.60 x 300 kg m-3 = 3.56 e12 kgC or 3.56 PgC
Delta may have taken up 2% of atmospheric C over the glacial interglacial period!



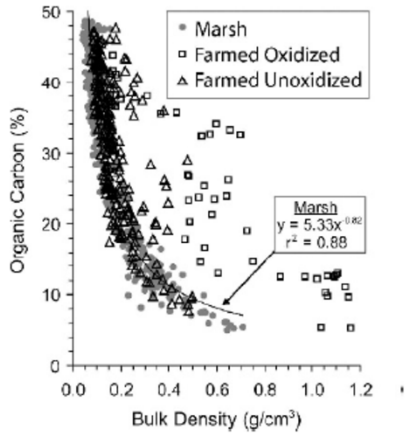
Brian Bergamaschi writes

Your calculation seems a bit high to me for the following reasons. First, the total original volume of peat in the Delta is calculated in the PPIC report to be 4.5e9 m^3, much lower than your volumetric estimate of 2.5e10. The OC content and bulk density you are using also seems a bit high - 30-50%OC is the range we see. So I would calculate a number about a factor of 10 lower than yours. It's still an astoundingly big number, though

Remaining Peat Thickness

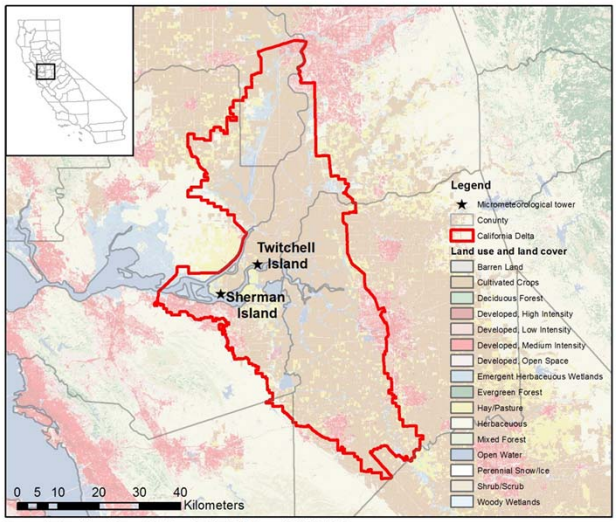


Bulk Density, C content and Land Use



Drexler et al 2009 Wetlands

Delta Land Use



Source: National Land Cover Database 2001; UTM Zone 10, NAD 1983

Agricultural Production

- Gross Annual Value: $500 Million
- Crops: corn, hay, sugarbeets, alfalfa, asparagus, tomatoes, fruits, safflower

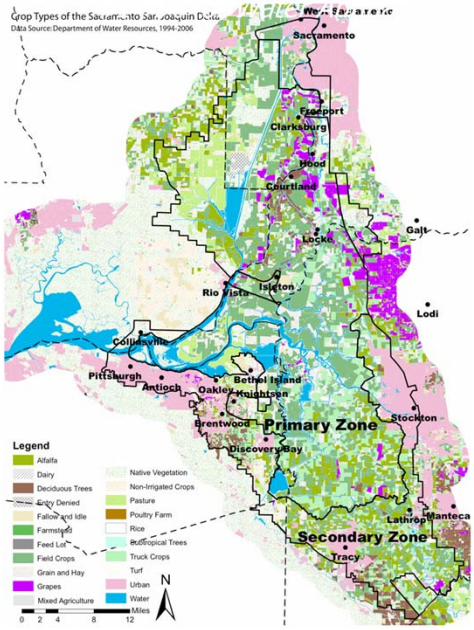
Agriculture
±500,000 Acres

Relatively low-value (and water-intensive) crops occupy most lands

Area

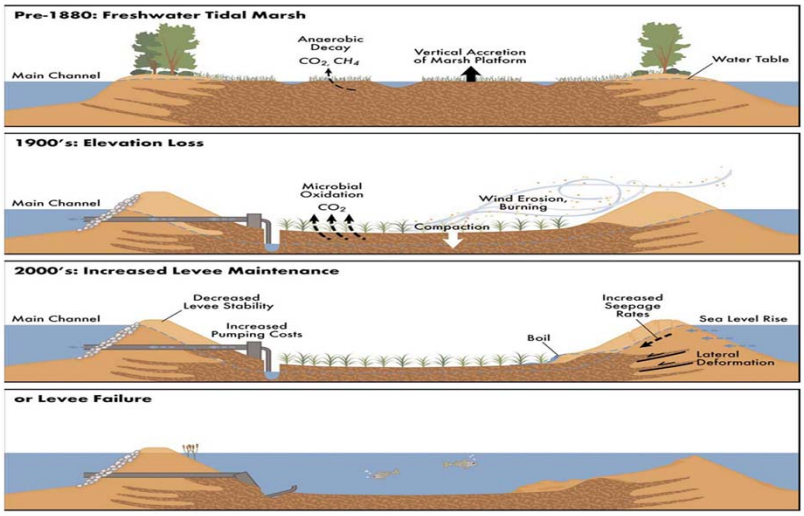
Value

- Field crops: ***corn, alfalfa, safflower***
- Truck crops: tomatoes, asparagus
- Tree, vine
- Pasture
- Nursery and seed



Bergamaschi and Fujii

Gains and Losses of Peat



Mount and Twiss 2009

Breaching Levees and Wetland Restoration?:

- Rebuilding intertidal elevations by breaching levees:
- 4 cm/yr, sub tidal habitats
- 1 cm/yr intertidal habitats
- Native tule will recolonate intertidal zones, invasives eg hyacinth will be pervasive in subtidal zones
- Occurrence and density of introduced fish will remain
- Vegetation restoration on deeply subsided areas may take 100 years
- Stagnant Wetlands PromoteMosquitoes, disease and methane
- Can’t Breach them Everywhere, only West Delta

Simenstad Breached Levee study

Mosiquitoes and diseases if there is restoration??

Where is the Delta?

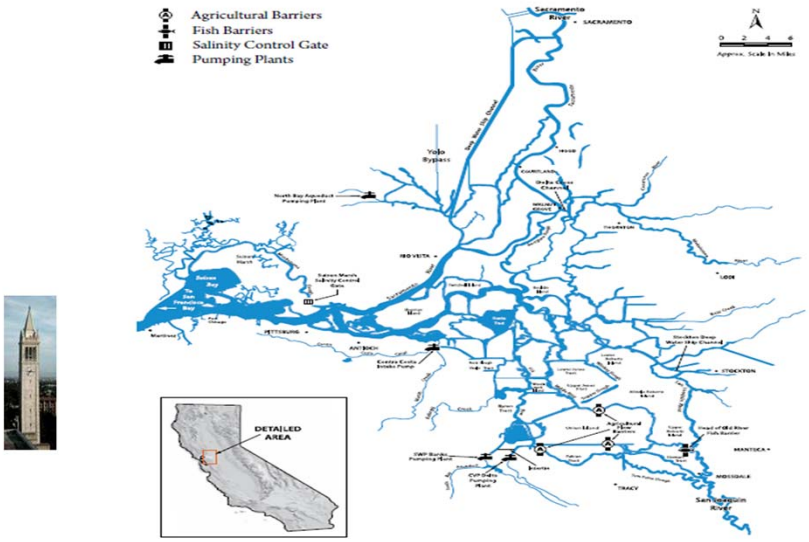


Figure 1.1. Map of the Sacramento-San Joaquin Delta (the Delta) showing major landmarks. (Source: California Department of Water Resources)

History

- Pre-Settlement
  - Native Americans, Miwok, Yokuts, Patwin
- Sited by Spanish 1772
- Gold Rush
  - 1849 first agricultural use
- Levees and Taming Floods
  - 1869 first levees on Sherman Is.
  - 1880-1916 Dredging and levee construction
- Water Supply, Quality +Exportation
  - 1933 Central Valley Project Authorized
  - 1940 Contra Costa Canal
  - 1943 Shasta Dam
  - 1951 Delta Mendota Canal
  - 1973 Calif Aqueduct
  - 1982 Defeat of Peripheral Canal
  - 1988 NorthBay Aqueduct/Suisun Salinity Control
- Restoring the Delta
  - CALFED, 2000
  - 2008 State of the Bay-Delta Science and Delta Vision Reports

?????Peripheral Canal????
A Plausible Solution or a Mechanism to turn
the Delta into a Cess Pool?

Now Do you Believe the Land has Subsided?