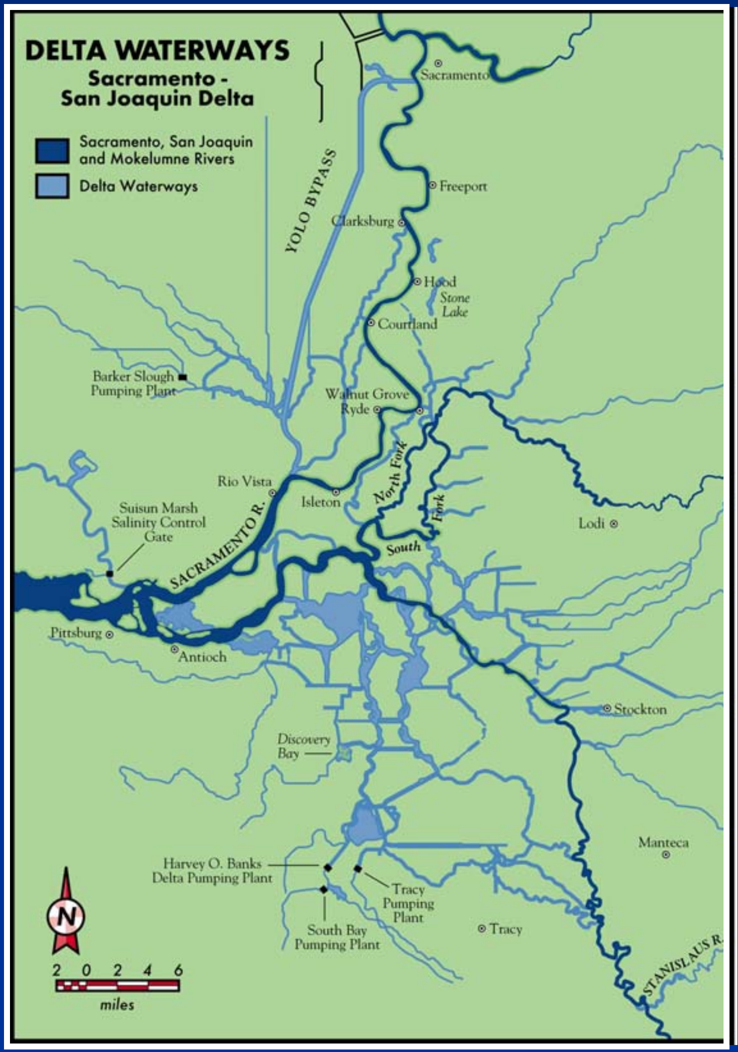
Subsidence, Seismicity and Sea Level Rise: Projected Impacts on the Delta*



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UC Davis

**this presentation does not represent the views of California's State Reclamation Board or Bay-Delta Authority Independent Science Board*

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- **Bob Twiss, Jack Keller** and CBDA Independent Science Board
- Resources: **NHI, PWA, NHC** and **USGS**
- Illustrations: **Janice Fong**, UC Davis

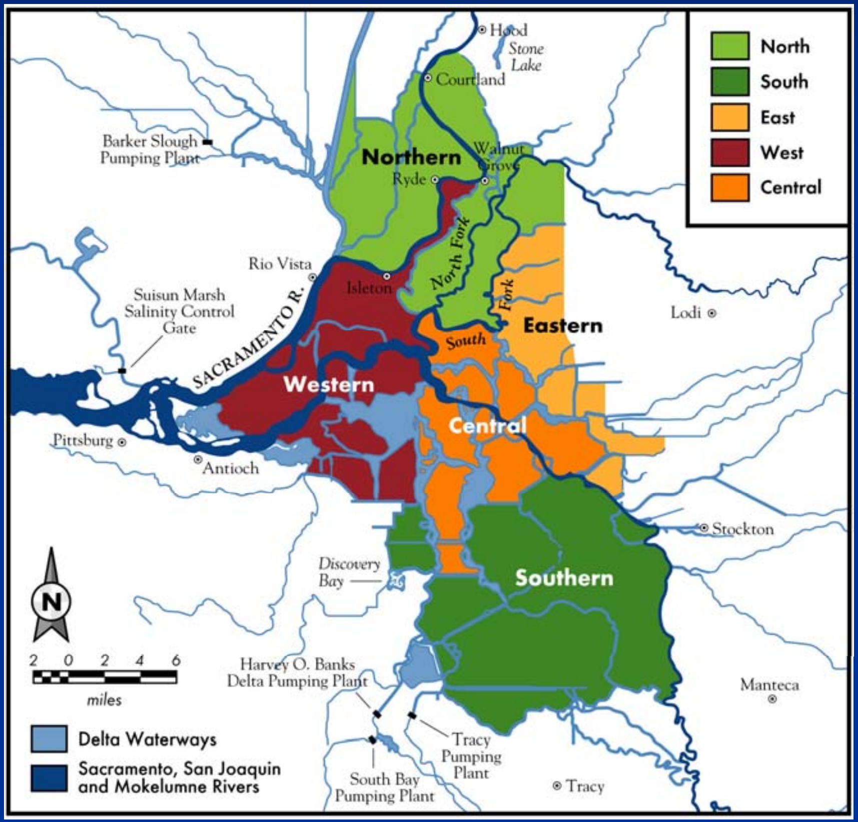
Old News Revisited as a Hypothesis

- The Delta is a dynamic landscape undergoing significant change at multiple scales
- Change will be considerable in the future due to continued subsidence and sea level rise
- There is a high probability that abrupt change will take place in the next 50 years
- There is no institutional capacity to respond to dynamic Delta landscapes

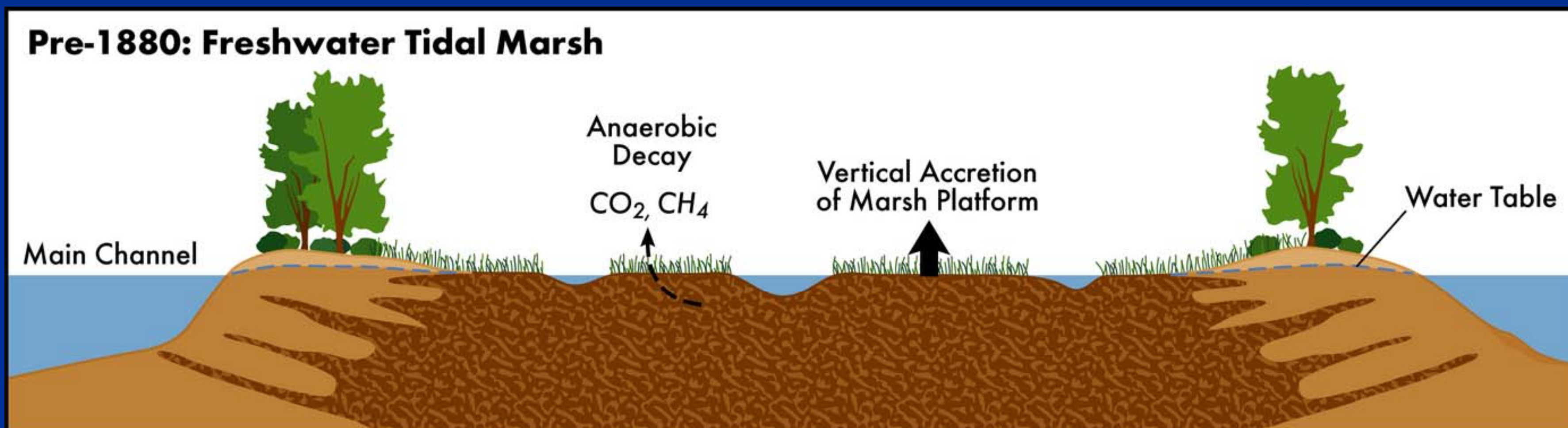
Static-Landscape Planning Initiatives

- Water Supply Reliability
- Drinking Water Quality
- Ecosystem Restoration
- Levee System Integrity

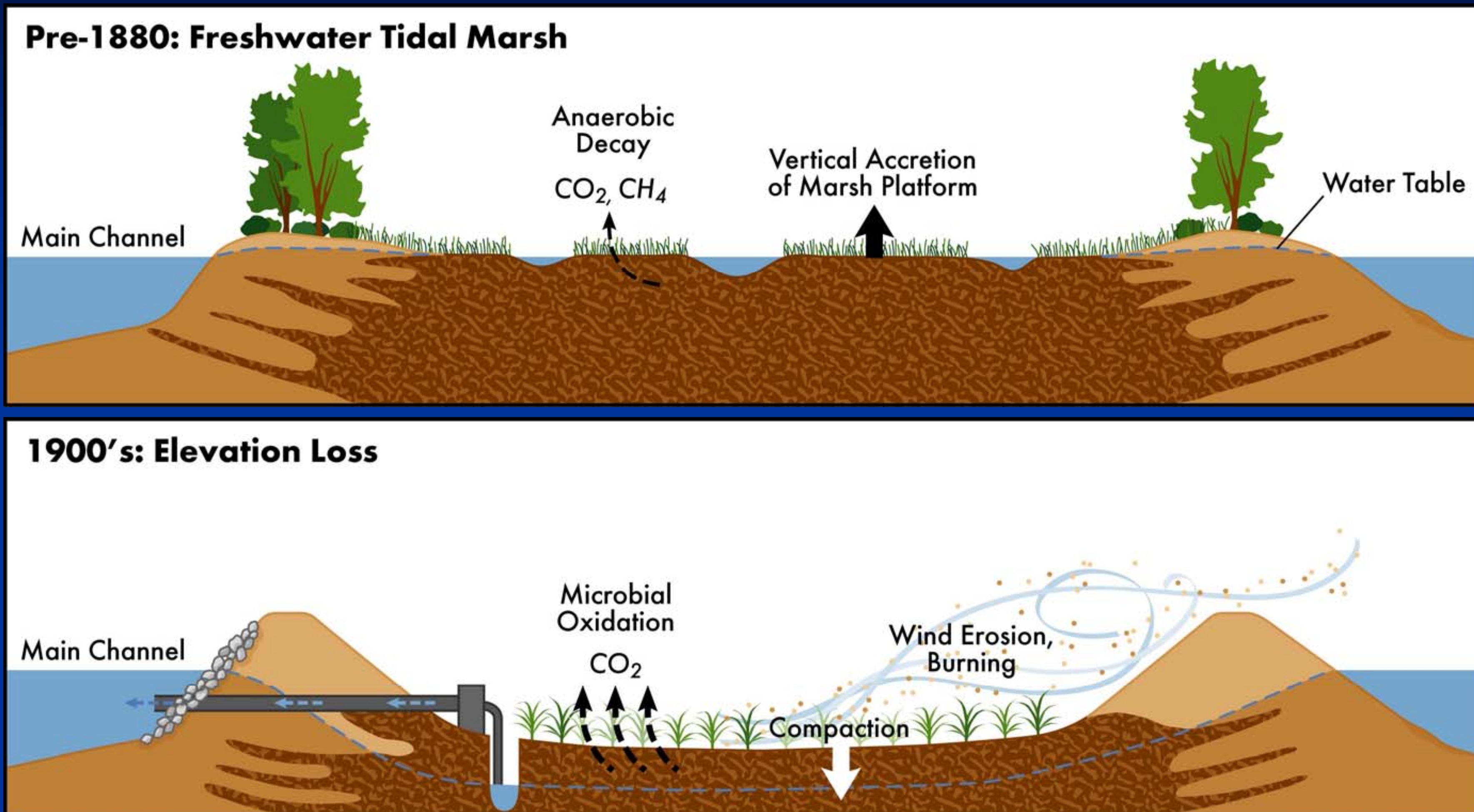
Delta Landscape Processes

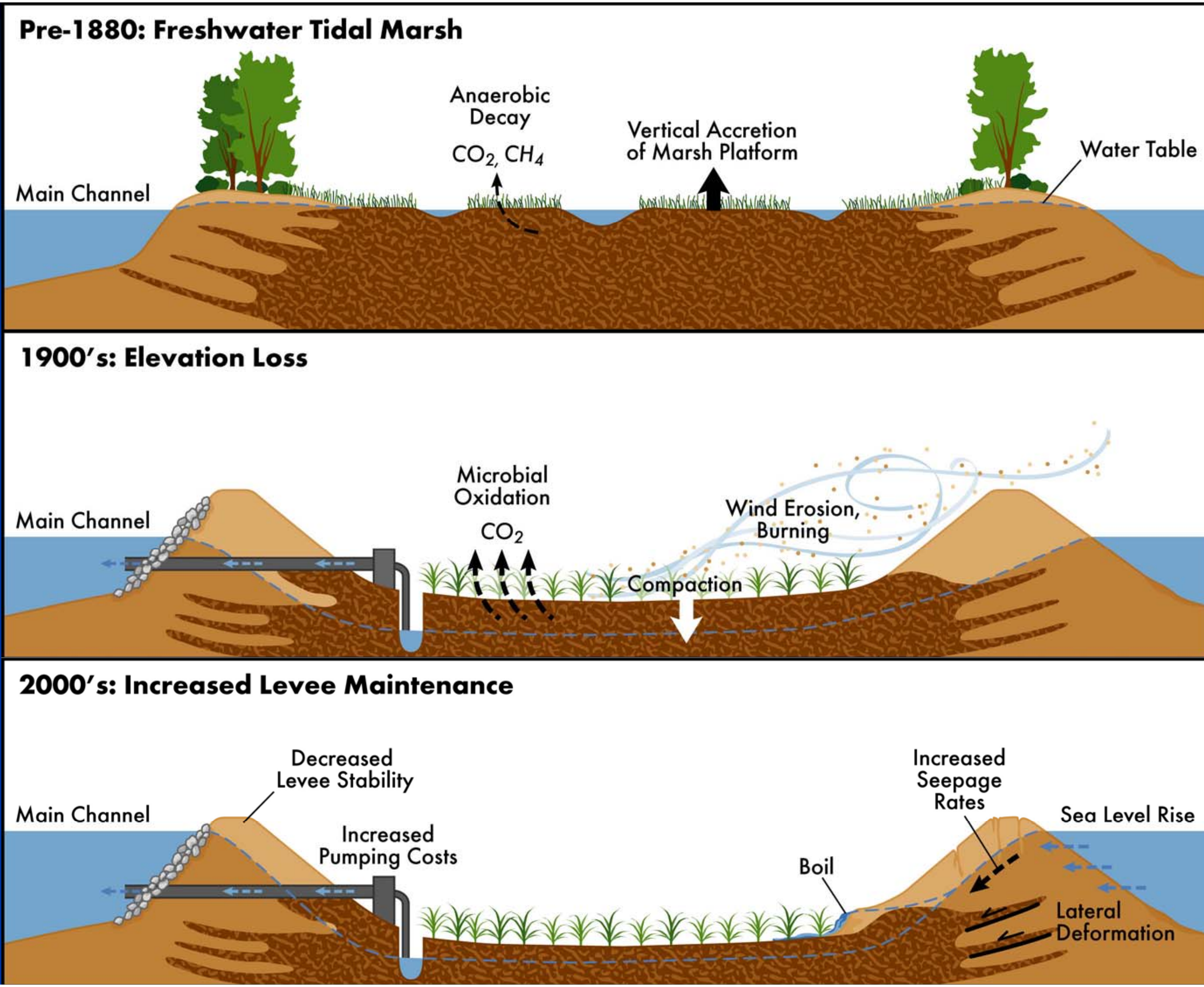


- Subsidence
- Sea Level
- Seismicity
- Sedimentation
- Climate Change
- Hydrology
- Land Use



Pre-1880: Freshwater Tidal Marsh
Anaerobic Decay
CO_2, CH_4
Vertical Accretion of Marsh Platform
Water Table
Main Channel


Pre-1880: Freshwater Tidal Marsh
Anaerobic Decay
CO_2, CH_4
Vertical Accretion of Marsh Platform
Water Table
Main Channel
1900's: Elevation Loss
Microbial Oxidation
CO_2
Wind Erosion, Burning
Main Channel
Compaction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CO_2, CH_4
Vertical Accretion of Marsh Platform
Water Table
Main Channel
1900's: Elevation Loss
Microbial Oxidation
CO_2
Wind Erosion, Burning
Main Channel
Compaction
2000's: Increased Levee Maintenance
Decreased Levee Stability
Main Channel
Increased Pumping Costs
Boil
Increased Seepage Rates
Sea Level Rise
Lateral Deformation

Indices of Change: Potential vs Consequent

- Anthropogenic accommodation space as a proxy for the consequence of landscape change
- Regional hydrostatic force as a proxy for potential levee failure

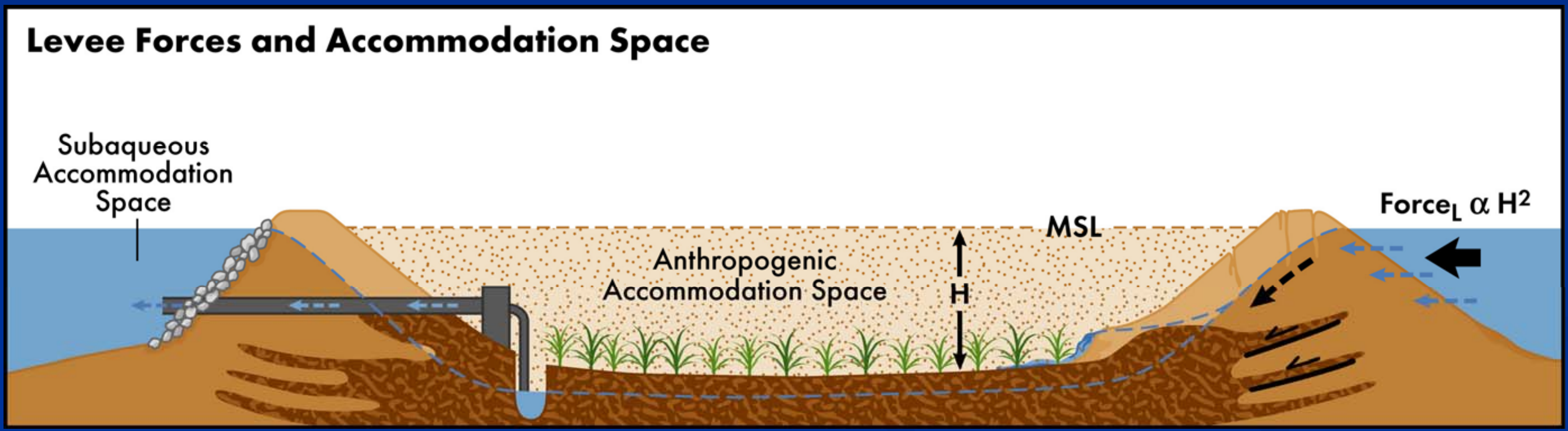
Accommodation Space Index

$$ASI = (A_s + A_a)/A_s$$

Where:

A_a = Anthropogenic Accommodation Space

A_s = Subaqueous Accommodation Space



Levee Force Index

$$LFI = CF_t/CF_{1900}$$

Where:

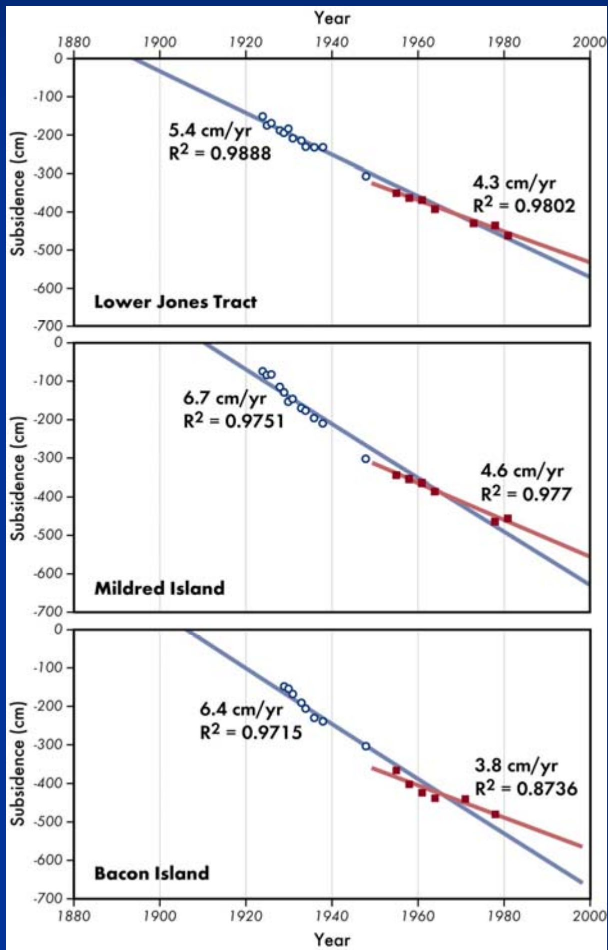
$CF_t = F_t$ x Levee Length

F_t = (hydrostatic pressure) x (depth x width) = Force/unit levee length

since $F_t = (.5\rho gH)(H \bullet b)$, then

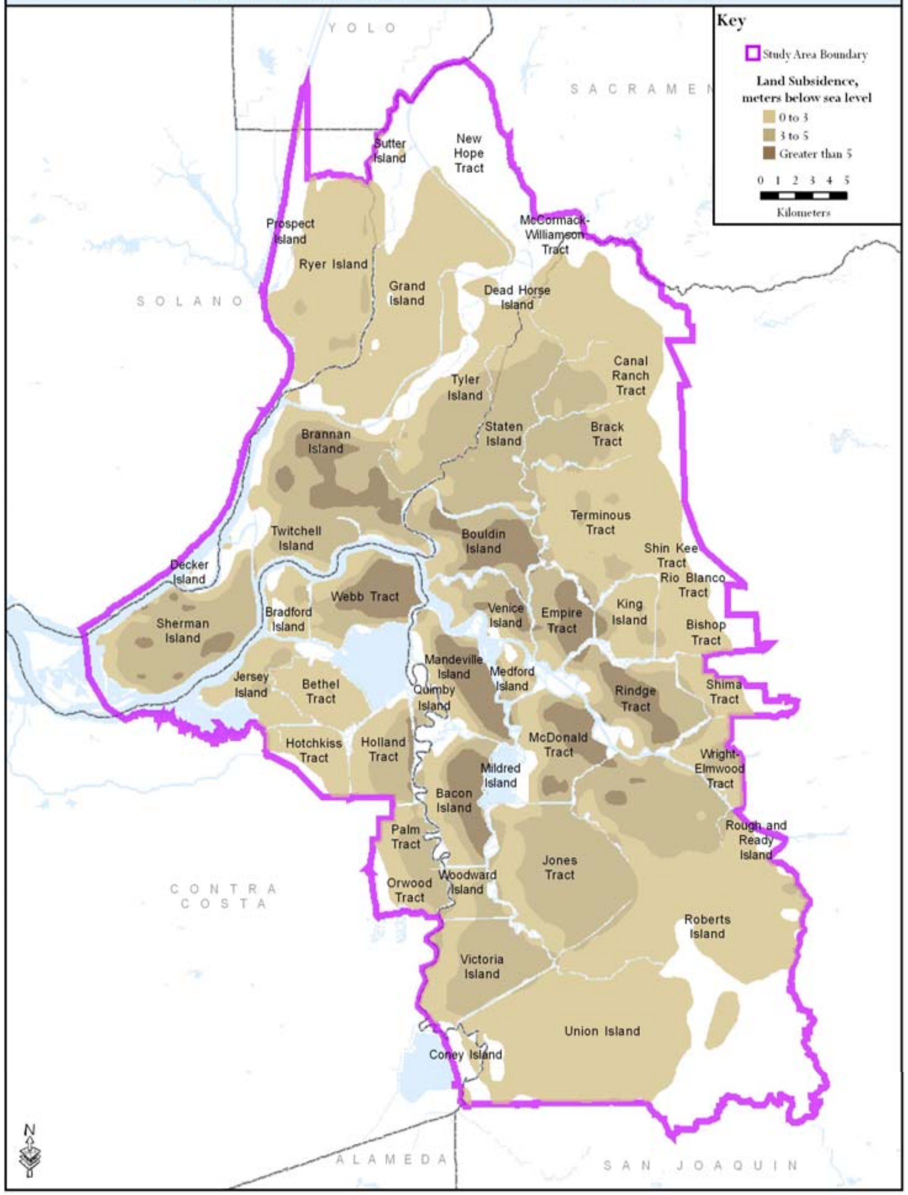
F_t is proportional to H^2

Methods: Simulations

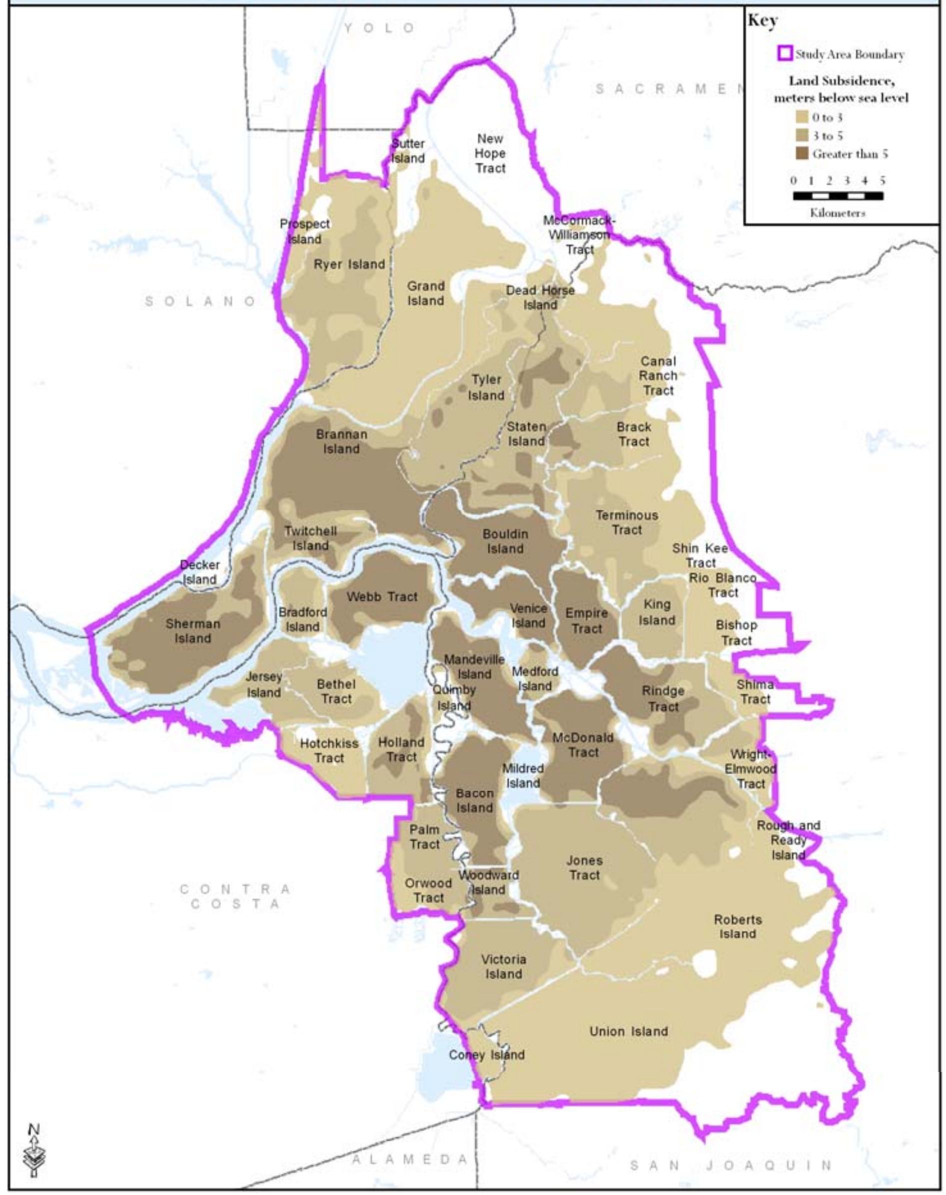


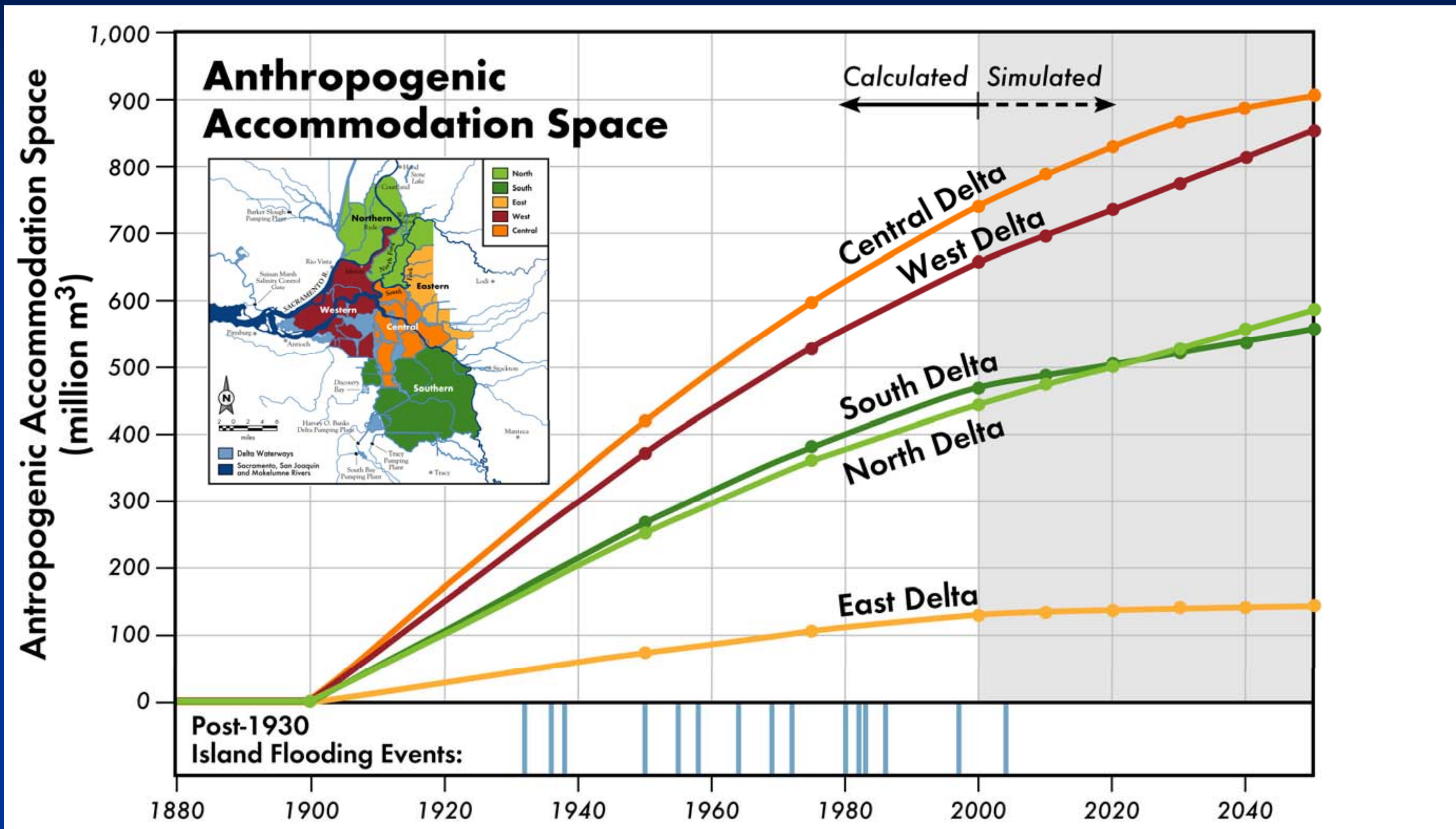
- Regressed 1920-1980 and post-1950 data (Deverel data)
- Estimate decline in subsidence rates on peat soils (conservative)
- Factored in IPCC sea level rise by 2050 (conservative)
- Assume business-as-usual conditions, simulated stepwise lowering of islands until base of peat layer encountered

TOPOGRAPHIC SETTING - YEAR 2000

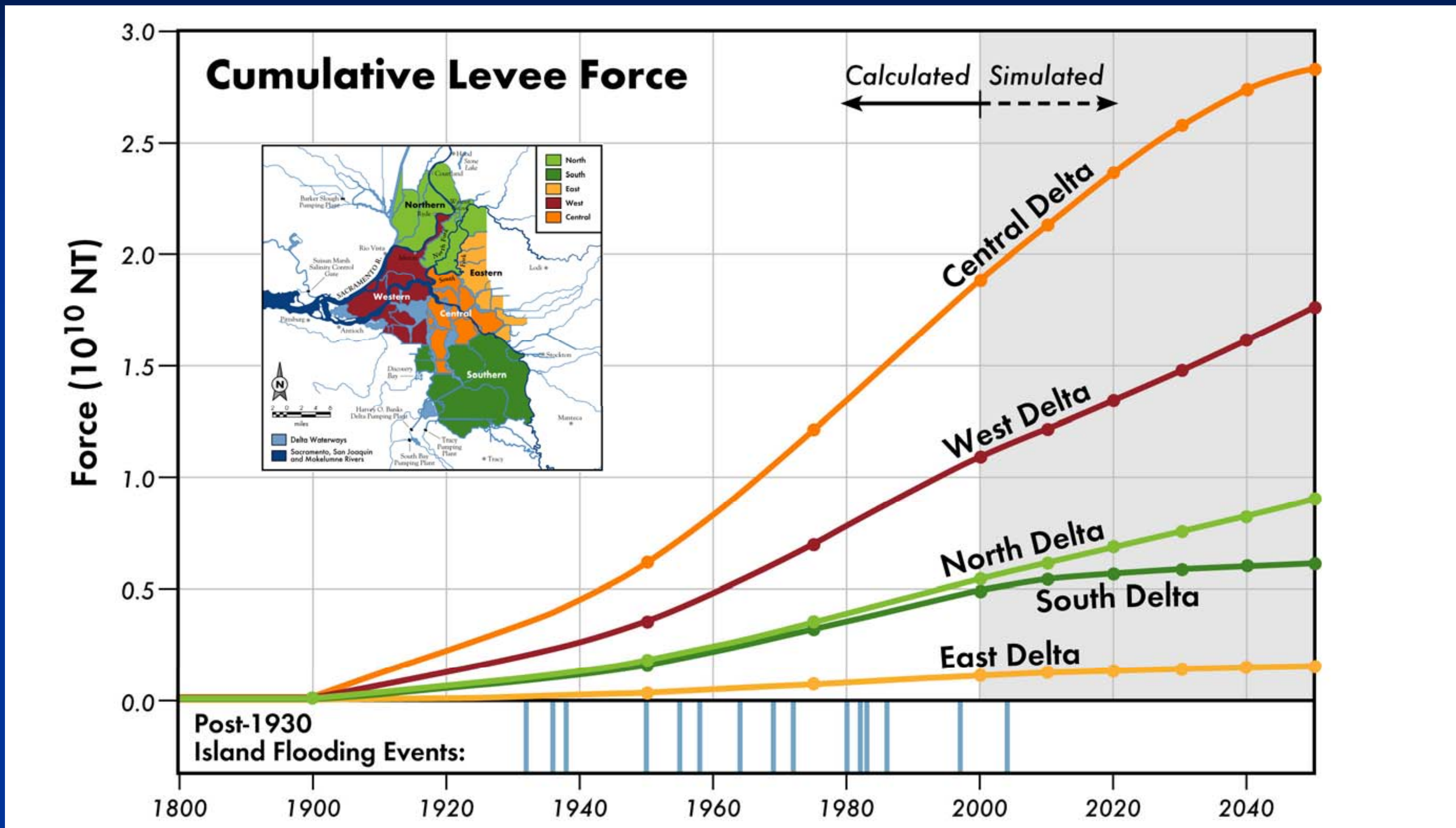


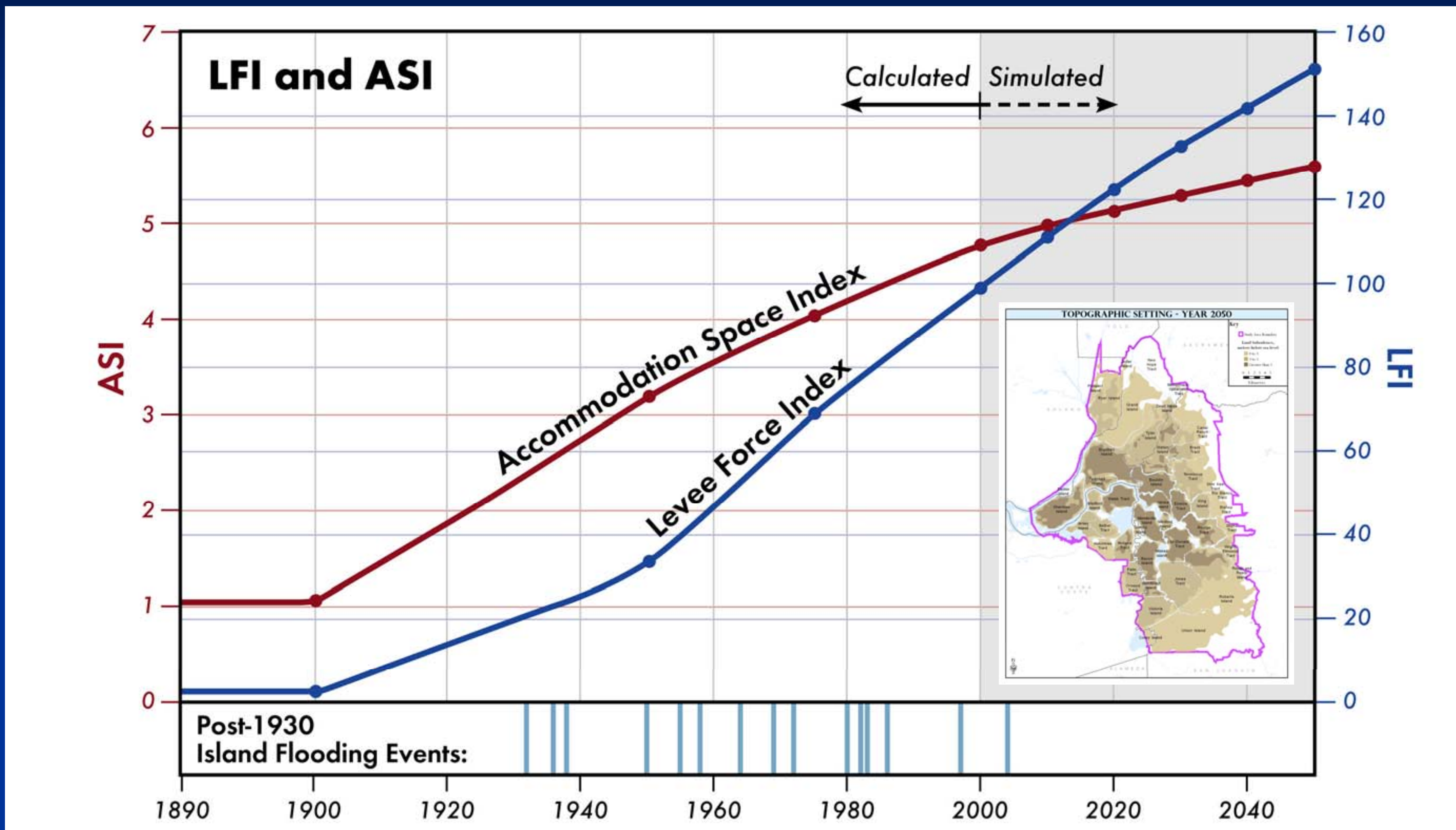
TOPOGRAPHIC SETTING - YEAR 2050



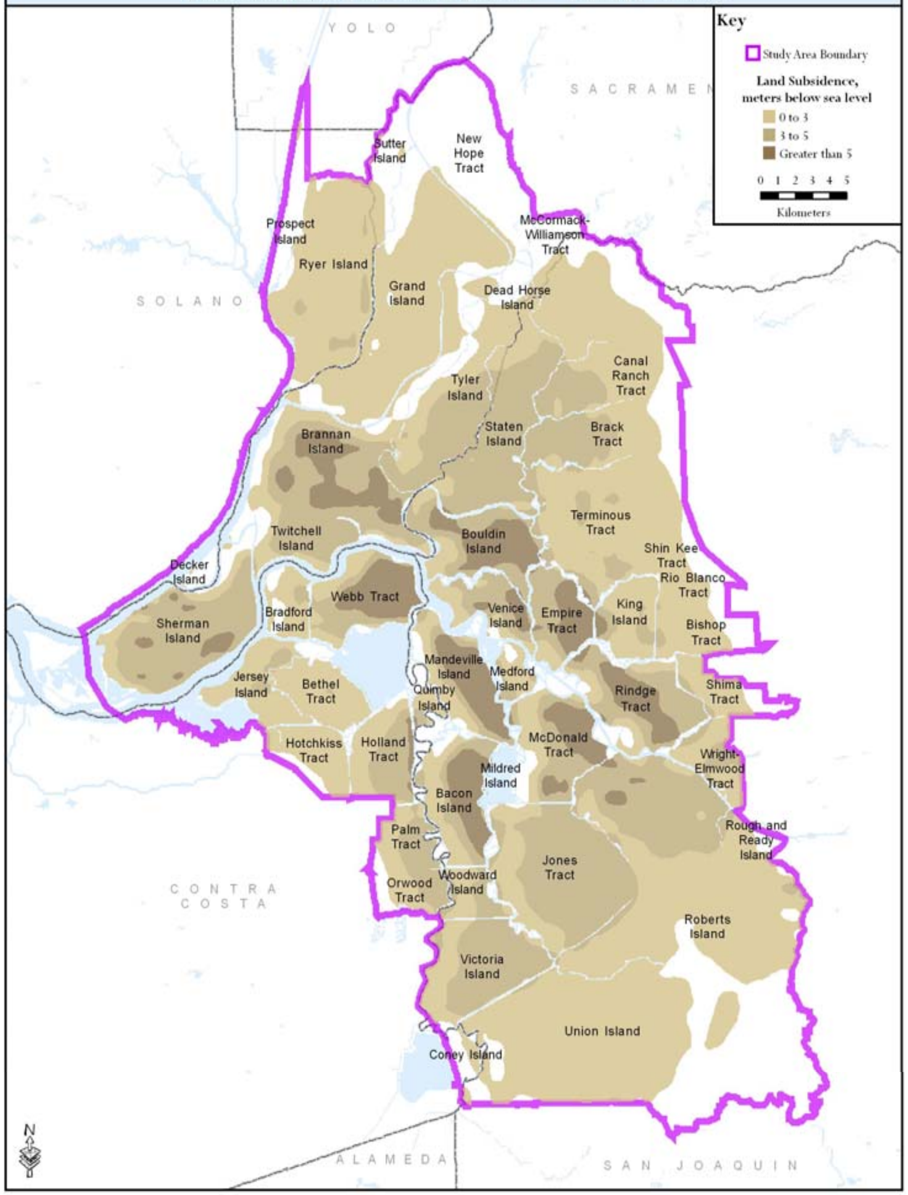

Anthropogenic
Accommodation Space
Calculated
Simulated
Central Delta
West Delta
South Delta
North Delta
East Delta
Antropogenic Accommodation Space
(million m3)
1,000
900
800
700
600
500
400
300
200
100
0
Post-1930
Island Flooding Events:
1880
1900
1920
1940
1960
1980
2000
2020
2040
North
South
East
West
Central
Northern
Eastern
Western
Central
Southern
Delta Waterways
Sacramento, San Joaquin and Mokelumne Rivers

- 2.5 Hydraulic Mining Eras worth of current space (Gilbert, 1917)
- 1500 years to restore existing space with current sediment loads (Schoellhamer, USGS), <u>but</u>
- Sea level rise <u>alone</u> creates almost twice the annual space that sediment is capable of filling
- Average daily increase of more than 27,000 m^3

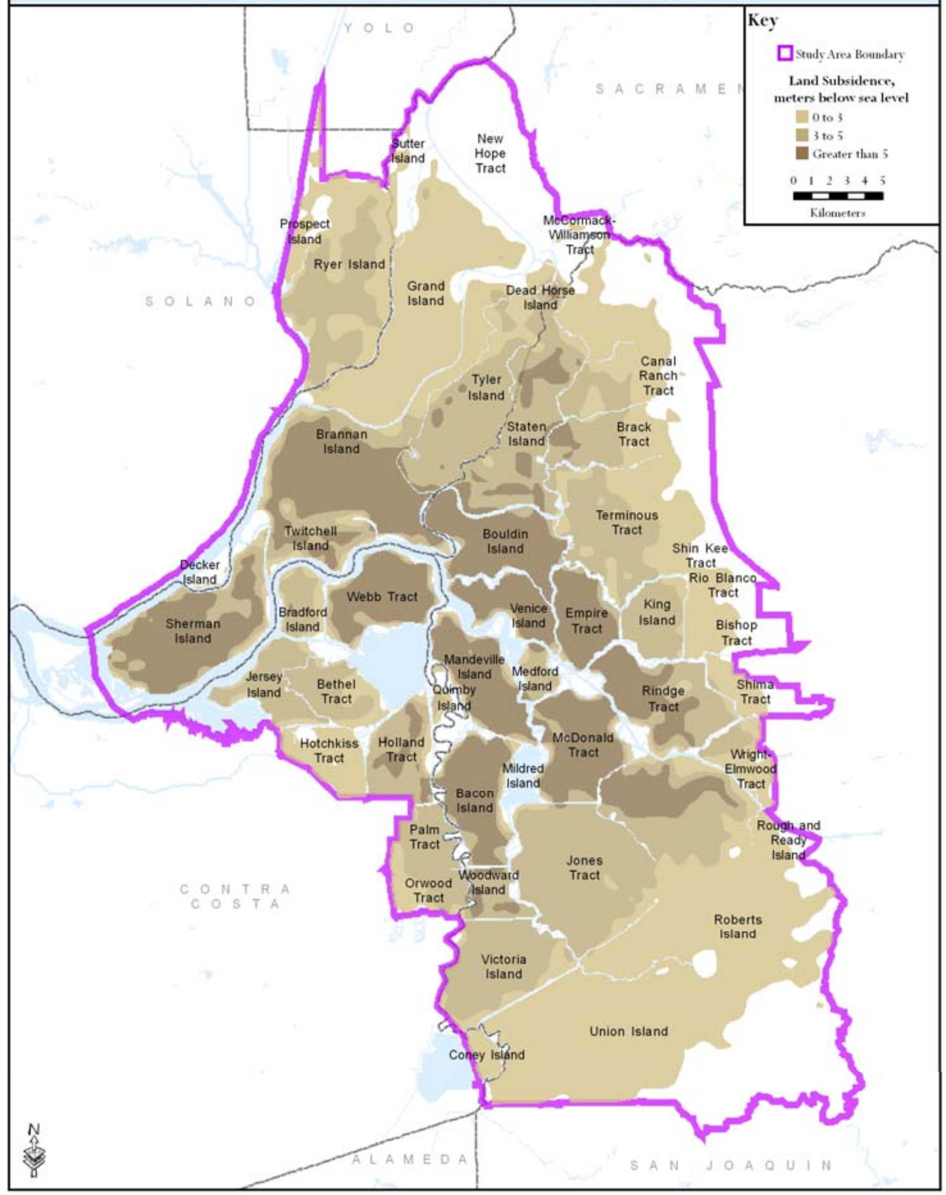

Cumulative Levee Force
Calculated
Simulated
Force (10^{10} NT)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Central Delta
West Delta
North Delta
South Delta
East Delta
Post-1930
Island Flooding Events:
1800
1900
1920
1940
1960
1980
2000
2020
2040
North
South
East
West
Central
Northern
Western
Eastern
Central
Southern
Delta Waterways
Sacramento, San Joaquin and Mokelumne Rivers


LFI and ASI
Calculated
Simulated
Accommodation Space Index
Levee Force Index
ASI
LFI
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
140
160
TOPOGRAPHIC SETTING - YEAR 2050
Post-1930
Island Flooding Events:
1890
1900
1920
1940
1960
1980
2000
2020
2040

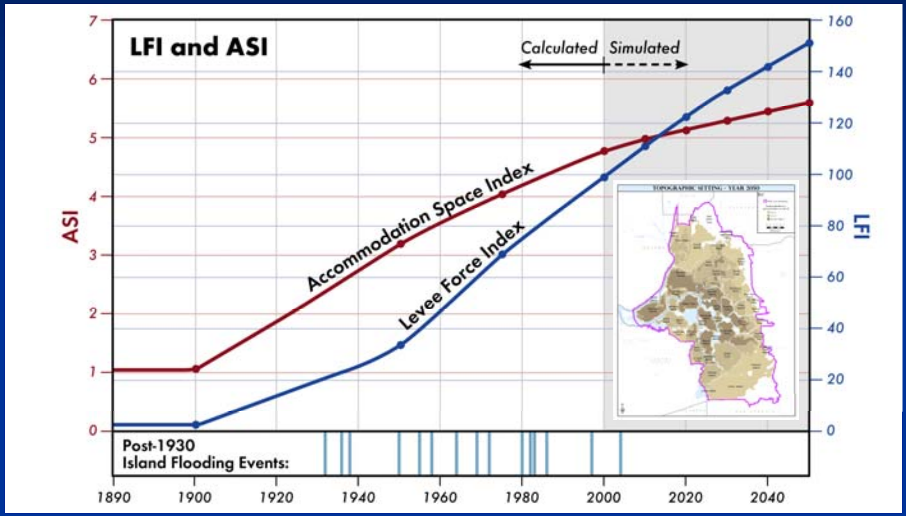
TOPOGRAPHIC SETTING - YEAR 2000



TOPOGRAPHIC SETTING - YEAR 2050



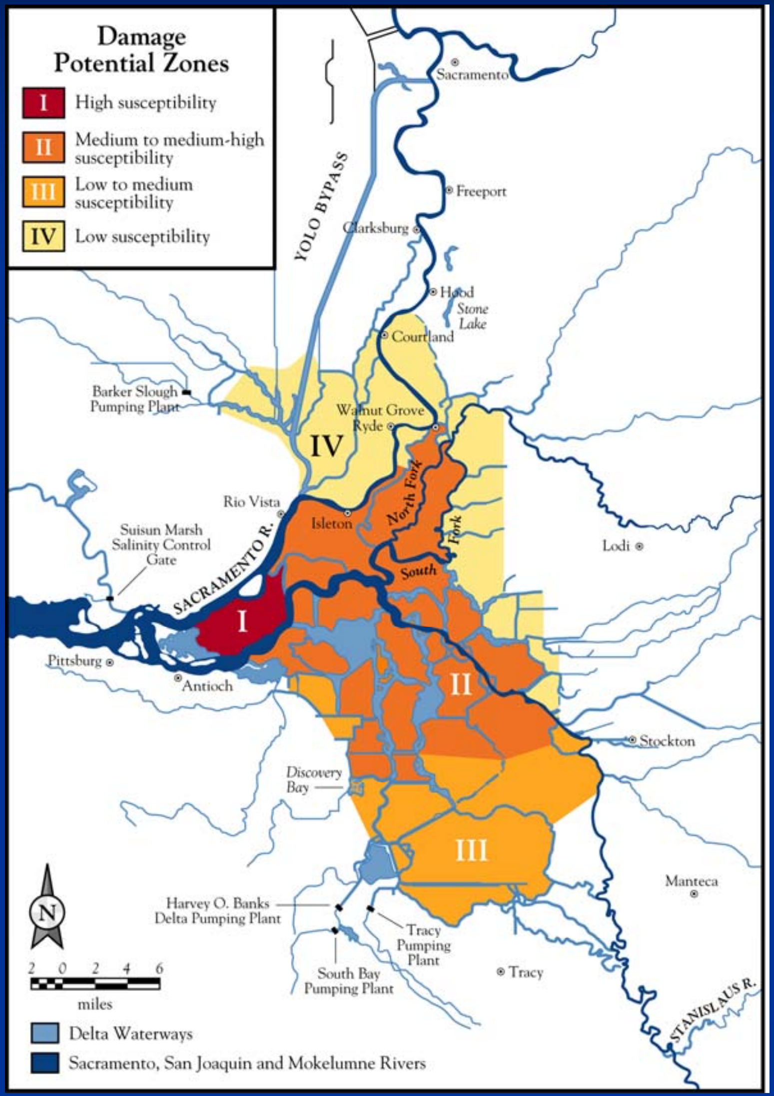
Gradual Landscape Change: Tendencies and Trajectories



- Continued accommodation space generation
- Significant increase in cumulative hydrostatic force on levees
- Increase in tendency for island flooding with unknown impacts
- $1B+ backlog in maintenance and upgrade to 1986 conditions

Gradual vs Punctuated Landscape Change

Abrupt Landscape Change



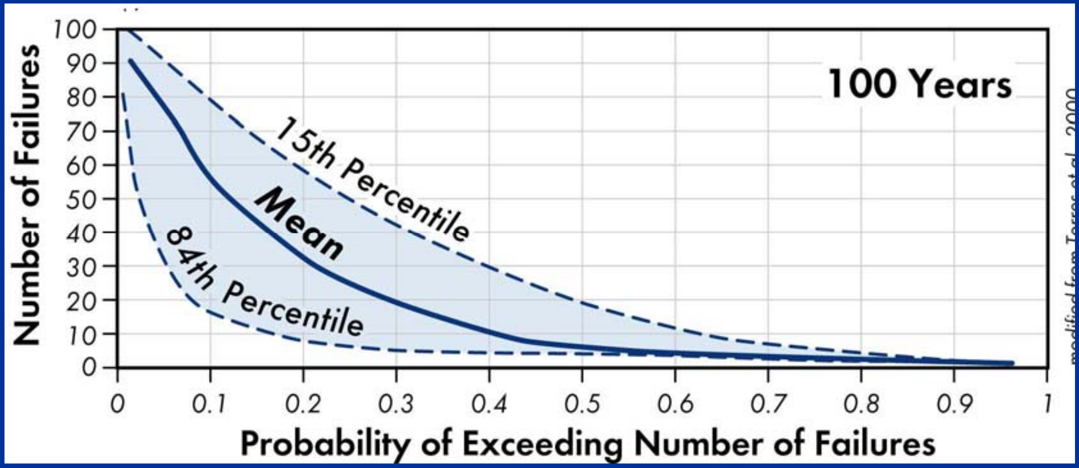
- Potential for significant island flooding during modest seismic events of >100-year recurrence interval (.01 exceedance probability)
- 5-20 levee segments fail due to substandard foundations and construction in 100-year seismic event
- 100-year recurrence interval flood capable of similar multiple levee failures over large region

Torres et al. (2000)

Abrupt Change in 50 Years: Remote or Real?

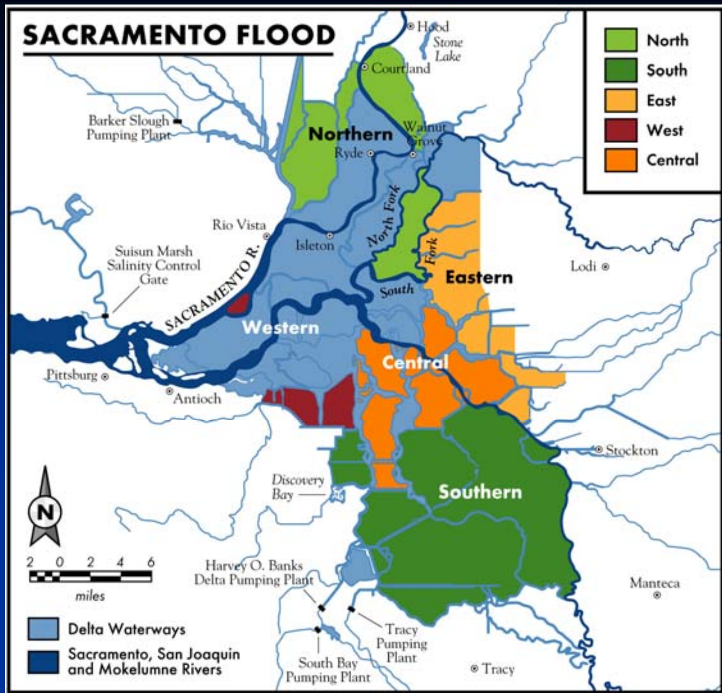
$$P = 1-[1-1/T]^n$$

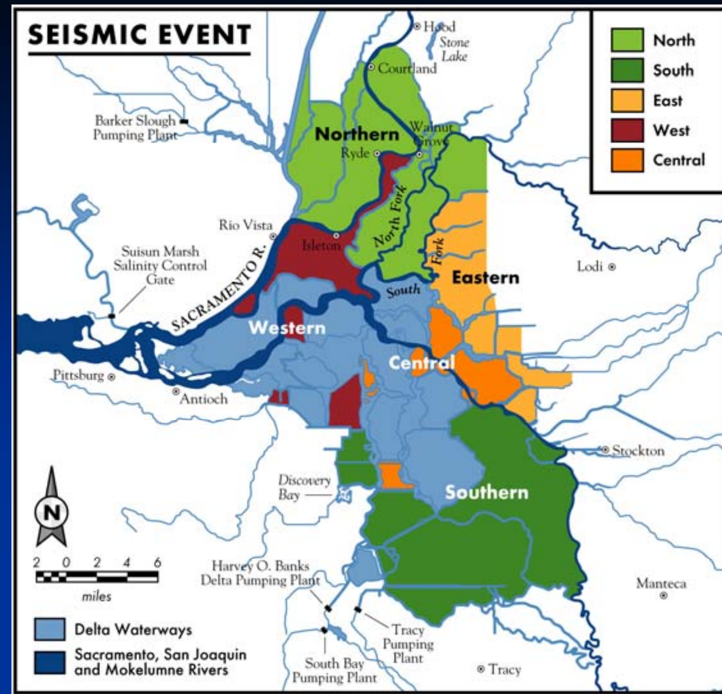
- 100-year earthquake = .40
- 100-year flood event = .40
- 100-year earthquake AND flood = .16
- 100-year earthquake OR flood = .64



Torres et al. (2000)

It is a 2-in-3 probability that abrupt change will occur in the Delta in the next 50 years


SACRAMENTO FLOOD
North
South
East
West
Central
Hood
Stone Lake
Courtland
Barker Slough Pumping Plant
Northern
Walnut Grove
Ryde
North Fork
Rio Vista
Isleton
Suisun Marsh Salinity Control Gate
SACRAMENTO R.
South Fork
Eastern
Lodi
Western
Central
Pittsburg
Antioch
Stockton
Discovery Bay
Southern
Harvey O. Banks Delta Pumping Plant
Manteca
Tracy Pumping Plant
South Bay Pumping Plant
Tracy
2 0 2 4 6
miles
Delta Waterways
Sacramento, San Joaquin and Mokelumne Rivers


SEISMIC EVENT
North
South
East
West
Central
Hood
Stone Lake
Courtland
Barker Slough Pumping Plant
Northern
Walnut Grove
Ryde
North Fork
Rio Vista
Isleton
Suisun Marsh Salinity Control Gate
SACRAMENTO R.
South Fork
Eastern
Lodi
Western
Central
Pittsburg
Antioch
Stockton
Discovery Bay
Southern
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South Bay Pumping Plant
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2 0 2 4 6
miles
Delta Waterways
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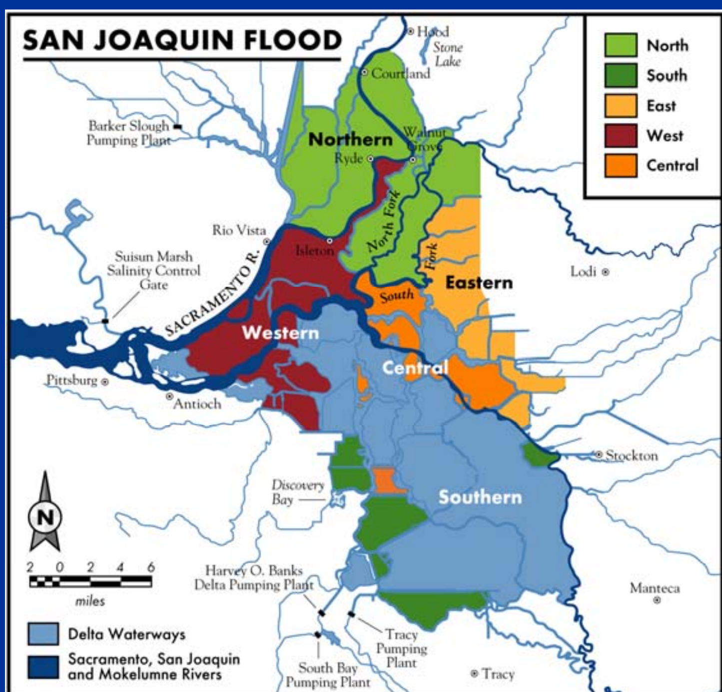
SAN JOAQUIN FLOOD
North
South
East
West
Central
Hood
Stone Lake
Courtland
Barker Slough Pumping Plant
Northern
Walnut Grove
Ryde
North Fork
Rio Vista
Isleton
Suisun Marsh Salinity Control Gate
SACRAMENTO R.
South Fork
Eastern
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2 0 2 4 6
miles
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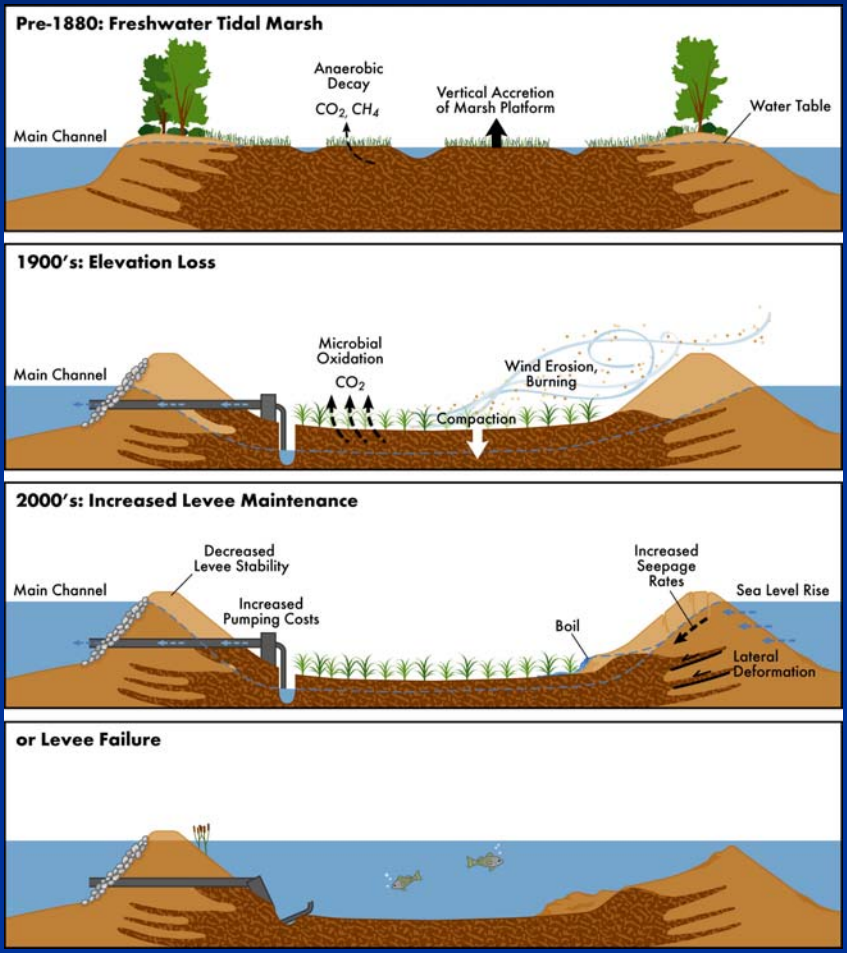
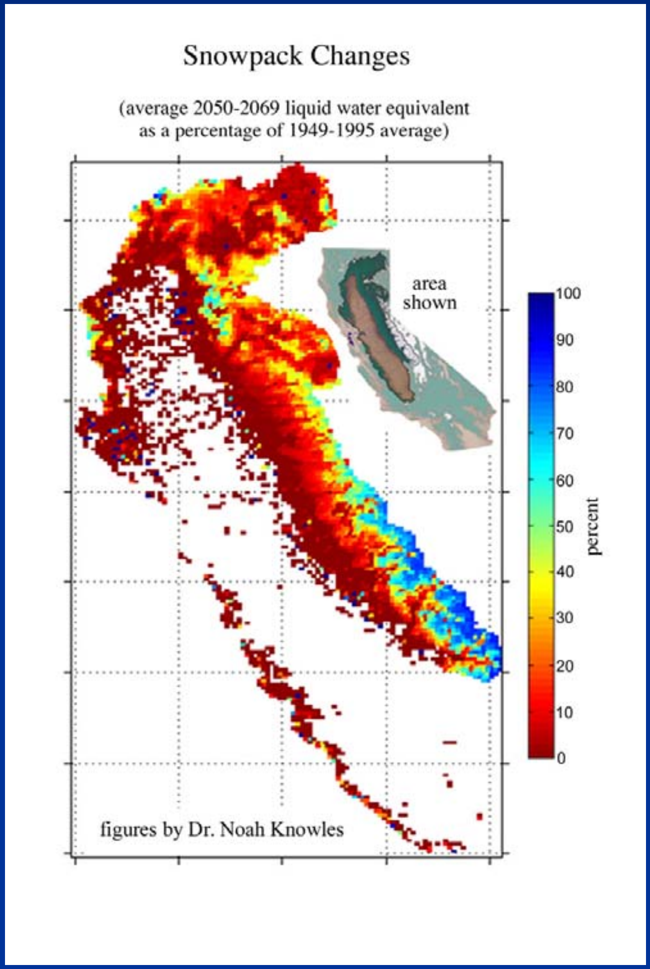
Punctuated Landscape Change



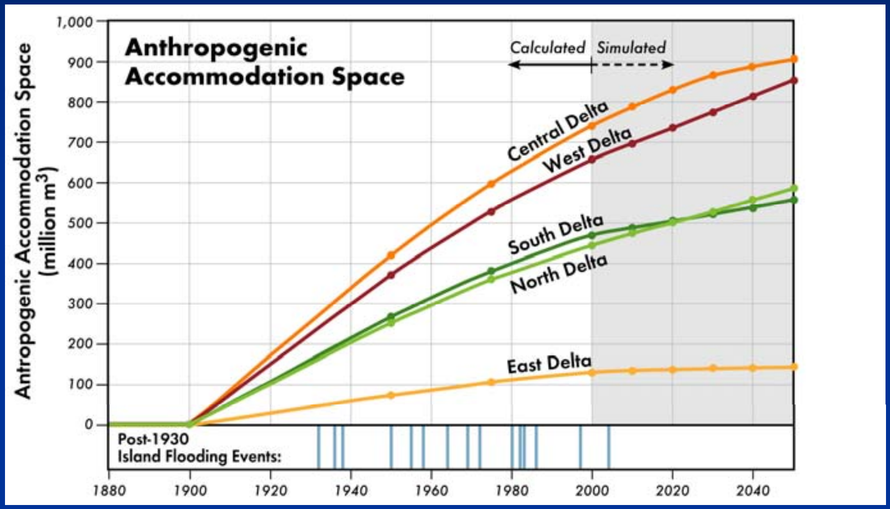
- Multi-billion dollar, multi-year disruption in water supply
- Loss of farms, existing habitats
- Self-accelerating island losses
- Conversion of the Central and Western Delta to subtidal estuary

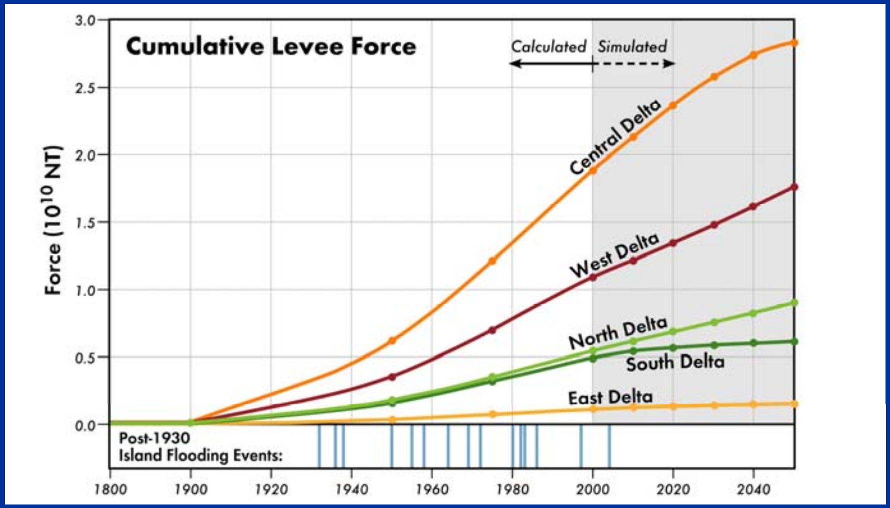
Conclusions



- Gradual landscape change a certainty; abrupt change highly likely
- Estimates here are <u>conservative</u> and do not reflect cascade effects or embedded thresholds
- Left out impacts of regional climate change, including higher temps and larger floods

Conclusions





- Increasing levee failures, with significant but unknown impact
- No economically feasible method to restore elevations
- Current planning remains predicated on a fixed, rather than dynamic landscape