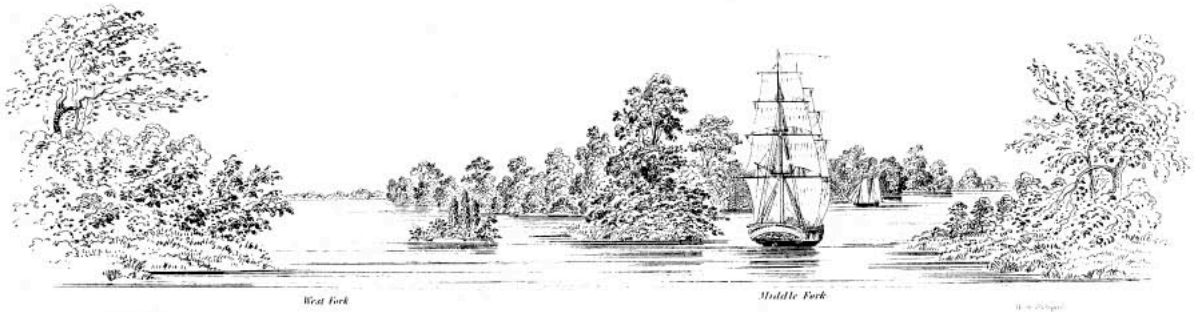
The Sacramento-San Joaquin Delta Levees: Past, Present and Uncertain Future

Marks for entering the Sacramento and its Forks at their confluence



Mark for entering the second section of the Middle Fork of the Sacramento River

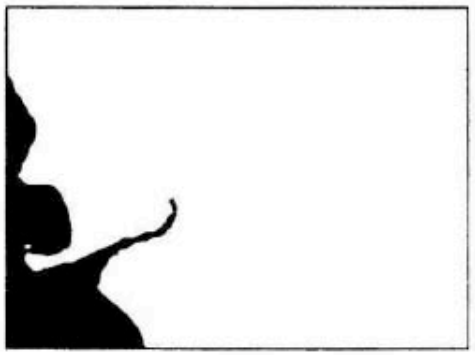
Jeffrey Mount, Jay Lund, Ellen Hanak, William Fleenor, William Bennett, Richard Howitt, Peter Moyle, Robyn Suddeth

Center for Watershed Sciences
UCDAVIS

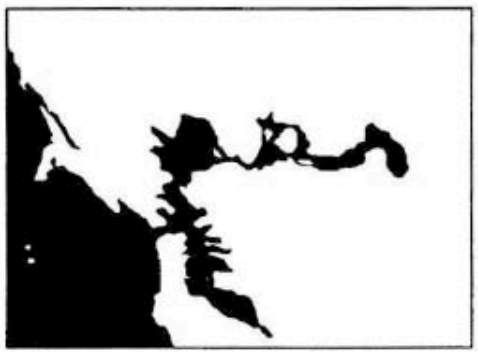
Delta of the Past

- 700,000 acre tidal marsh
- Mostly fresh water, with brackish water at western end
- A product of Holocene rise in sea level
- Extraordinary organic accumulations
- High hydrologic residence time

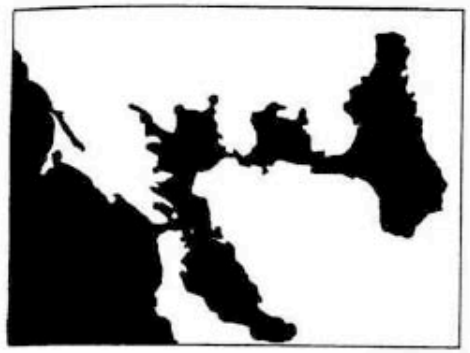
15,000 Years Ago
(End of last Ice Age--sea level approximately 400 feet below present level; rivers not shown)



10,000 Years Ago
(Formation of Farallon Islands and intrusion into the "Golden Gate")

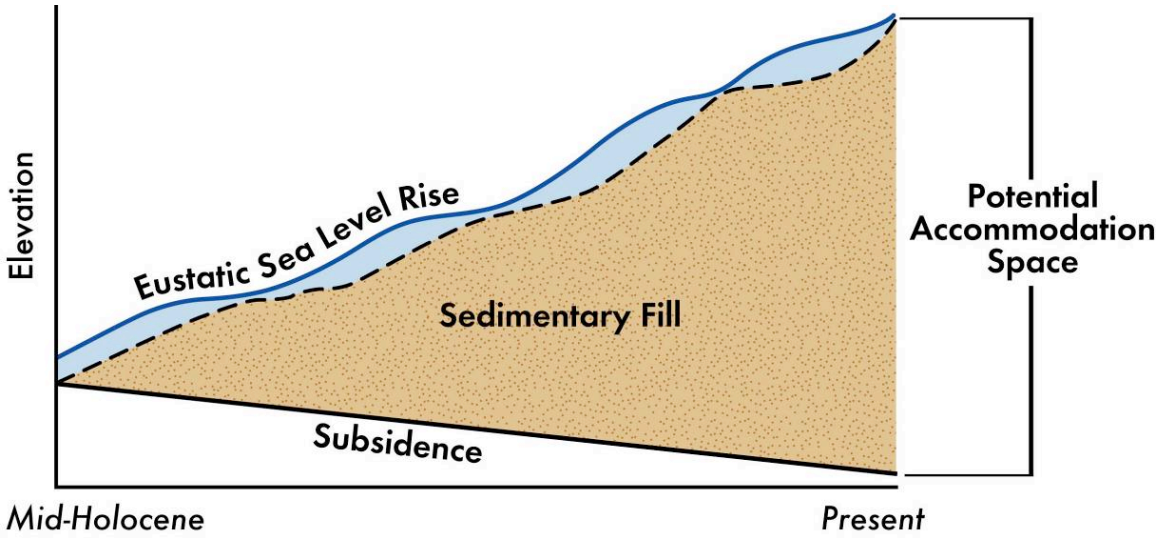


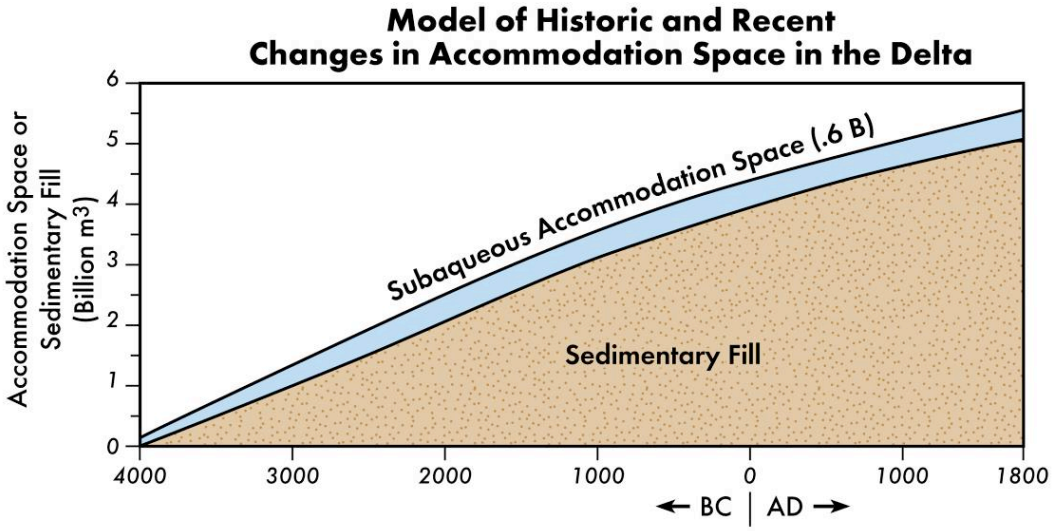
5,000 Years Ago
(Formation of Bay and Delta Basins)

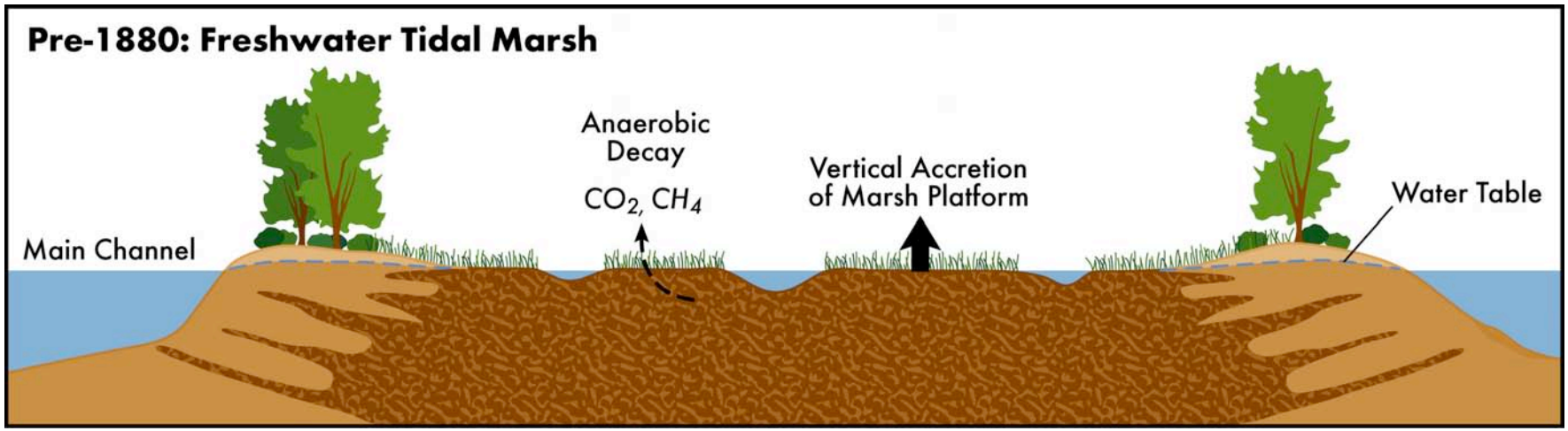


125 Years Ago
(Landward edge of undiked tidal marsh)

From: Atwater, 1982

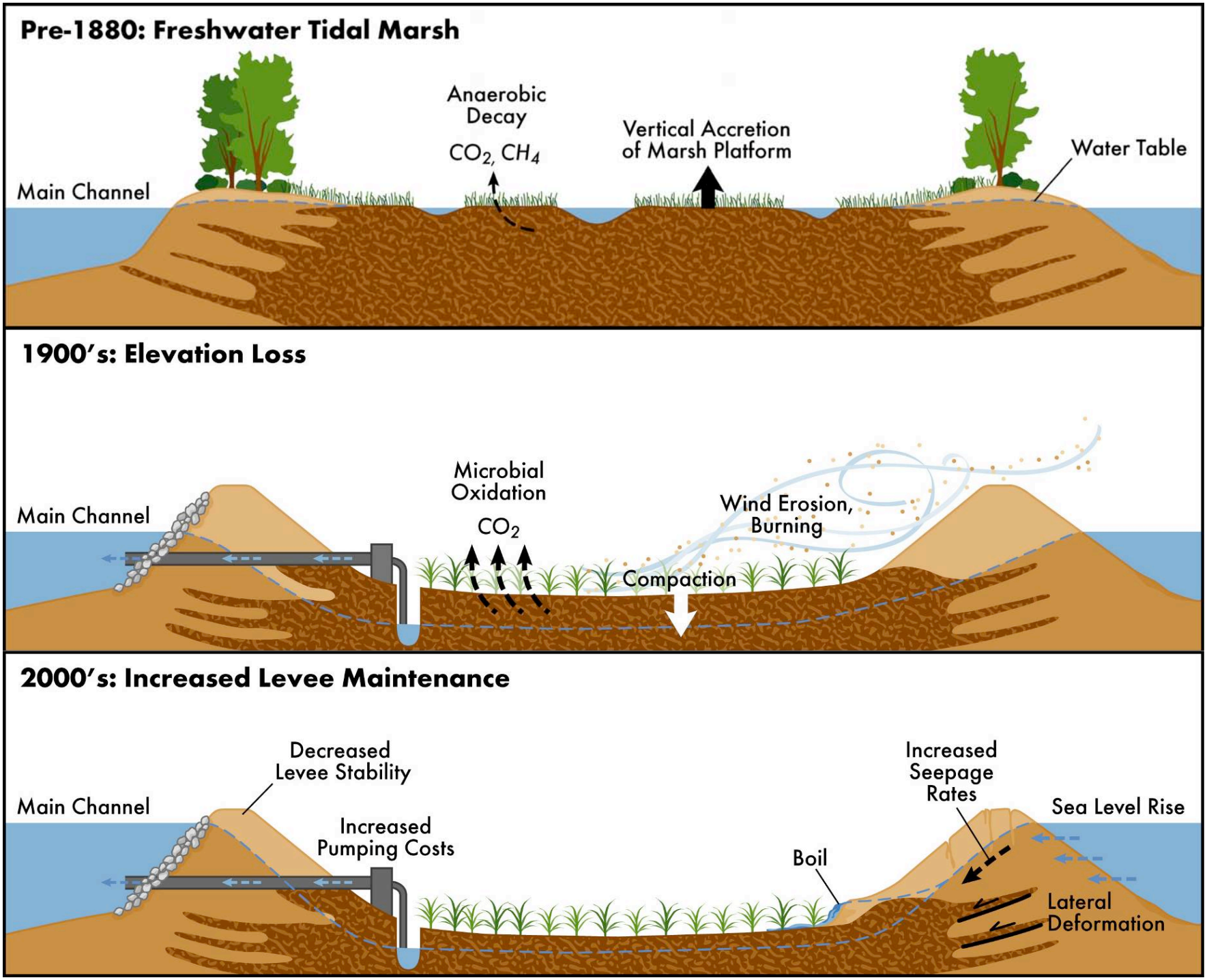



Model of Historic and Recent
Changes in Accommodation Space in the Delta
Accommodation Space or
Sedimentary Fill
(Billion m3)
6
5
4
3
2
1
0
Subaqueous Accommodation Space (.6 B)
Sedimentary Fill
4000
3000
2000
1000
0
1000
1800
← BC | AD →


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

Transition to the 20th Century Delta

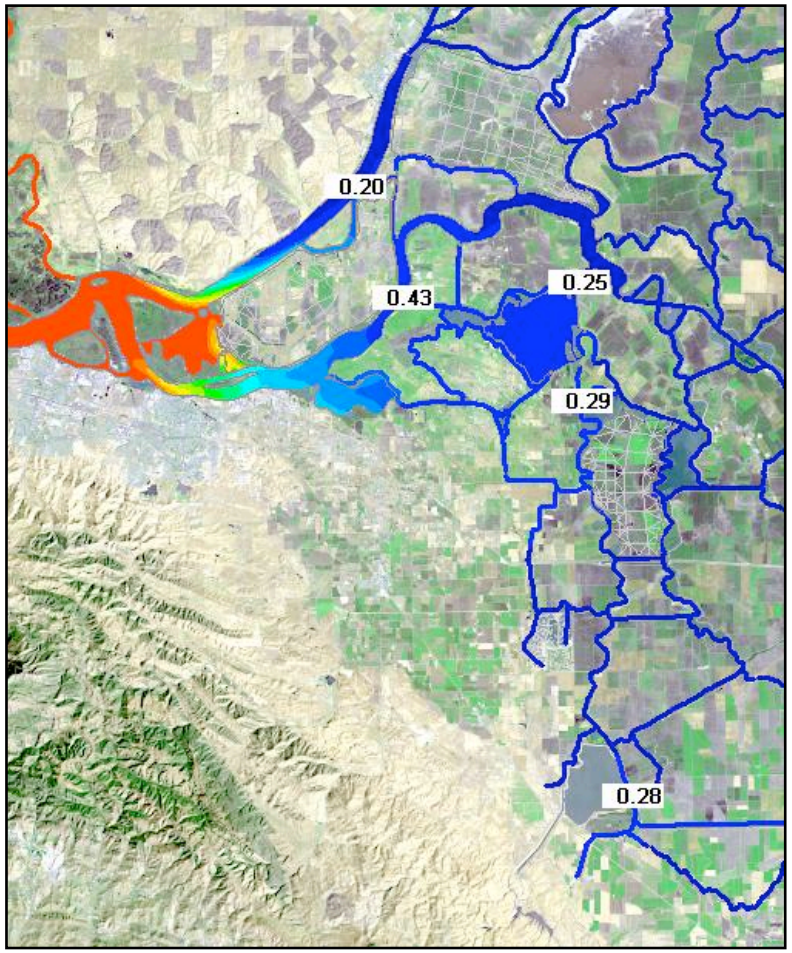
- Reclamation of 700,000 acres of tidal freshwater marsh
- 1100 miles of levees separate land from water (most of the time)
- Transition from dynamic, self-adjusting to static, homogeneous Delta

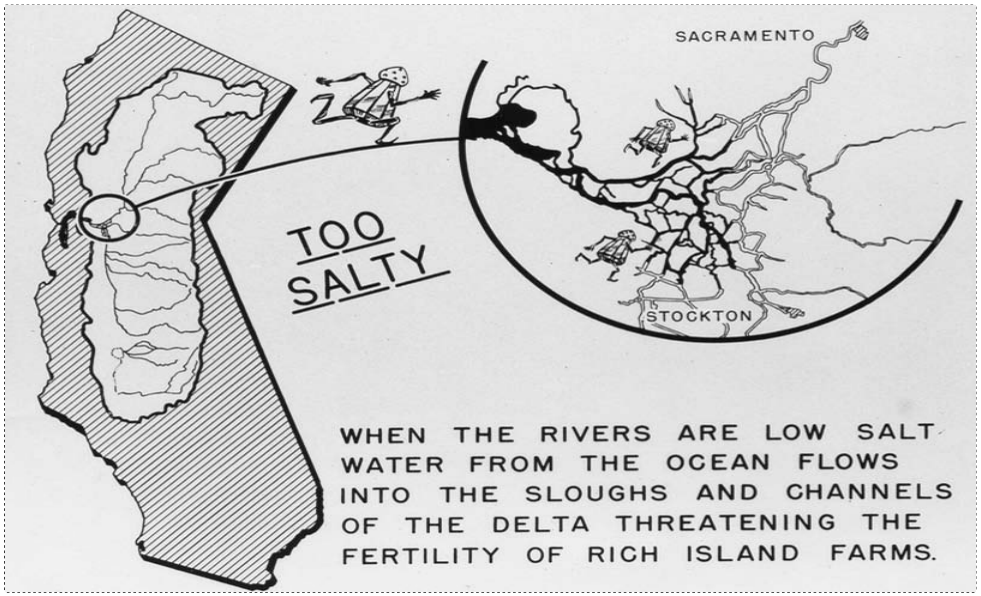

Pre-1880: Freshwater Tidal Marsh
Anaerobic Decay
CO_2, CH_4
Vertical Accretion of Marsh Platform
Water Table
Main Channel
1900's: Elevation Loss
Microbial Oxidation
CO_2
Wind Erosion, Burning
Main Channel
Compaction
2000's: Increased Levee Maintenance
Decreased Levee Stability
Increased Seepage Rates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

Water Supply: an Afterthought

- Second largest ecosystem service of the Delta
- 1800 diversions
- 7.5 MAF/year export

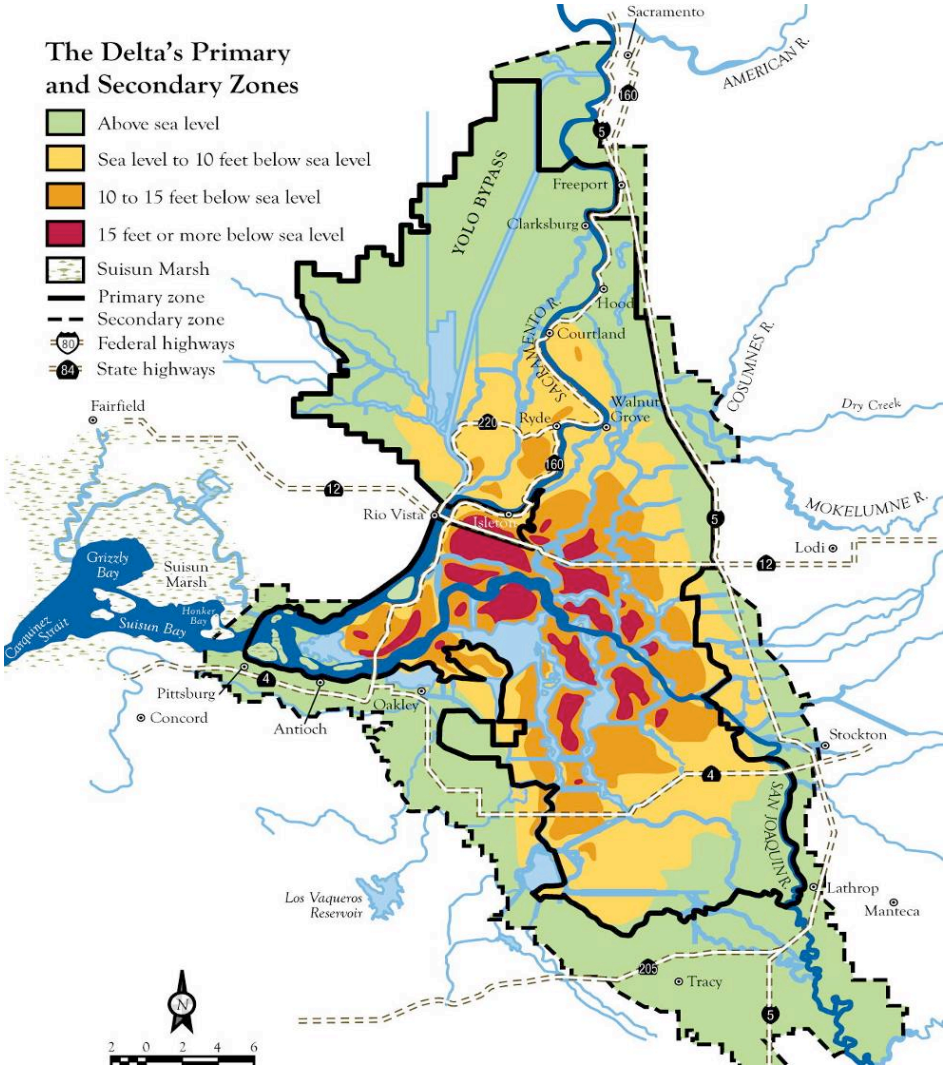
Keeping the Delta fresh, all the time

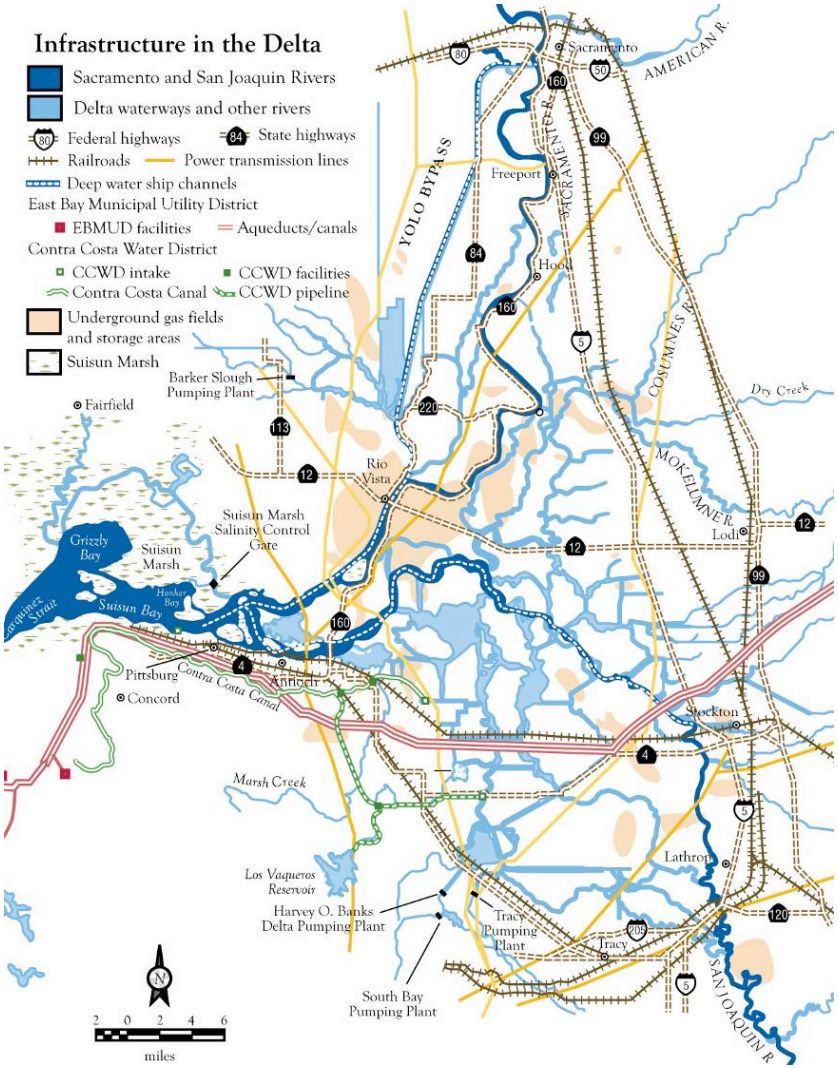




A policy since the 1940s to maintain the Delta as an unvarying, freshwater “estuary”, through carriage releases to reduce impacts of tides

The 20th Century Sacramento-San Joaquin Delta

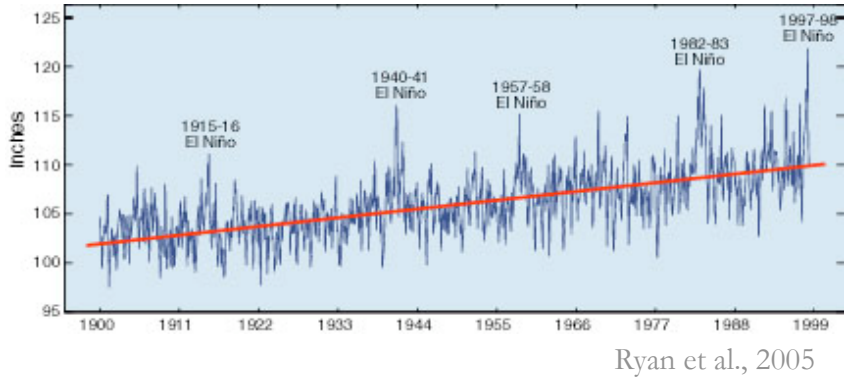




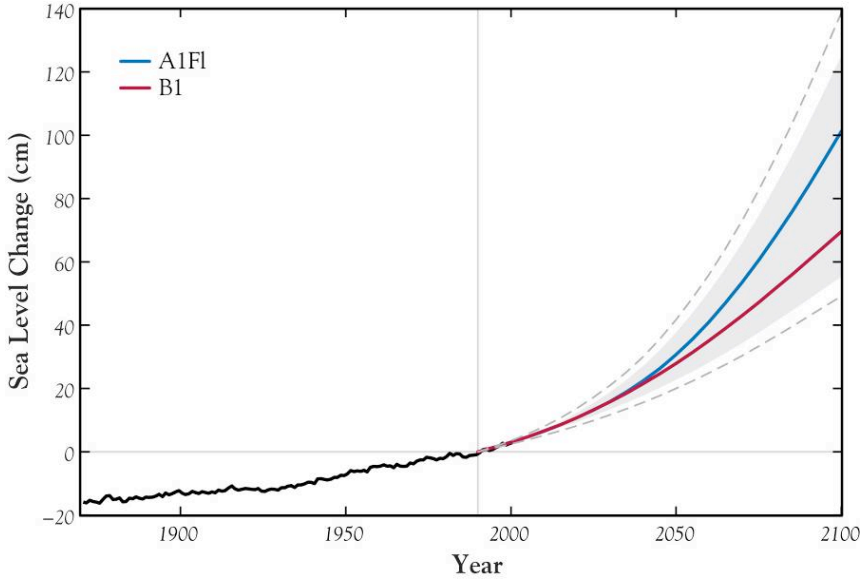
Transition to the 21st Century Delta: Drivers of Change

- Sea Level Rise
- Subsidence
- Changing Inflows
- Seismicity
- Economic
  - Competing Public Interests
  - Limited Public Funds

Sea Level Rise

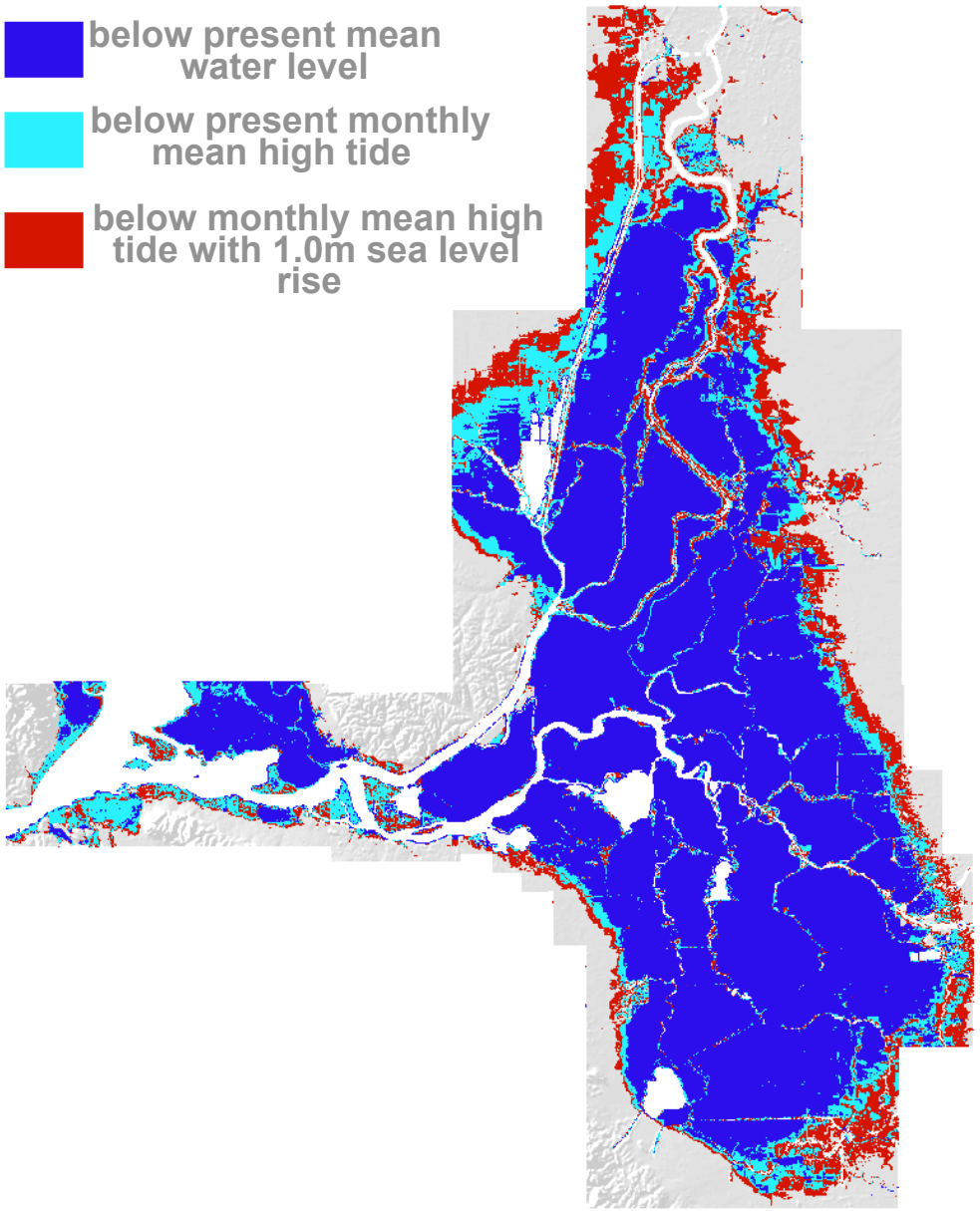


Ryan et al., 2005



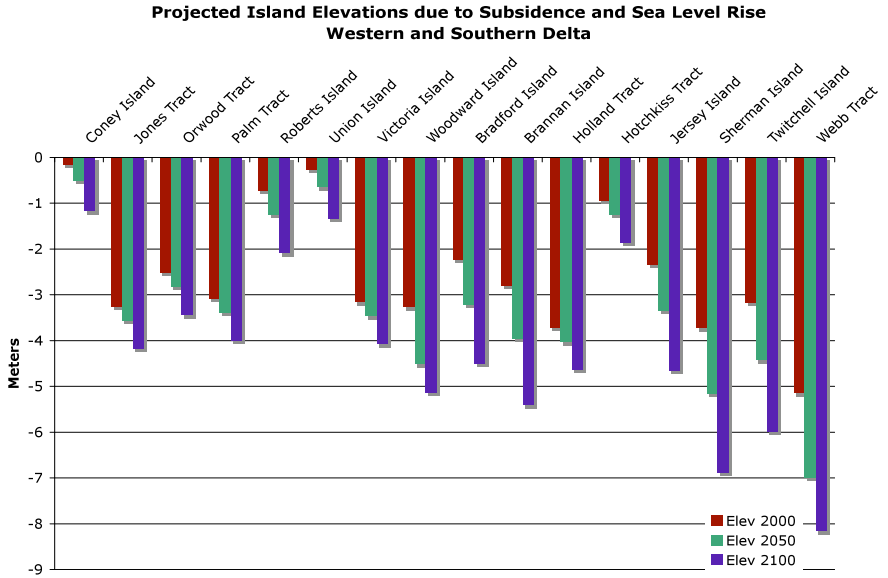
- Character of Delta based on sea level
- All hydrodynamics, habitat conditions, levee heights tied to sea level
- Rate of sea level rise increasing
- A modest rise overwhelms current Delta levee network

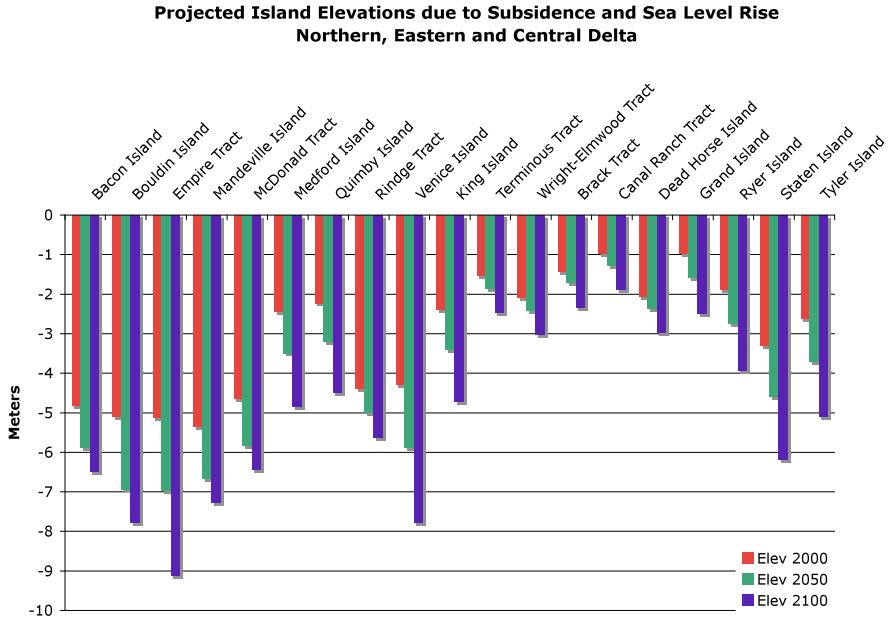
- 1 m sea level rise = 750,000 acres of potential inundation
- Most protected by levees
- Most of Delta is below current and future sea level

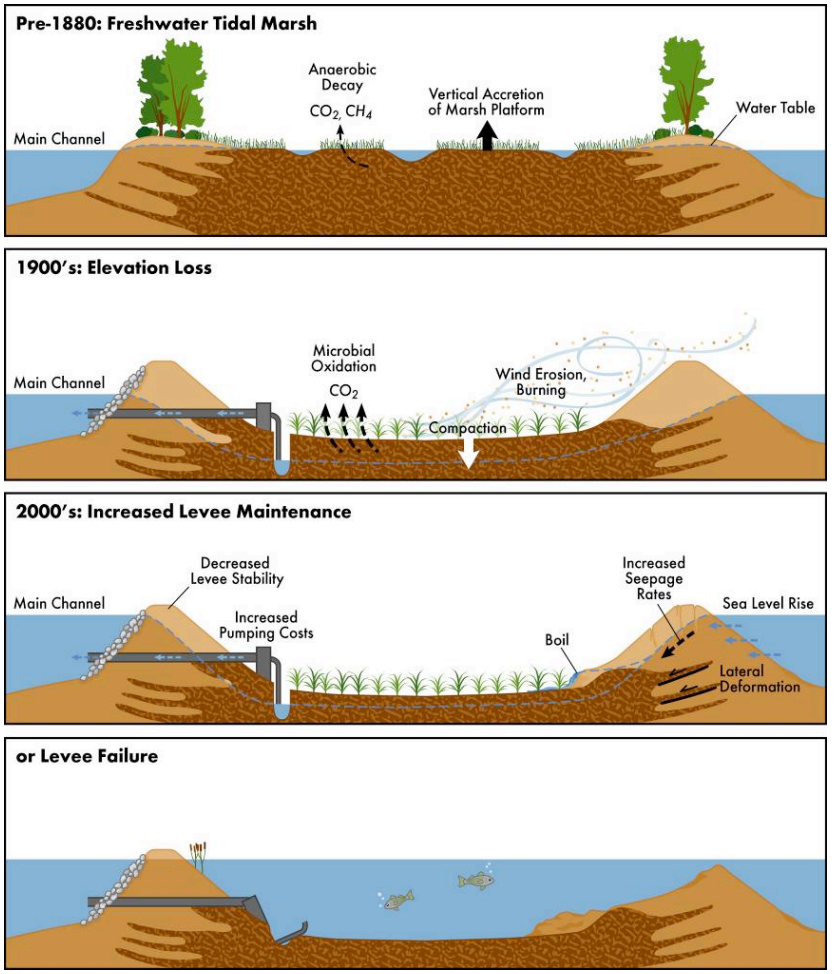


Courtesy: Noah Knowles, USGS

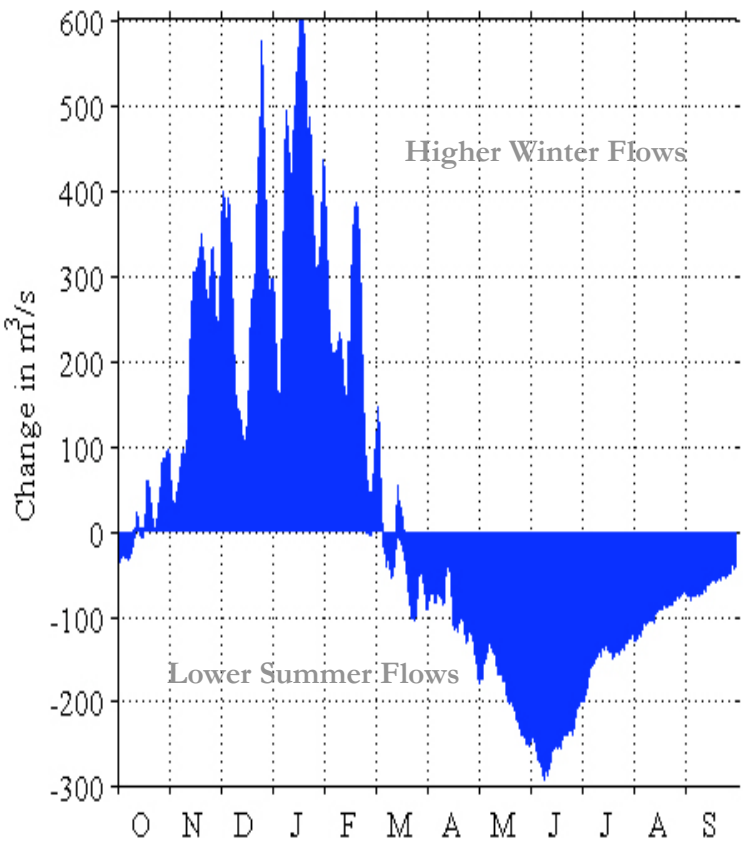
Subsidence


Projected Island Elevations due to Subsidence and Sea Level Rise
Western and Southern Delta
Coney Island
Jones Tract
Orwood Tract
Palm Tract
Roberts Island
Union Island
Victoria Island
Woodward Island
Bradford Island
Brannan Island
Holland Tract
Hotchkiss Tract
Jersey Island
Sherman Island
Twitchell Island
Webb Tract
Meters
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
Elev 2000
Elev 2050
Elev 2100


Projected Island Elevations due to Subsidence and Sea Level Rise
Northern, Eastern and Central Delta
Bacon Island
Bouldin Island
Empire Tract
Mandeville Island
McDonald Tract
Medford Island
Quimby Island
Rindge Tract
Venice Island
King Island
Terminous Tract
Wright-Elmwood Tract
Brack Tract
Canal Ranch Tract
Dead Horse Island
Grand Island
Ryer Island
Staten Island
Tyler Island
Meters
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Elev 2000
Elev 2050
Elev 2100


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
2000's: Increased Levee Maintenance
Decreased Levee Stability
Increased Seepage Rates
Sea Level Rise
Main Channel
Increased Pumping Costs
Boil
Lateral Deformation
or Levee Failure

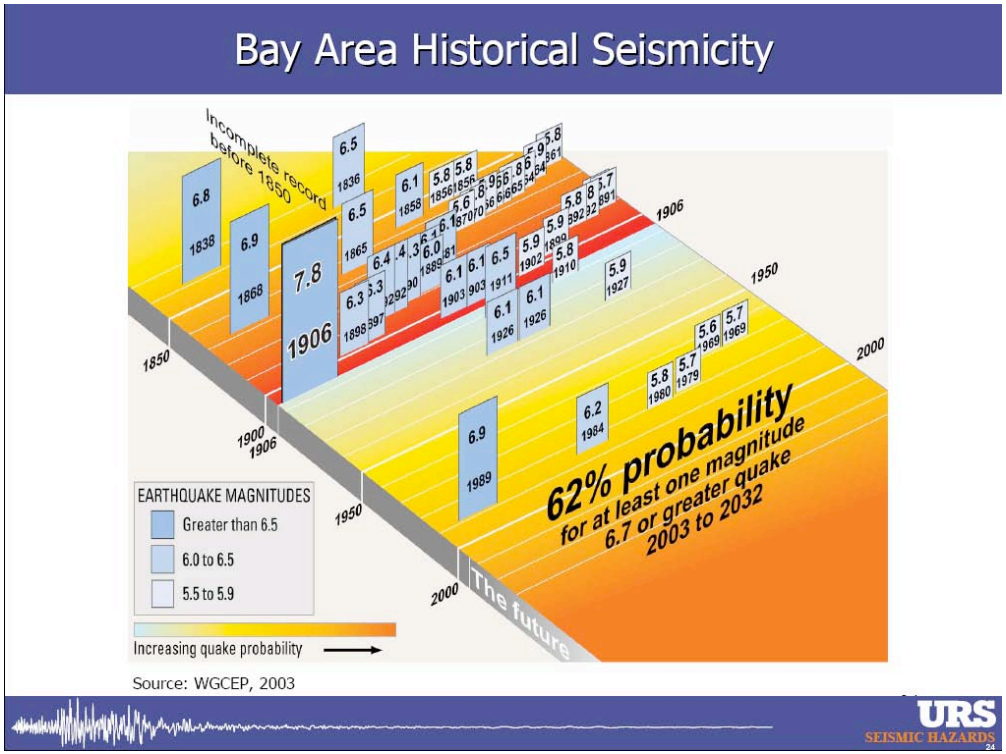
Changing Inflows

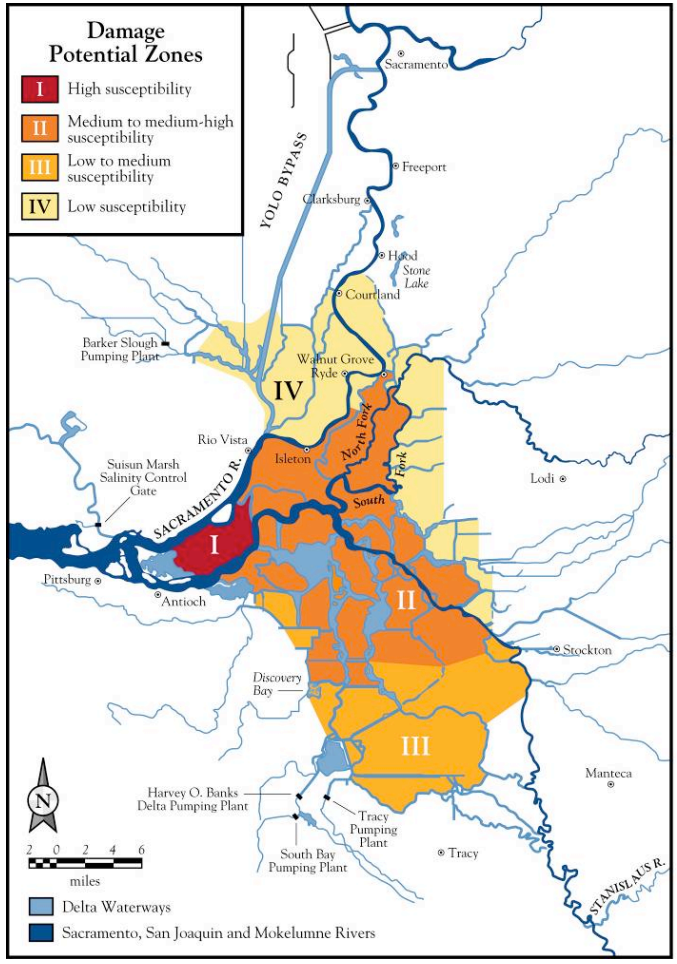


Change in inflows to Delta in 2060 (Knowles and Cayan, 2004)

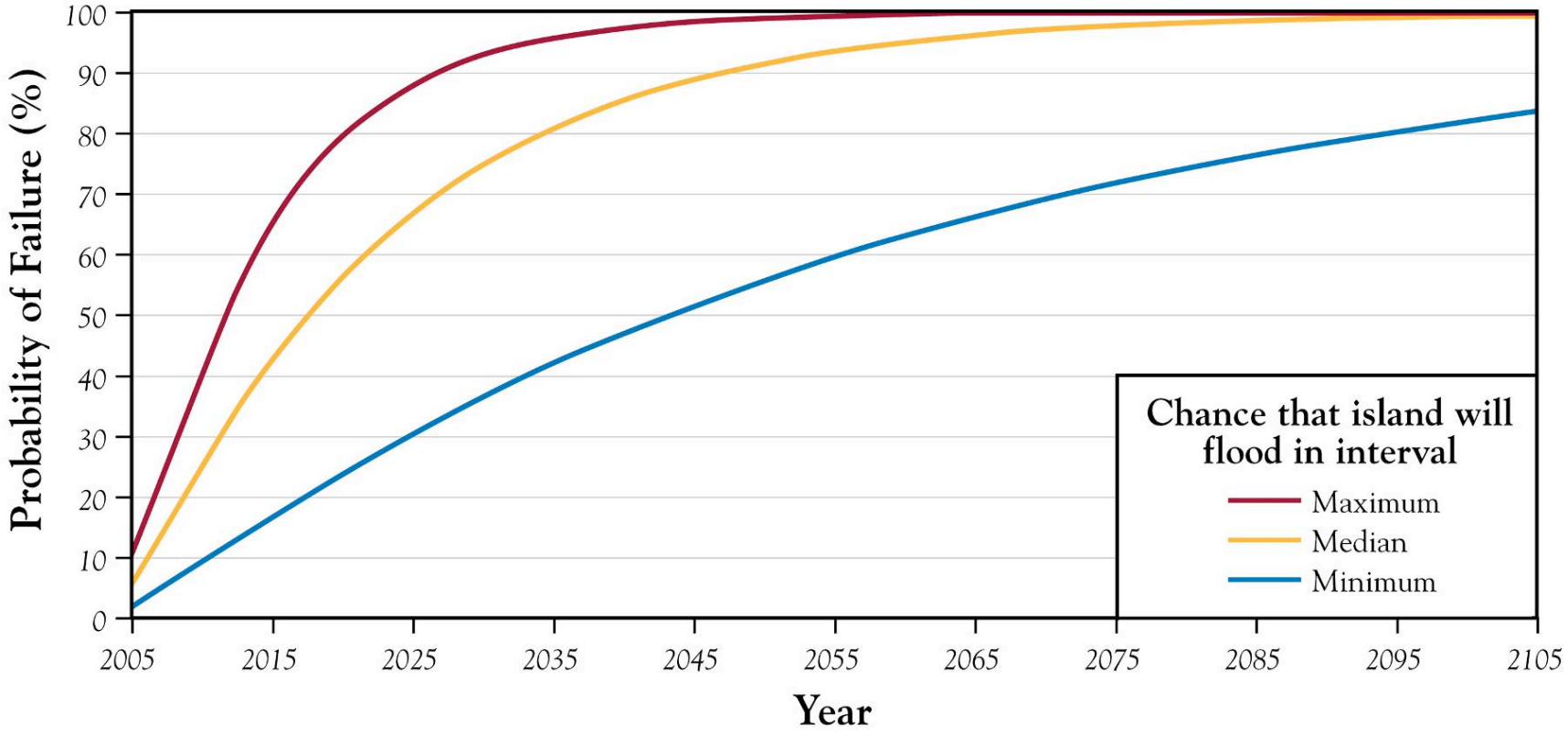
- Changing inflows to the Delta associated with changing upstream conditions and operations
- Shift in timing of runoff to winter
- Increase in frequency and magnitude of flood events
- ***Historical hydrology not a good predictor of future***

Increasing likelihood and consequences of levee failure/island flooding



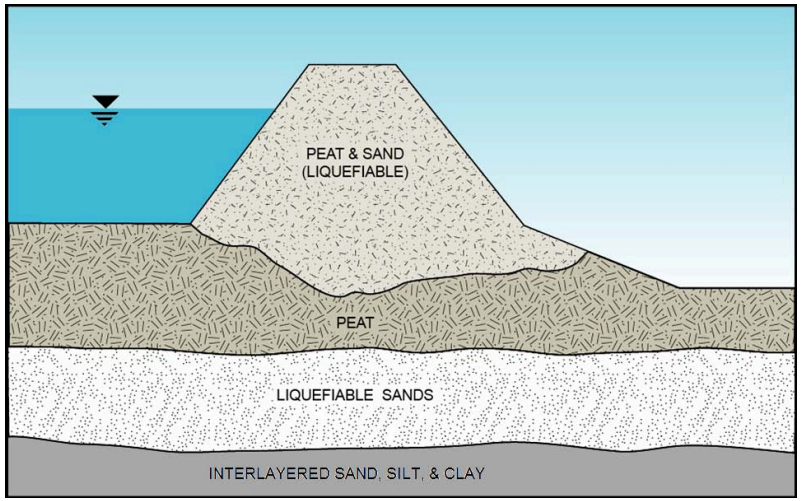


Flooding Inevitable

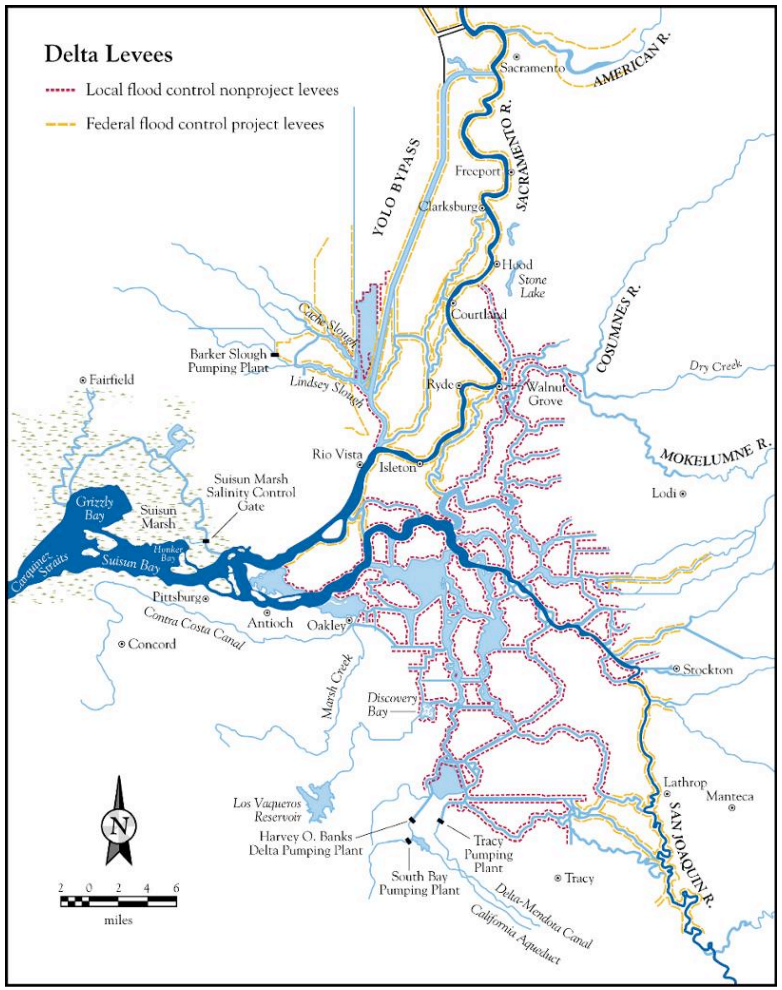


Cumulative probability of levee failure/island flooding due to earthquake OR flood for a given interval of time (based on DRMS draft data)

Current Focus on Levees
(Ballot Propositions 1E and 84)

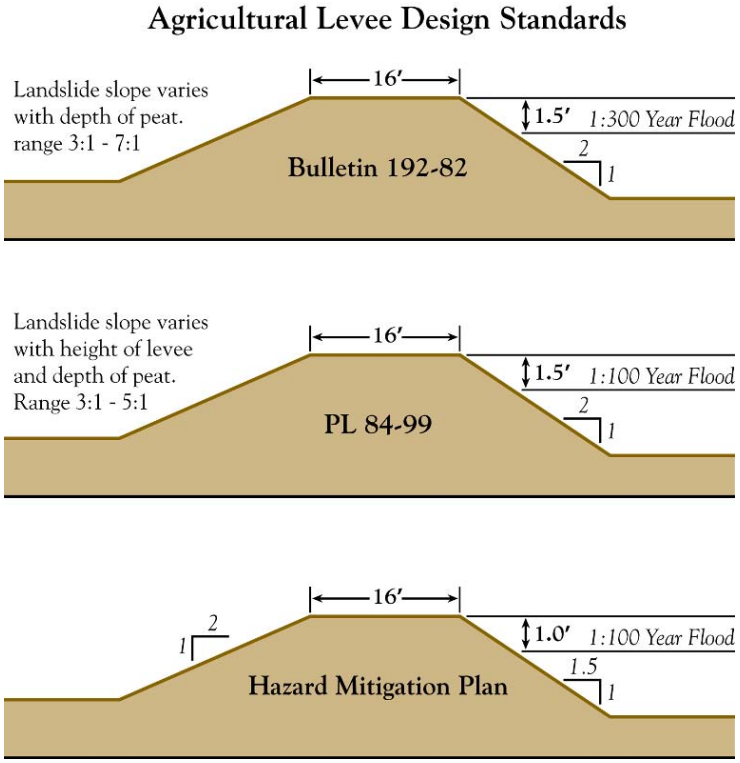


Economic Drivers of Change



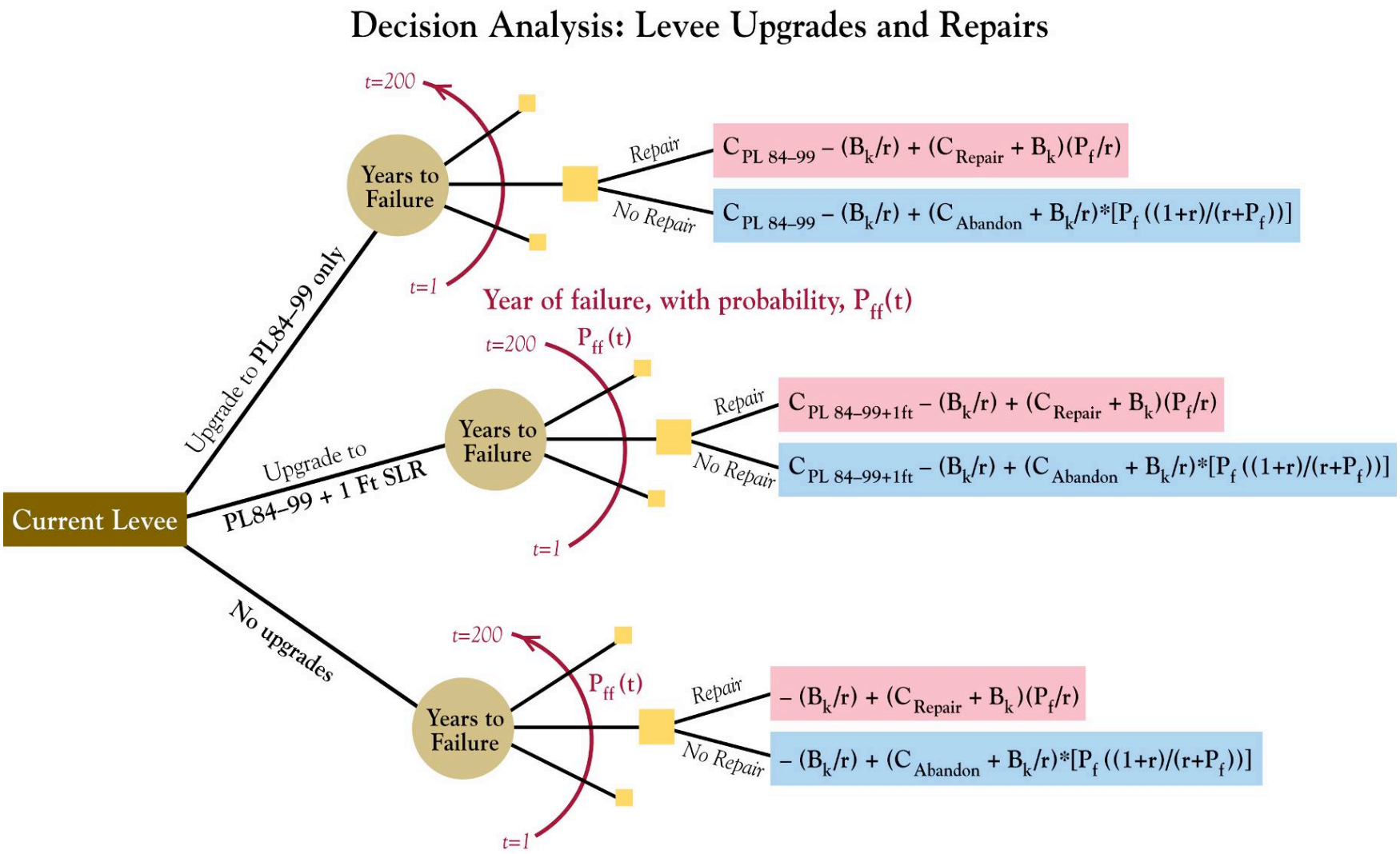
- A measure of resiliency of the Delta is the ability or willingness to repair levees and restore islands
- Evaluated net present value of upgrades and repairs for 34 non-urban islands

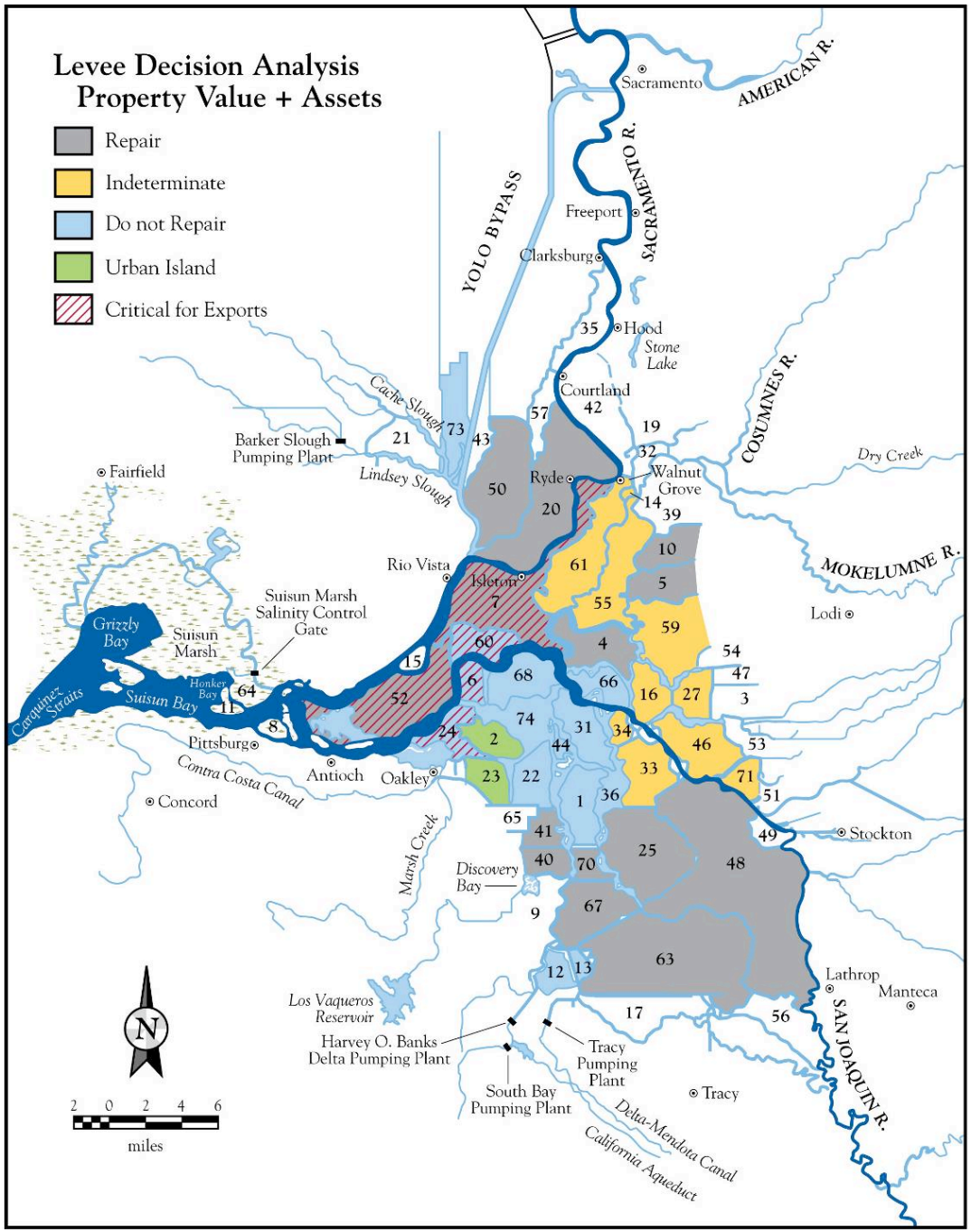
Upgrade and/or Repair Levees?



Option Number	Current Upgrade Policy	Future Repair Decision
1	No Upgrade	Repair
2	No Upgrade	No Repair
3	PL 84-99	Repair
4	PL 84-99	No Repair
5	PL 84-99 + 1ft SLR	Repair
6	PL 84-99 + 1ft SLR	No Repair

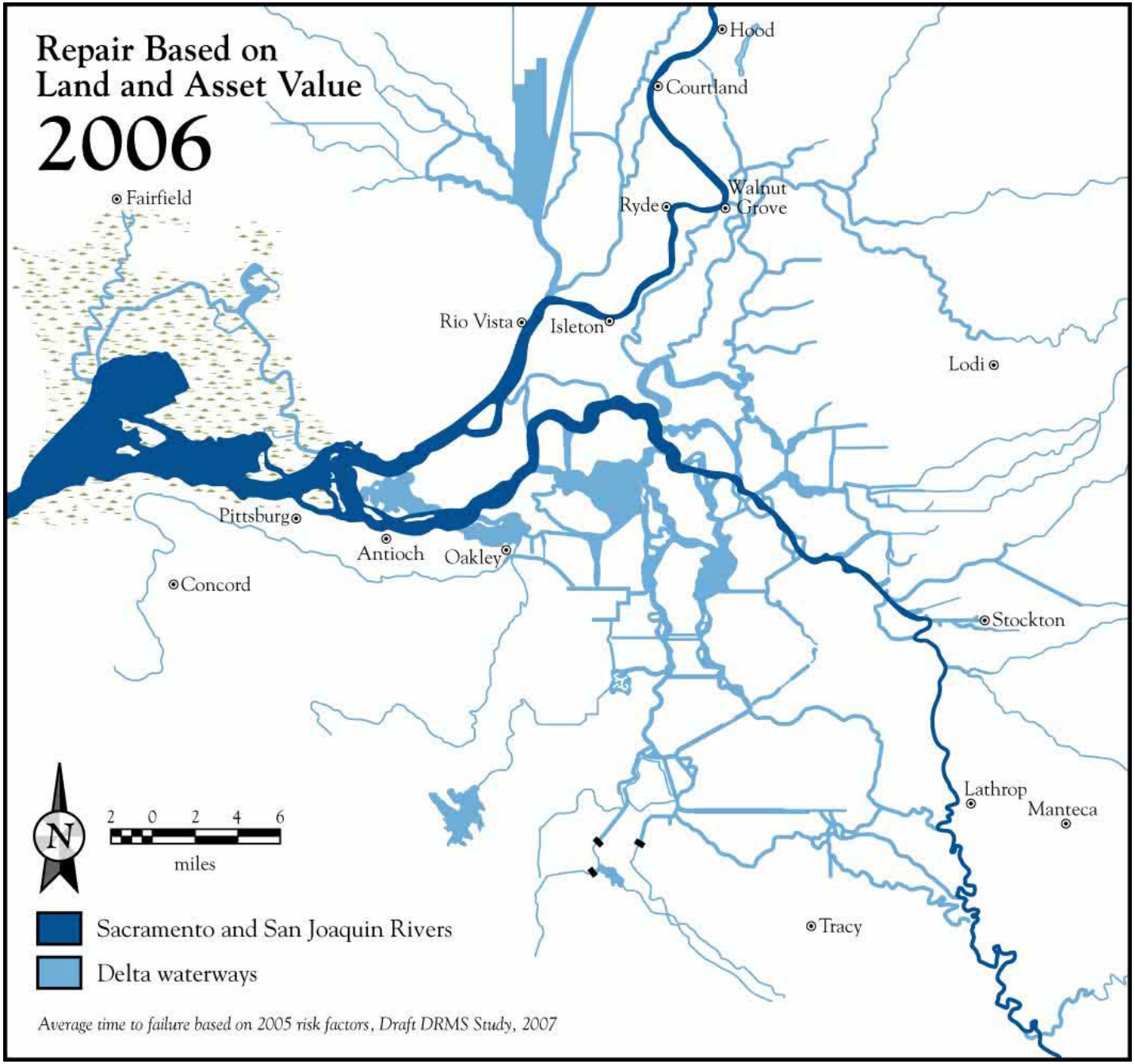
Island levee decision analysis tree for assessing whether to upgrade levees and to restore islands following flooding





Conclusions

- **10-19 of the 34 islands analyzed do not warrant repair following failure**
- **It is not economically viable to invest in upgrades due to low overall performance**
- **These results are robust. Increasing land values or levee performance does not significantly change upgrade/repair choices**


Repair Based on
Land and Asset Value
2006
Hood
Courtland
Fairfield
Ryde
Walnut
Grove
Rio Vista
Isleton
Lodi
Pittsburg
Antioch
Oakley
Concord
Stockton
Lathrop
Manteca
Tracy
N
2 0 2 4 6
miles
Sacramento and San Joaquin Rivers
Delta waterways
Average time to failure based on 2005 risk factors, Draft DRMS Study, 2007

Concerns About Flooded Islands

- **Habitat** -
  invasive species
- **Water Quality** -
  salinity increases
- **Surrounding Levees** -
  wave action & seepage

Habitat & Water Quality Implications of Flooded Islands: Current Understanding

"The impact of a … levee breach … depends in good part on the **timing** of the event… In the **long run**, permanently ***flooded islands in the right place could increase the amount of favorable habitat for delta smelt.***" (Moyle, 2008)

Flooded Island Habitat and Water Quality Effects Depend On:

1. **Geometry**
   - Depth
   - Breach Location
   - Surrounding Channel Network
2. **Location**
   - Proximity to Rivers
   - Tidal Influence
3. **Wave Fetch**

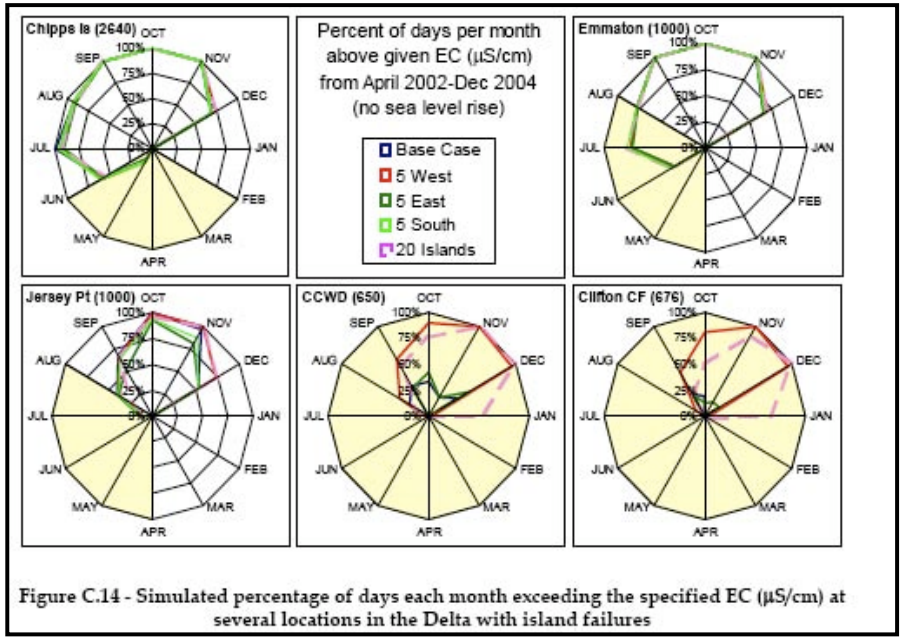


Figure C.14 - Simulated percentage of days each month exceeding the specified EC (µS/cm) at several locations in the Delta with island failures

(Fleenor et. al, 2008)

"More Research Needed"

1. California's Water Code and Other Delta-Specific Legislation:

Water Code - Lack of Legislative Intent

Section 12981:

"… the physical **… delta should be preserved essentially in …** ***present form***; and the key to preserving the delta's physical characteristics is the ***system* of levees**..."

Assembly Bill No. 955:

"However, the Legislature recognizes that it **may not be economically justifiable** to maintain all delta islands."

DPC Delta Land Use & Resource Mgmt Plan

Generalized Directives

2. Regulatory Laws

1. **Federal & State Clean Water laws**
   - Unrealistic salinity standards
   - Presumption of common needs
   - Lack of flexibility

2. **Endangered Species Acts**
   - Difficult to disprove a “taking”
   - Possible exceptions for experimentation

3. **CEQA and NEPA**

3. Common Law
Takings Clause and Nuisance

1. **State Immunity**
   - Weaker than Federal
   - CA Water Code Section 12983

2. **Takings Clause - Amendment 14 Extends 5th Amendment to the States**
   - "Private property may be taken or damaged for public use **only when just compensation** is paid."

3. **Precedent?**
   - Paterno - Liable for an "unreasonable" plan
   - Jones Tract Lawsuit

Legal implications for *privately*-owned levees are unclear.

Key Conclusions

- Sea level rise will increase Delta salinity, no matter what
- Island flooding will increase in frequency and consequence with time
- Low resiliency (willingness to pay) means permanently flooded islands
- Delta of the past is gone; Delta of the present is unstable and at a tipping point; Delta of the future is going to be very different and irreversible
- “Restored” aquatic habitat in abundance, but unseen historically.
- No levee policy in place to deal with this.

19th Century Delta

20th Century Delta

21st Century Delta

"If a man neglect to strengthen his dike and do not strengthen it, and a break be made in his dike and the water carry away the farmland, the man in whose dike the break has been made shall restore the grain which he has damaged."

-The Code of Hammurabi (circa 2250 BCE), translation by Robert Francis Harper (1904)