International Association for Hydro-Environment Engineering and Research

Supported by Spain Water and IWHR, China

IAHR World Water Day Forum on "Hydro-environment Engineering and Adaptation to Climate Change"

Lecture 1

Water Security and Ecosystem Services*

Peter GOODWIN
University of Maryland Center for Environmental Science

University of Maryland Center for Environmental Science

University System of Maryland

** Keynote Lecture presented at the Croucher Advanced Study Institute on "Global Water Security: Integrated Modeling and Adaptive Management", HKUST, January 8-11, 2019*

Presentation Outline

- The Grand Challenge
- Ecosystem Services
- The California Experience

  Co-equal Goals of water security and ecosystem recovery
- Adaptive Management

  Science and Engineering to inform policy and management actions

The ultimate sustainability challenge:

maintaining and improving the quality of life for the nation within a healthy Earth system.

Tim Killeen,
SEES, National Science Foundation. 2012

The Grand Challenge

Snow, C.P. 1960. *Science and Society*. The Godkin Lecture. Harvard University

Giosan, L, 2014. *Protect the World's Deltas*. Nature 516. December 4. 31-33.

National Academy of Engineering, 2018. *Environmental Engineering for the 21st Century: Addressing Grand Challenges.* Prepublication Copy. National Academies Press. DOI 10.17226/25121

Luoma S.N., Dahm C.N., Healey M, and Moore J.N., 2015. *Challenges Facing the Sacramento-San Joaquin Delta: Complex, Chaotic or Simply Cantankerous?* San Francisco Estuary and Watershed Science, Volume 13, Issue 3. http://dx.doi.org/10.15447/sfews.2015v13iss3art7

Ecosystem Services

Yarnell, S.M. et al. 2015. *Functional Flows in Modified Riverscapes: Hydrographs, Habitats and Opportunities* BioScience 2015. doi: 10.1093/biosci/biv102

Borden, C., P. Goodwin and D. Swanson, 2016. *Integrated Hydro-Environment Assessment with Latitude (IHEAL): A framework for conceptualizing and quantifying Water Use Sustainability in IWRM.* Proceedings of the 37th IAHR World Congress August 13 – 18, 2017, Kuala Lumpur, Malaysia.

Millennium Assessment, 2003. *Ecosystems and Human Well-being: A Framework for Assessment*. Island Press, Washington, DC.

The California Experience

Delta Stewardship Council, 2018. Delta Plan, *Appendix 1B: Adaptive Management.*

San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC). 2016. *A Delta Renewed: A Guide to Science-Based Ecological Restoration in the Sacramento-San Joaquin Delta.* A Report of the Resilient Landscapes Program, Publication #799, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA. Report is available at www.sfei.org/projects/delta-landscapes.

Goals project. 2015. *The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015* prepared by the San Francisco Bay area Wetlands Ecosystem Goals project. California State Coastal Conservancy.

Ecosystem Services

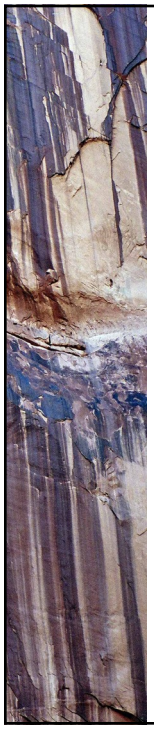
The Millennium Ecosystem Assessment defines Ecosystem Services as:

"the benefits people derive from ecosystems"

Examples include:

- Provisioning services: food, wood, raw materials
- Regulating services: pollination of crops, prevention of floods or soil erosion, water purification
- Cultural services: recreation, sense of place

www.IUCN.org



What is the Millennium Ecosystem Assessment?

Largest assessment ever undertaken of the health of ecosystems

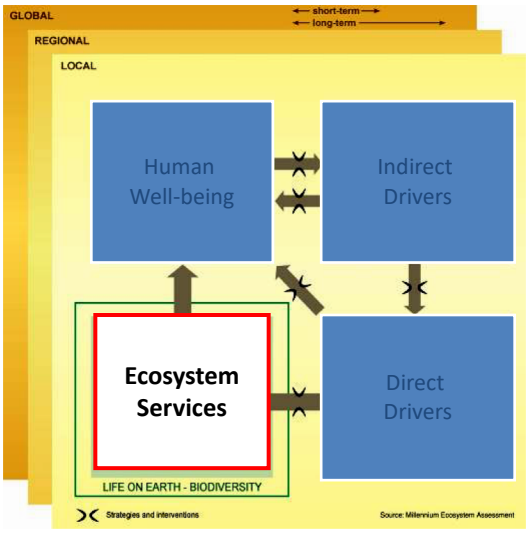
- Prepared by 1360 experts from 95 countries; extensive peer review
- Consensus of the world's scientists

Designed to meet needs of decision-makers among government, business, civil society

- Information requested through 4 international conventions

courtesy: Richard Norgaard

Millennium Ecosystem Assessment scientists developed a complex systemic framework with people – including their culture, science, and economies – inside the system they were trying to understand.



Millennium Ecosystem Assessment

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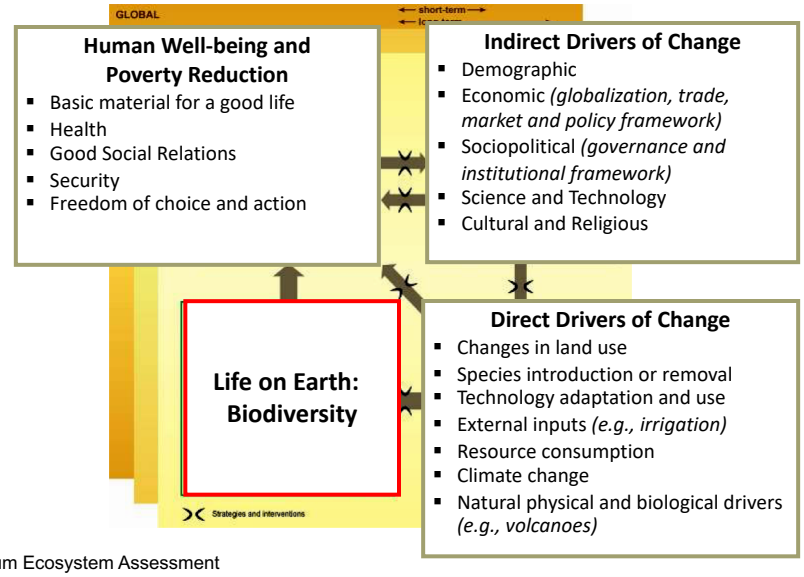
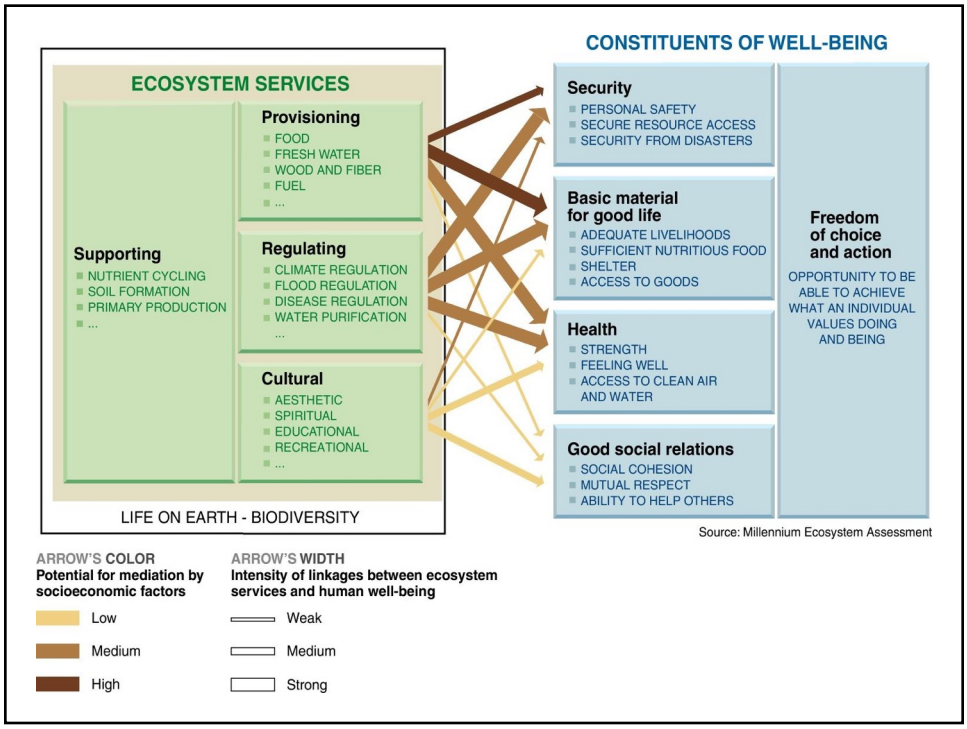


Millennium Ecosystem Assessment



Impact on Biodiversity by Driver and Ecosystem

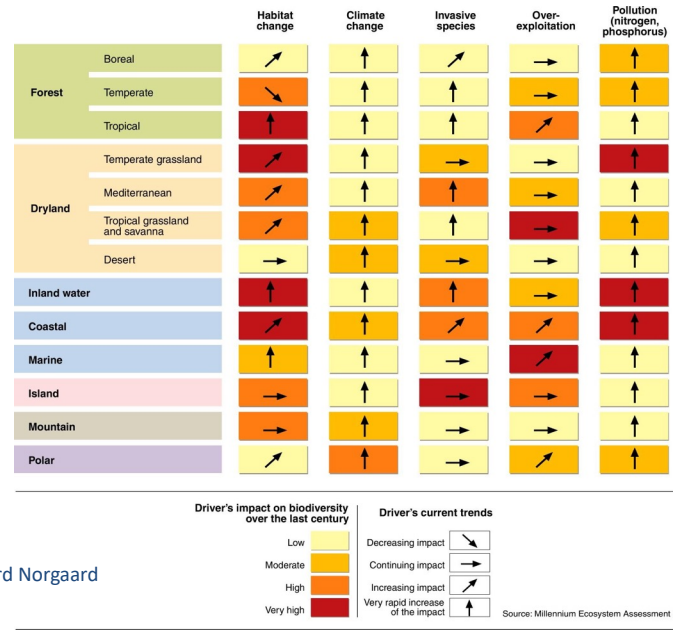


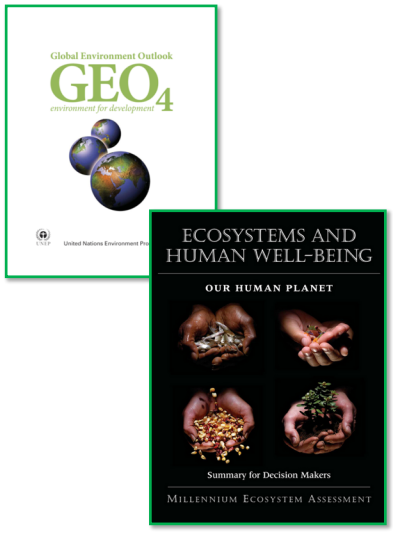
Image courtesy: Dr. Richard Norgaard

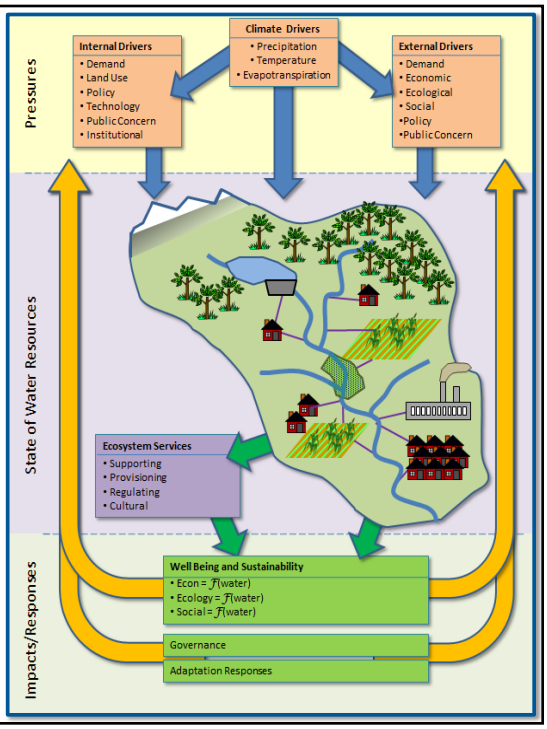
Integrated Water Resources Management

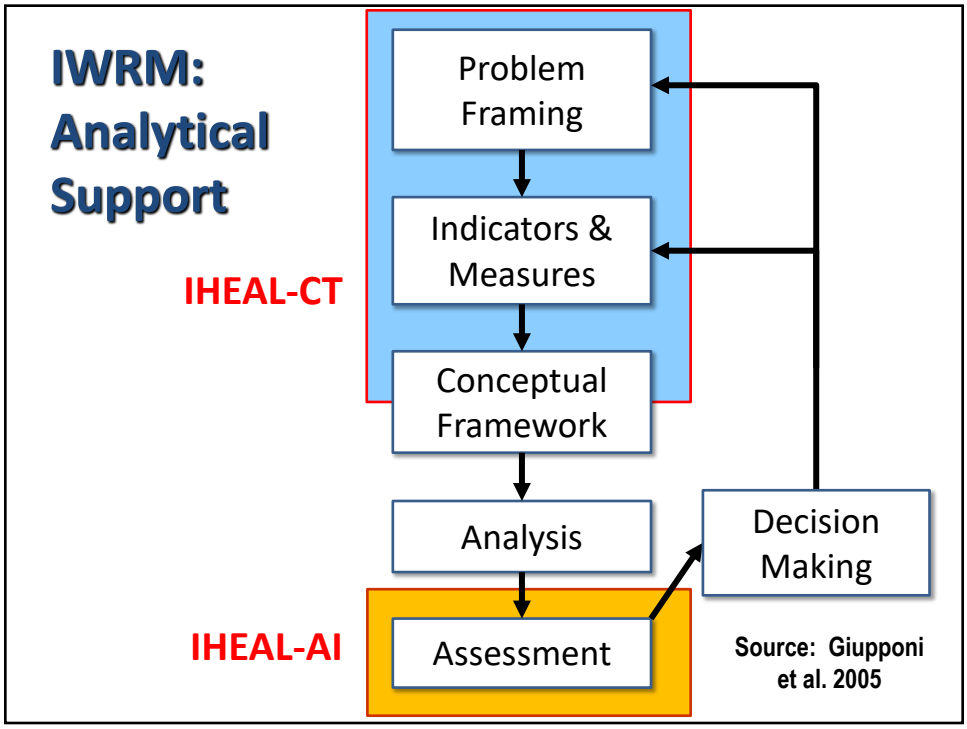
"a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems"

Source: GWP , 2004

iHEAL





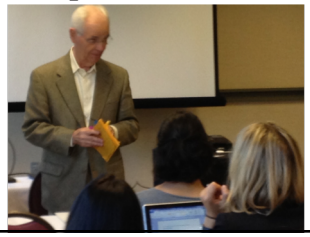

IWRM:
Analytical
Support
IHEAL-CT
IHEAL-AI
Problem Framing
Indicators & Measures
Conceptual Framework
Analysis
Assessment
Decision Making
Source: Giupponi et al. 2005


Leadore, ID
USDA Farm Service Agency
age © 2013 TerraMetrics
Copyright ©2009 Mark Gamba ALL RIGHTS RESERVED
44°43'11.18" N 113°08'49.00" W elev 7889 ft
Eye alt

C.P. Snow

Godkin Lecture, Harvard University, 1960

Let me say at once that I have no easy answers at all. If there were any easy answers, they would have been found by now. The whole problem is an intractable one, one of the most intractable that organised society has thrown up. It is partly the expression, in political and administrative terms of the split between two cultures that I have said something about elsewhere.[42]



Change is the only constant

'Stationarity is Dead' Milly et al. , 2008

We can no longer rely solely on the past to predict future conditions

Pressures include:
Climate change
Episodic events [seismic, extreme events, toxic spills]
Shifting land-use patterns
Population growth
Invasive species

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

WORLD METEOROLOGICAL ORGANIZATION | GLOBAL ATMOSPHERE WATCH

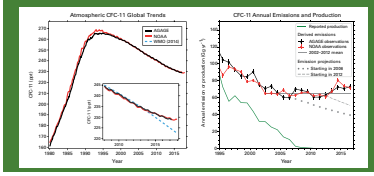
WMO GREENHOUSE GAS BULLETIN

The State of Greenhouse Gases in the Atmosphere
Based on Global Observations through 2017

No. 14 | 22 November 2018

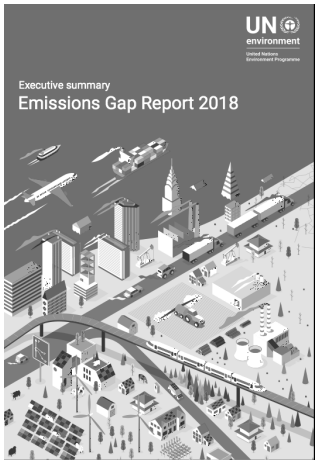
ISSN 2078-0796

Unexpected Increases in Global Emissions of CFC-11



between 2002 and 2012 [1, 2]. These global trends are shown in the left graph of the figure for the Advanced Global Atmospheric Gases Experiment (AGAGE; shown in black) and the National Oceanic and Atmospheric Administration (NOAA; shown in red) measurement networks. Also shown in the inset to this graph is the trend that was predicted in 2014 by WMO (blue dashed) assuming adherence to the Montreal Protocol [3].

Modelling results lead to the robust



An Exemplar

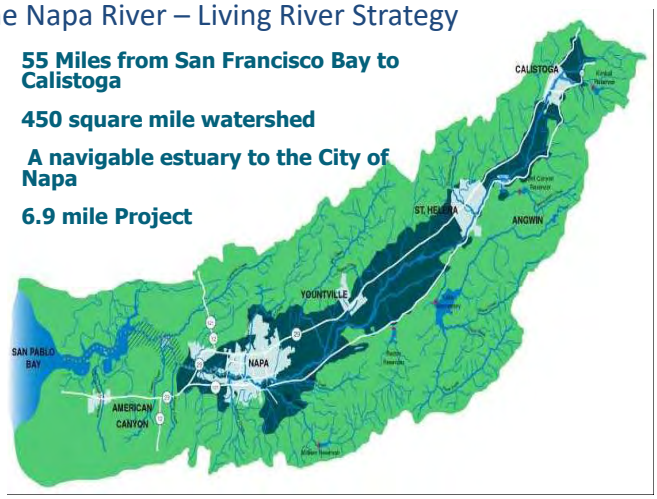
The Napa River – Living River Strategy

55 Miles from San Francisco Bay to Calistoga

450 square mile watershed

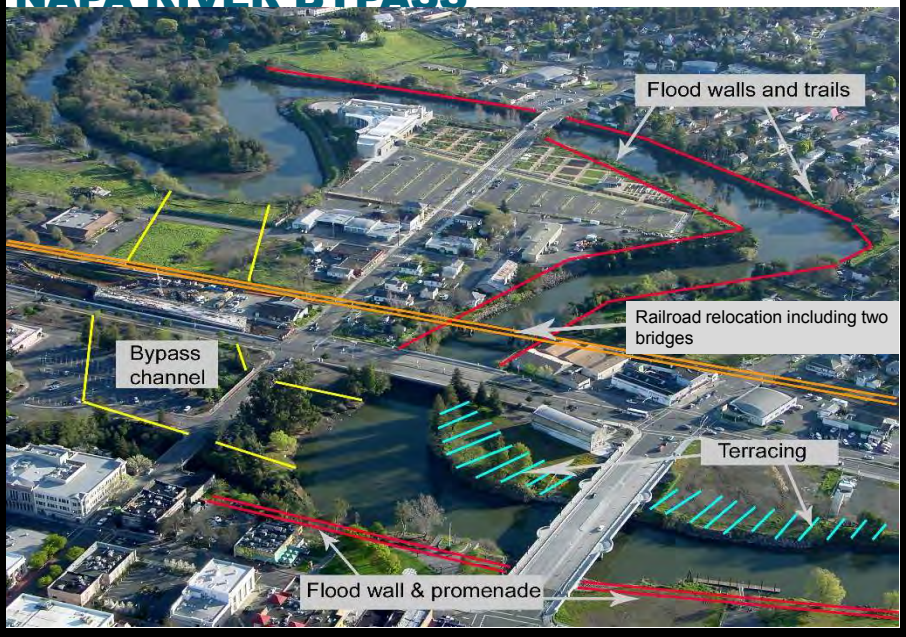
A navigable estuary to the City of Napa

6.9 mile Project



Creation of 659 acres of wetland, mudflat and open water

NAPA RIVER BYPASS

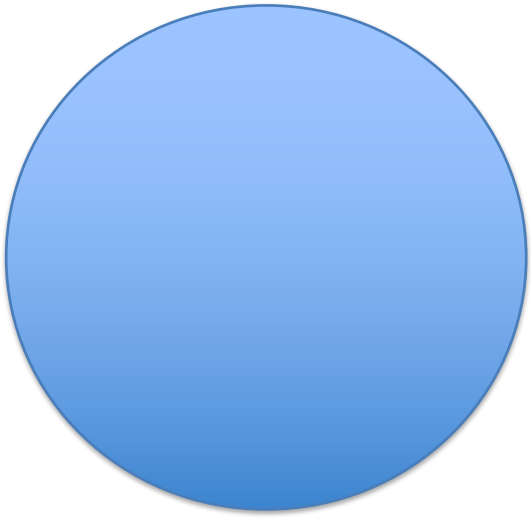


Fundamental Question:
will the ecosystem recover or was the fire a tipping point?

Unknown

Given the wicked (multifactorial) nature of the problems, however, we can expect that increased understanding will not solve the problem but only point the way to better management approaches.

NRC 2014



What do we mean by natural flows in complex and irreversibly altered systems?

Novel ecosystems (Moyle, 2014): resilient and desirable

Landscape ecology vs cumulative projects

Yarnell, S.M. et al. 2015. *Functional Flows in Modified Riverscapes: Hydrographs, Habitats and Opportunities* BioScience 2015. doi: 10.1093/biosci/biv102

Time-frame to inform management decisions

Mark Cowin, Director, California Department of Water Resources

When is good science good enough?

John Wiens, Independent Science Board. Delta Science Program

Polymath or Translators

Expert Panel on Adaptive Management, BDCP and NASEM Recommendations

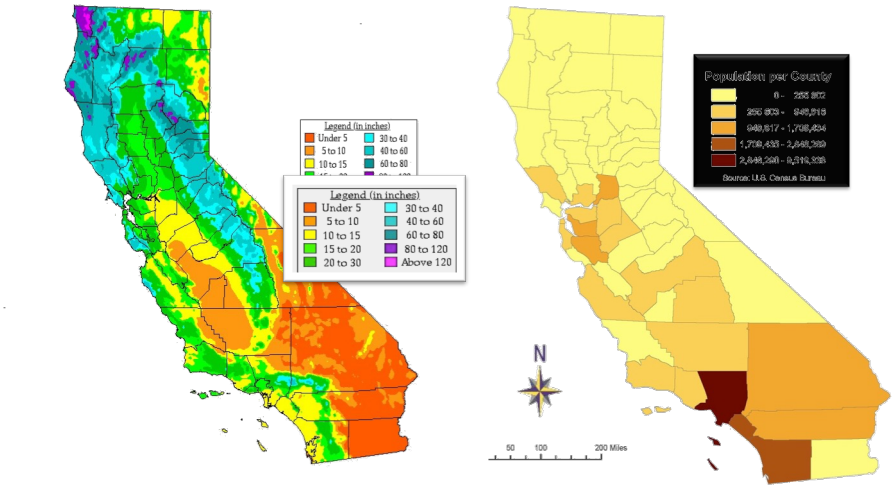
Who has responsibility and who has authority?

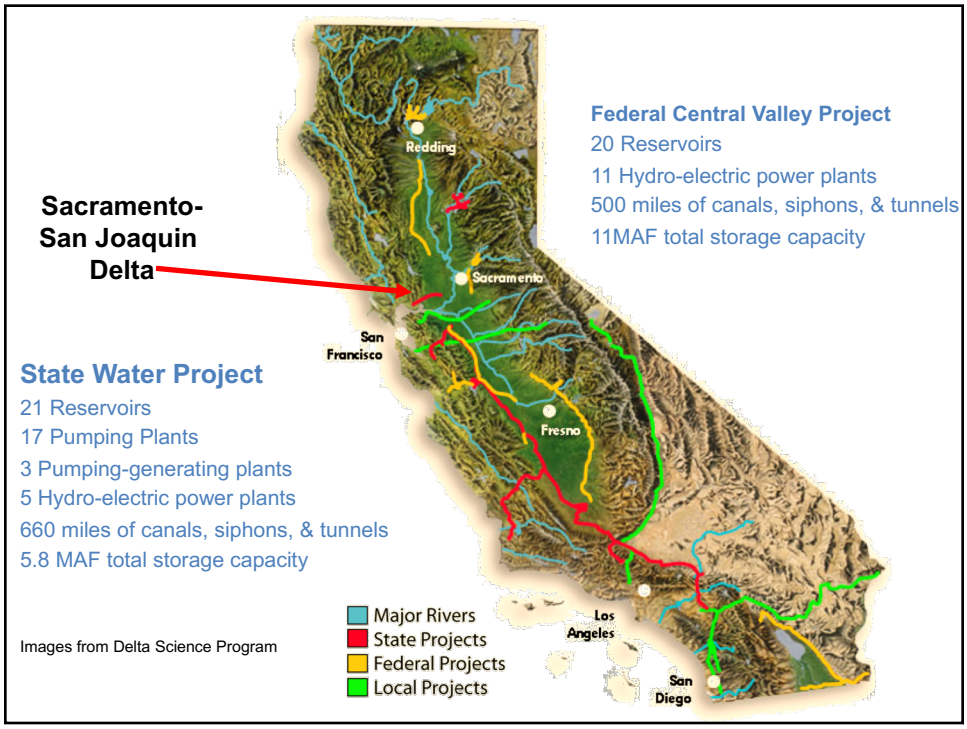
Universal challenge.

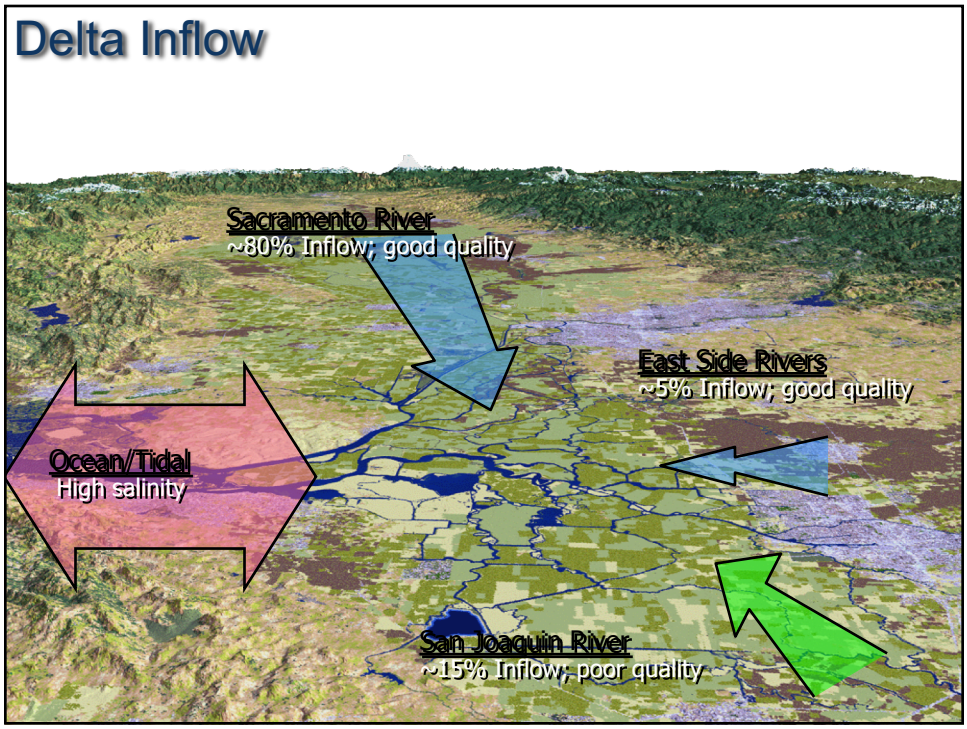
Other challenges include:

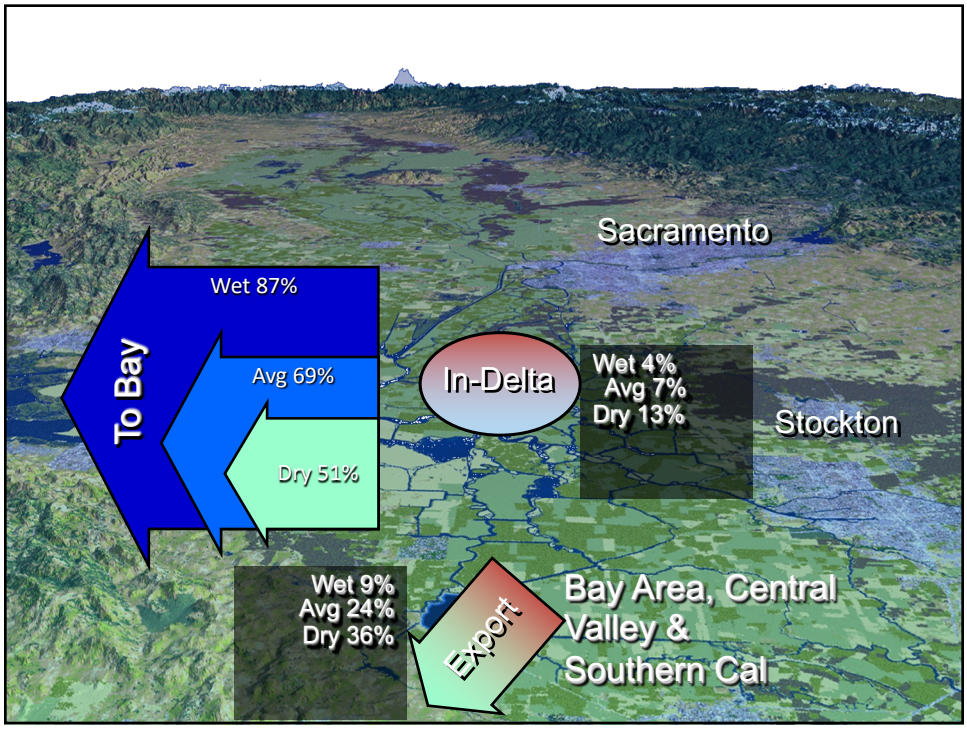
- Agencies are mission-bound
- Perturbations that induce significant change
- Environmental research is a journey not a destination – but '*experimentation*' is not embraced by politicians!
- Sustained commitment to resources is needed
  - monitoring
  - SYNTHESIS with the right team
  - communication

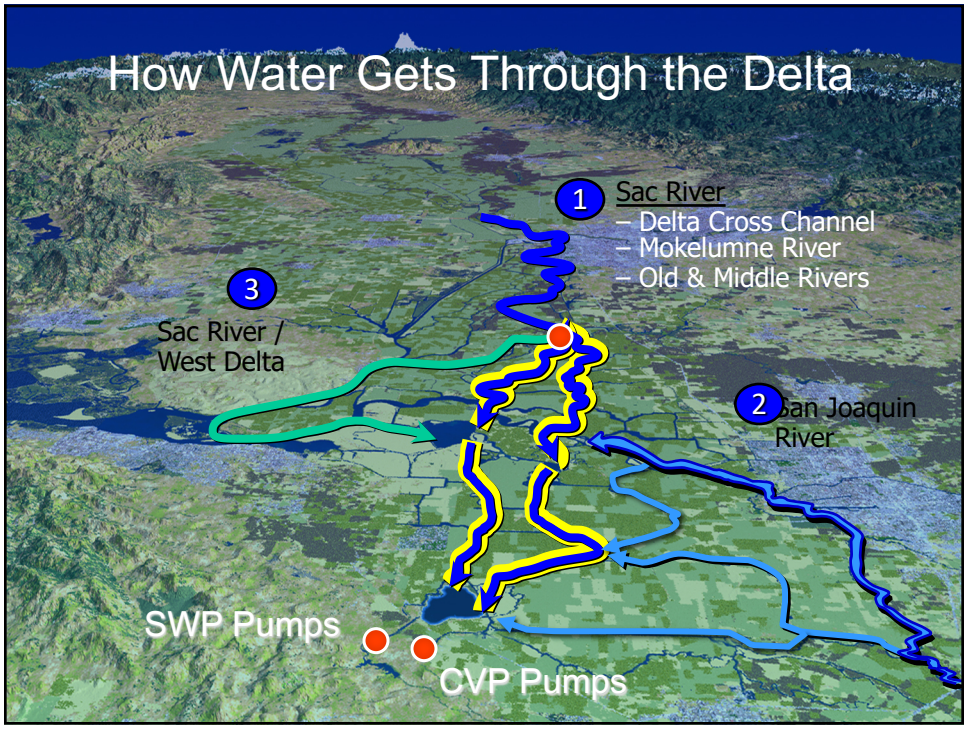
California Precipitation and Population

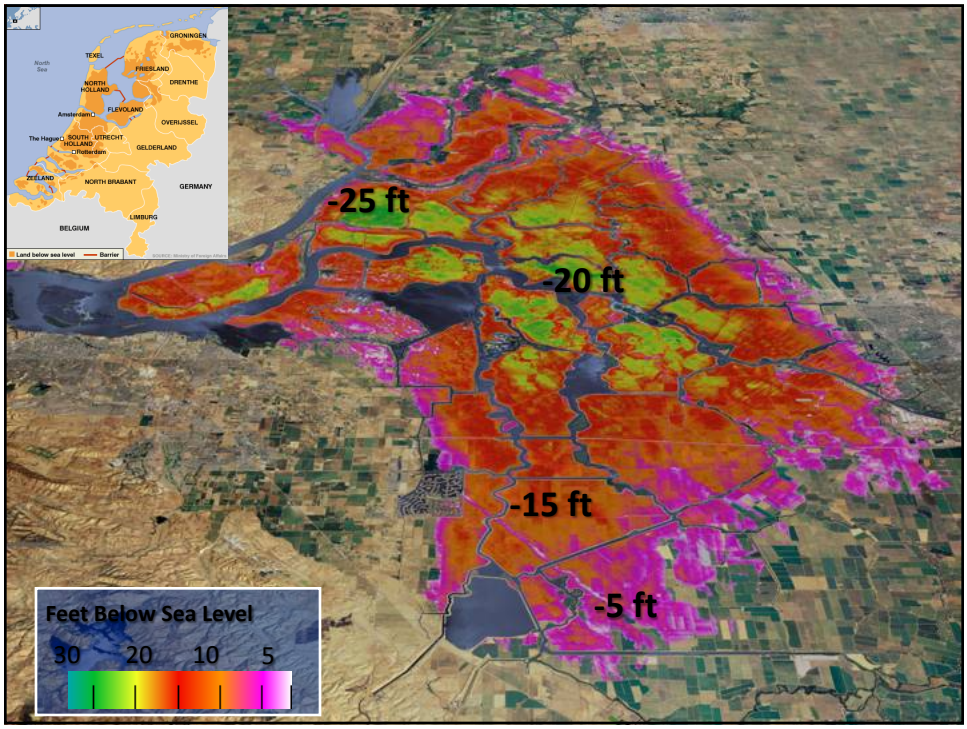



Sacramento-
San Joaquin
Delta
Federal Central Valley Project
20 Reservoirs
11 Hydro-electric power plants
500 miles of canals, siphons, & tunnels
11MAF total storage capacity
State Water Project
21 Reservoirs
17 Pumping Plants
3 Pumping-generating plants
5 Hydro-electric power plants
660 miles of canals, siphons, & tunnels
5.8 MAF total storage capacity
Images from Delta Science Program
Major Rivers
State Projects
Federal Projects
Local Projects
Redding
Sacramento
San Francisco
Fresno
Los Angeles
San Diego

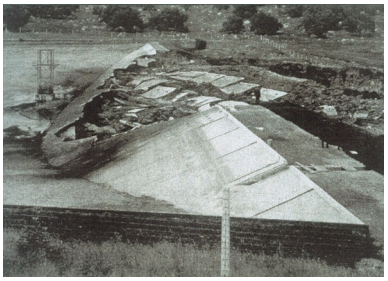

Delta Inflow
Sacramento River
~80% Inflow; good quality
East Side Rivers
~5% Inflow; good quality
Ocean/Tidal
High salinity
San Joaquin River
~15% Inflow; poor quality


Sacramento
To Bay
Wet 87%
Avg 69%
Dry 51%
In-Delta
Wet 4%
Avg 7%
Dry 13%
Stockton
Wet 9%
Avg 24%
Dry 36%
Export
Bay Area, Central Valley & Southern Cal


How Water Gets Through the Delta
1
Sac River
– Delta Cross Channel
– Mokelumne River
– Old & Middle Rivers
3
Sac River /
West Delta
2
San Joaquin
River
SWP Pumps
CVP Pumps



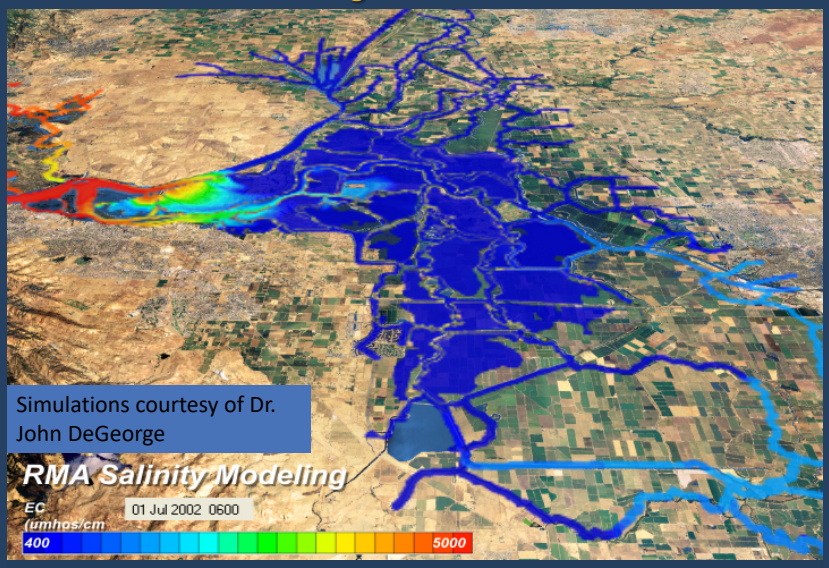
Delta Levees – Seismic Hazard



38

6.5 Magnitude Earthquake

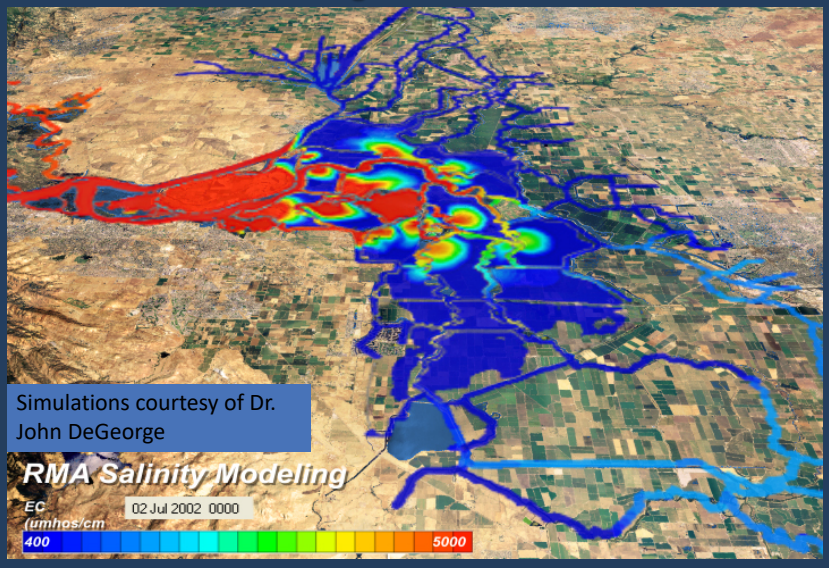
causing 20-Island Failure



0 – 6 hours: Islands flood with fresh water

6.5 Magnitude Earthquake

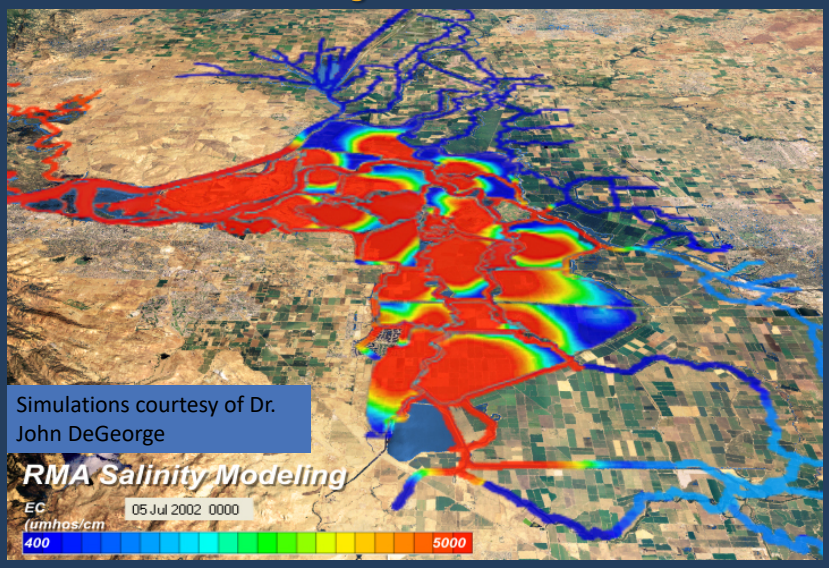
causing 20-Island Failure



12 – 24 hours: Salt water intruding into Delta

6.5 Magnitude Earthquake

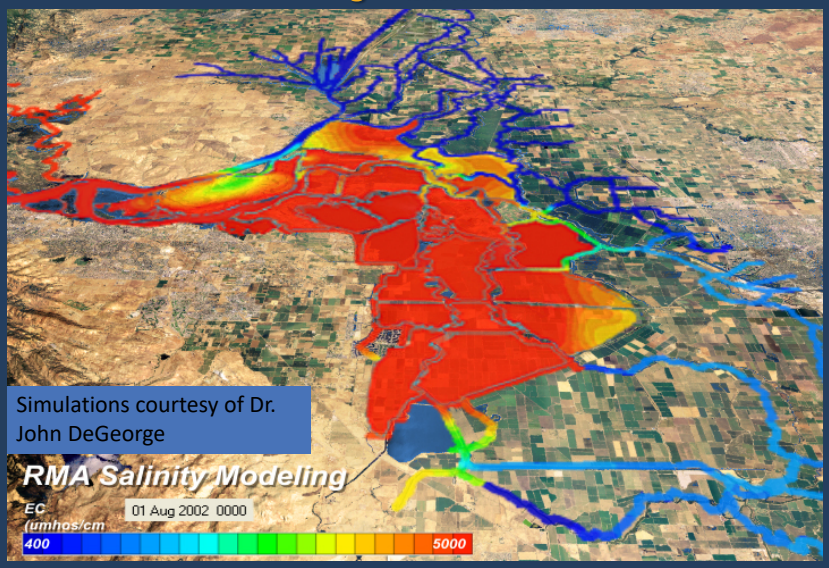
causing 20-Island Failure



1 – 7 days: Salt water throughout Delta

6.5 Magnitude Earthquake

causing 20-Island Failure

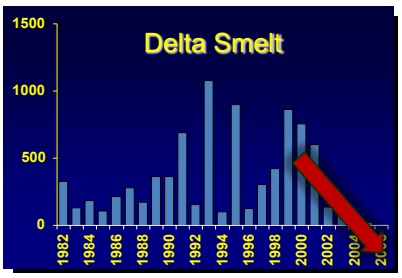


30 days: A saline estuary

The Problems facing California

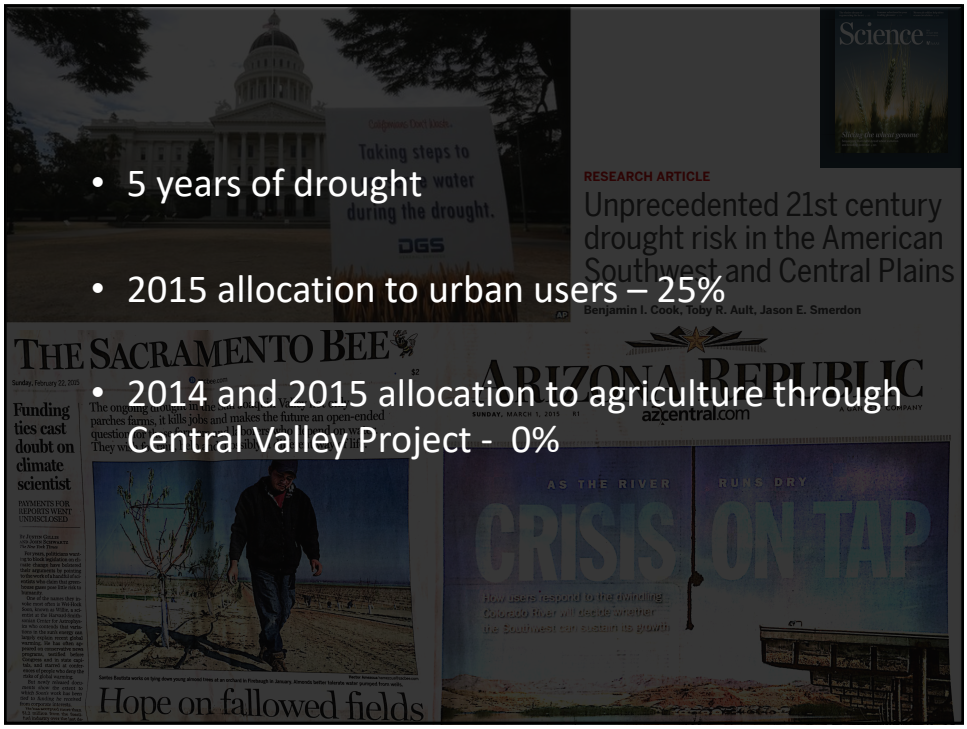
- → 2/3 of California residents rely on Delta water
- → Irrigates up to 4 million acres of California farmland
- → 80% of California's commercial fishery species rely on the Bay-Delta
- → Habitat for 700 species, including 50+ threatened or endangered
- → Hotspot for biodiversity
- → Greatest loss of biodiversity

A Collapse in Delta Smelt Protected by Endangered Species Act

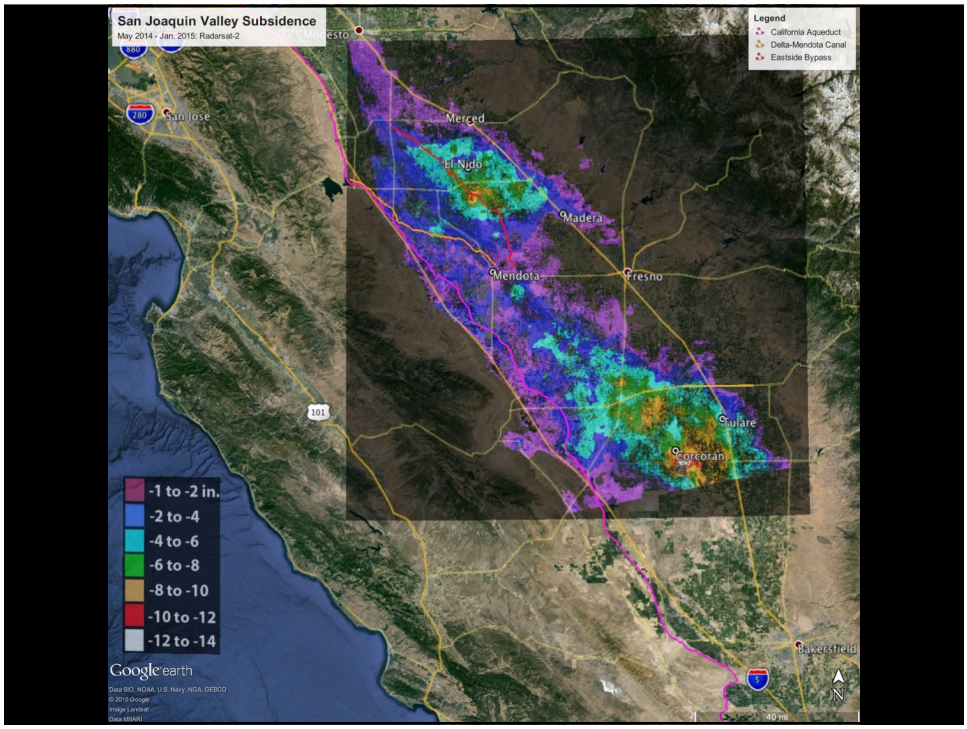


There are many other endangered species – many have conflicting needs (seasonally and spatially).

Who decides?

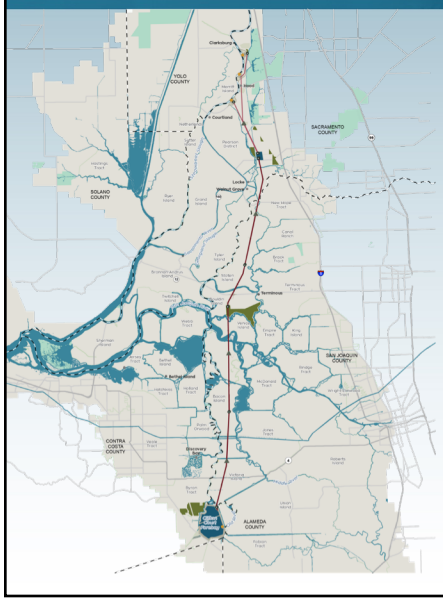


- 5 years of drought
- 2015 allocation to urban users – 25%
- 2014 and 2015 allocation to agriculture through Central Valley Project - 0%

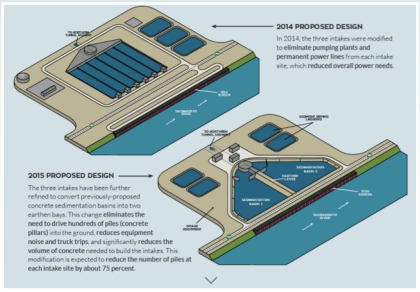


BAY DELTA CONSERVATION PLAN / CALIFORNIA WATER FIX

BAY DELTA CONSERVATION PLAN/CALIFORNIA WATER FIX
PARTIALLY RECIRCULATED DRAFT ENVIRONMENTAL IMPACT REPORT/SUPPLEMENTAL DRAFT ENVIRONMENTAL IMPACT STATEMENT

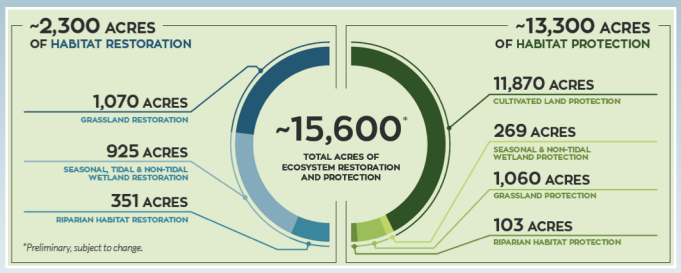


Sacramento-San Joaquin Delta /Project Area



BAY DELTA CONSERVATION PLAN / CALIFORNIA WATER FIX

BAY DELTA CONSERVATION PLAN/CALIFORNIA WATER FIX
PARTIALLY RECIRCULATED DRAFT ENVIRONMENTAL IMPACT REPORT/SUPPLEMENTAL DRAFT ENVIRONMENTAL IMPACT STATEMENT



Environmental Mitigation

CALIFORNIA ECO RESTORE
A STRONGER DELTA ECOSYSTEM.

20,000 hectares

Target: 450 km²

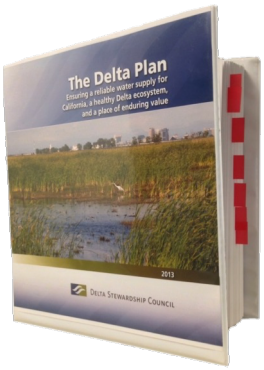
2009 State of California Legislation
The Coequal Goals

"'Coequal goals' means the two goals of providing a **more reliable water supply for California** and **protecting, restoring, and enhancing the Delta ecosystem**. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." *(California Water Code §85054).*

Delta Stewardship Council created to:

- Develop enforceable plan to achieve coequal goals of ecosystem restoration and statewide water supply reliability
- Ensure progress towards those goals
- Oversee and coordinate activities in the Delta among various agencies
- Inform decision-making with best available independent science

What is the Delta Plan?



- Delta Plan draws upon existing state and federal laws and policies and ongoing programs to chart a big-picture course
- The Delta Plan is:
  - ✓14 regulatory policies; 73 recommendations
  - ✓A plan that encourages state and local agencies to implement local and regional projects

Role of Science

- Through our joint federal-state partnership, and with science as our guide, we are taking a comprehensive approach to tackling California's water problems…"

  From July 25, 2012 Governor Brown and President Obama Administration joint announcement on California's water future.

- "In carrying out this section the Council shall make use of the **best available science**."

  California Water Code §85302(g)

There has to be a better way

230+ agencies

Combat Science vs. Collaborative Science

Principles:
Relevant, Credible, Legitimate, Transparent and Timely

Develop a Shared "*State of Delta Knowledge*"

Science should not be used as an excuse for inaction

What is Best Available Science?

Elements include:

- Conceptual Models
- Quantitative Models
- Journal articles [inc. SFEWS]
- Traditional knowledge
- Reports, conference papers
- Peer Review
- Collaborative synthesis
- Sounding Boards/Directed Research/RFPs

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE
Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

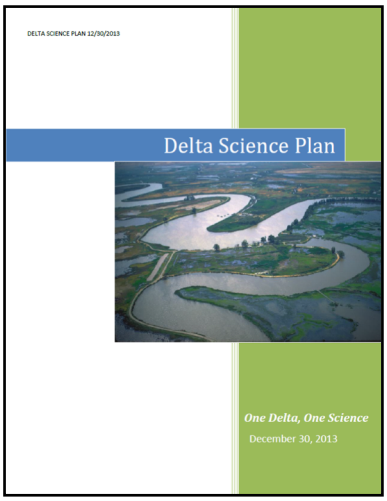
A Framework for Collaborative Science

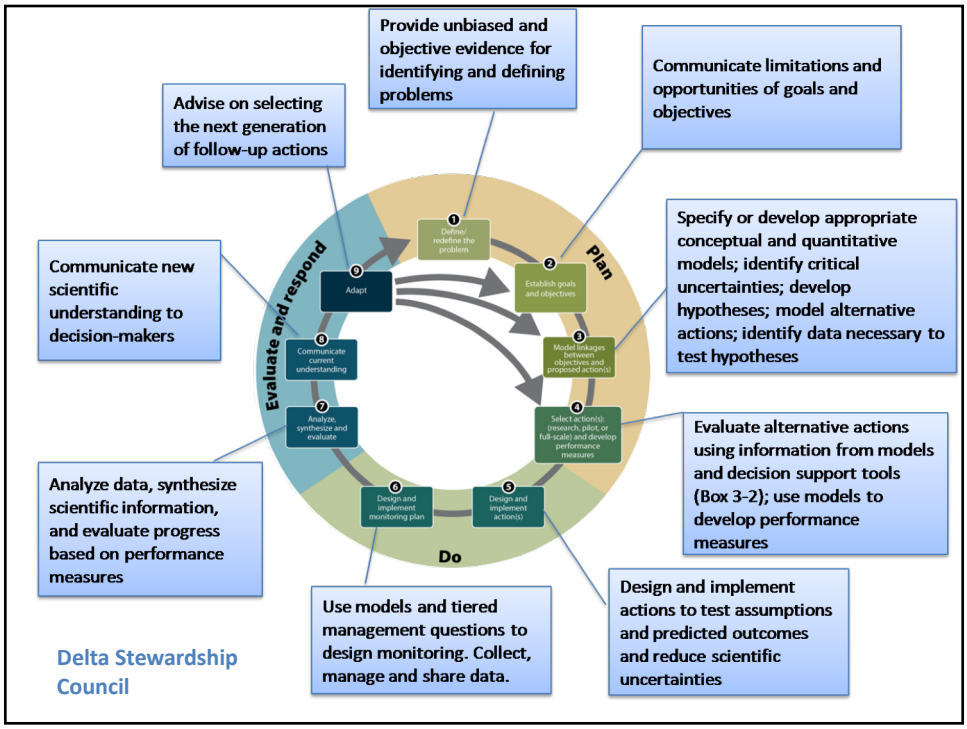
Delta Science Plan

One Delta, One Science

Completed
December 30, 2013
Updated Dec 2016

1000+ contributors
from 230+ organizations



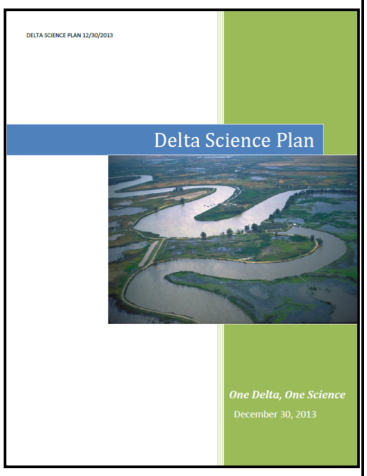


Challenges

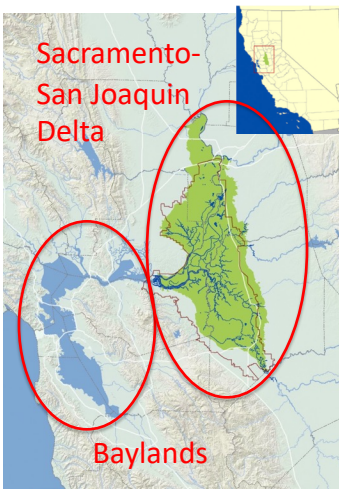
- Creating a perturbation big enough to learn?
  - transformative
  - high risk
- If unanticipated outcome – accept and move on?
- Planning for episodic events
- Who decides?
- Importance of leadership and decision authority
- Science to inform management and policy

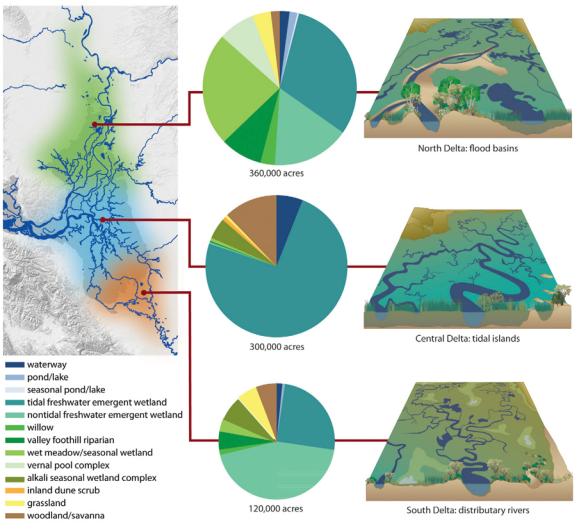
- Building a common body of knowledge
  - Credible, Legitimate, Relevant and Transparent
- Managing scientific conflict
  - embrace legitimate differences of opinion
  - sift out selective, obfuscated, biased information
- Infrastructure for Science
  - Data accessibility
  - Community Modeling

ONE DELTA ONE SCIENCE



Baylands and the Sacramento -San Joaquin Delta





The Baylands and Climate Change: WHAT WE CAN DO

SPUR
16 Feb 2016
San Francisco, CA

LETITIA GRENIER
SAN FRANCISCO ESTUARY INSTITUTE

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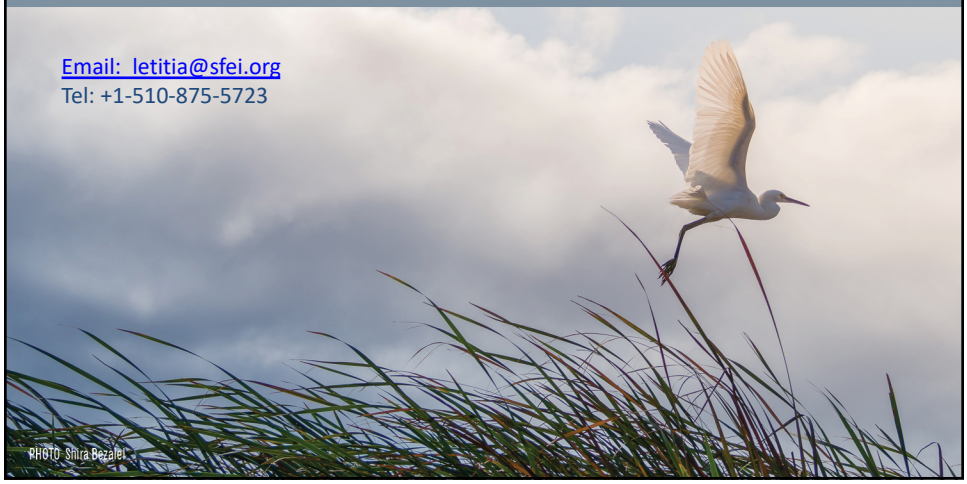
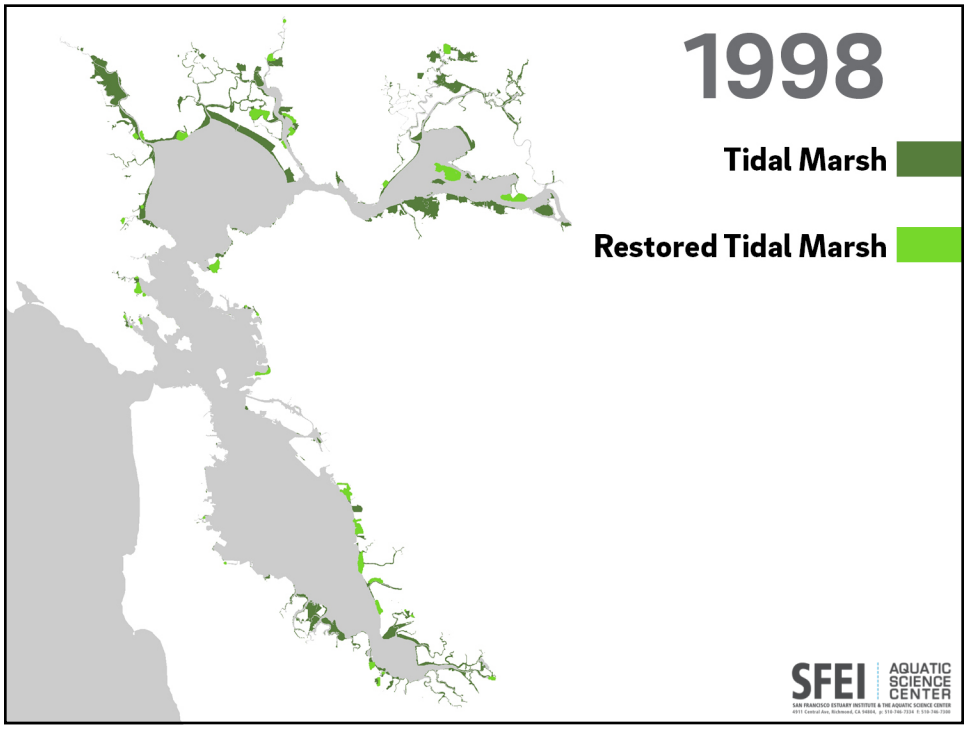
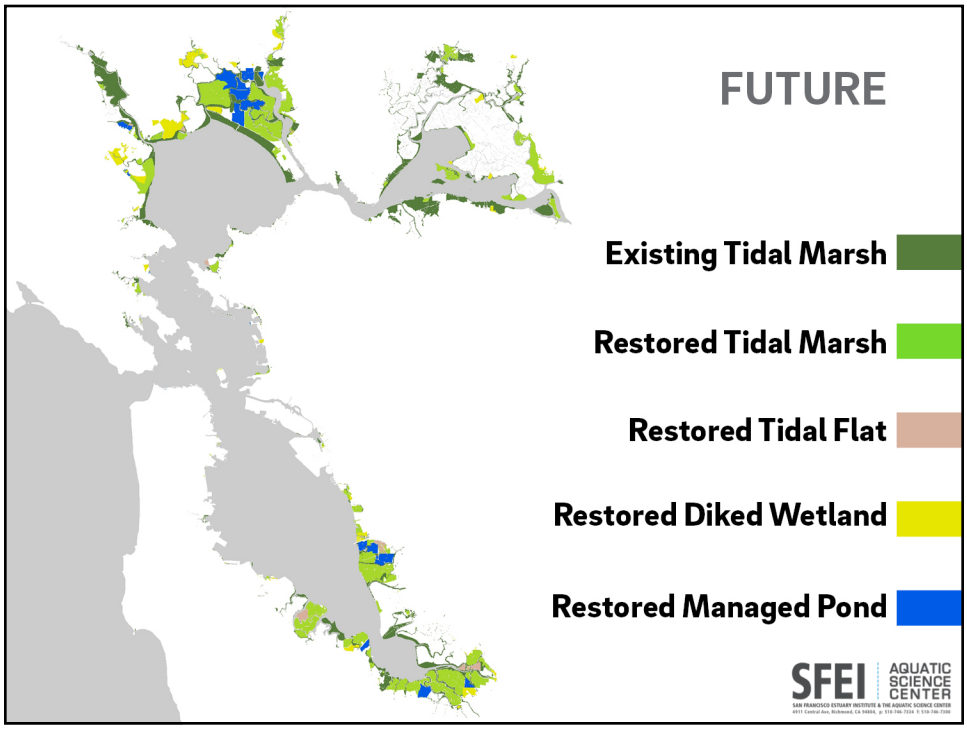
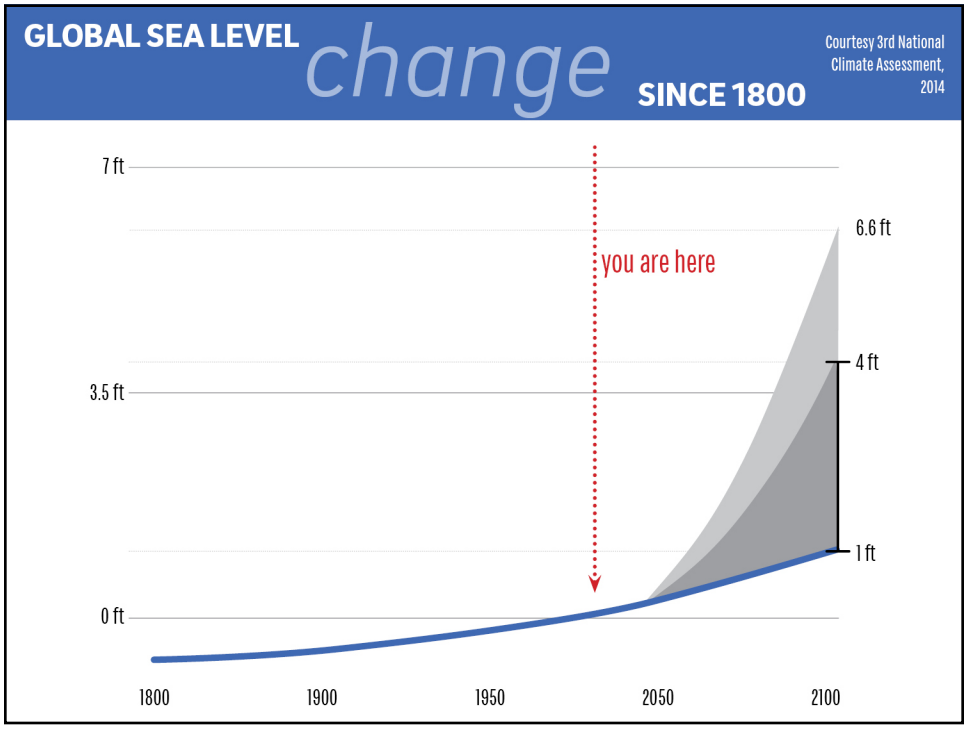
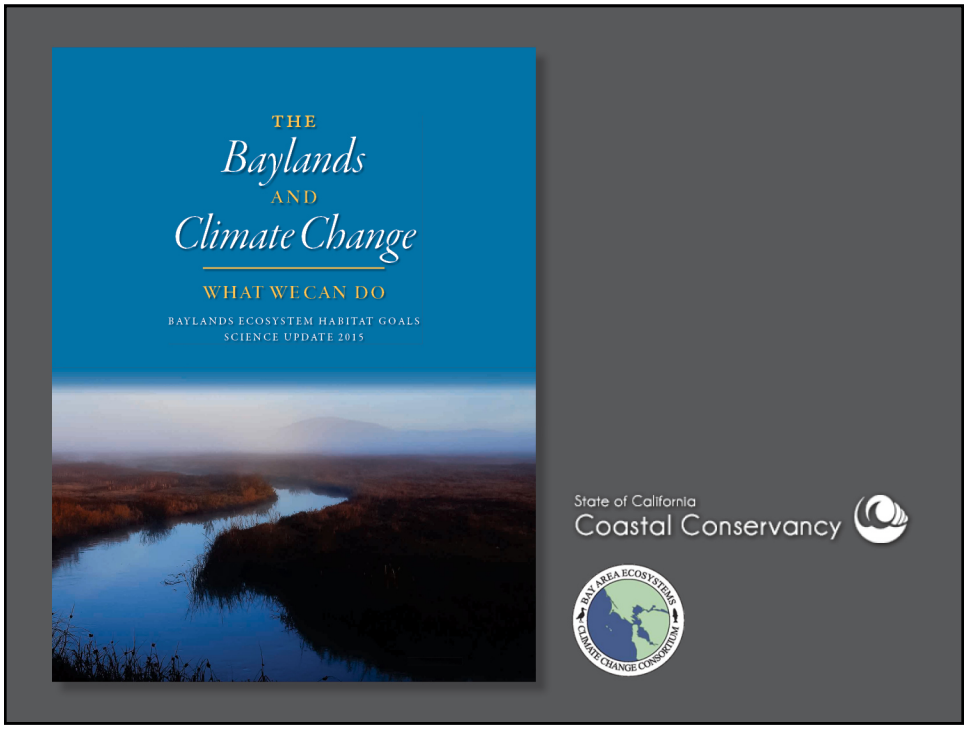


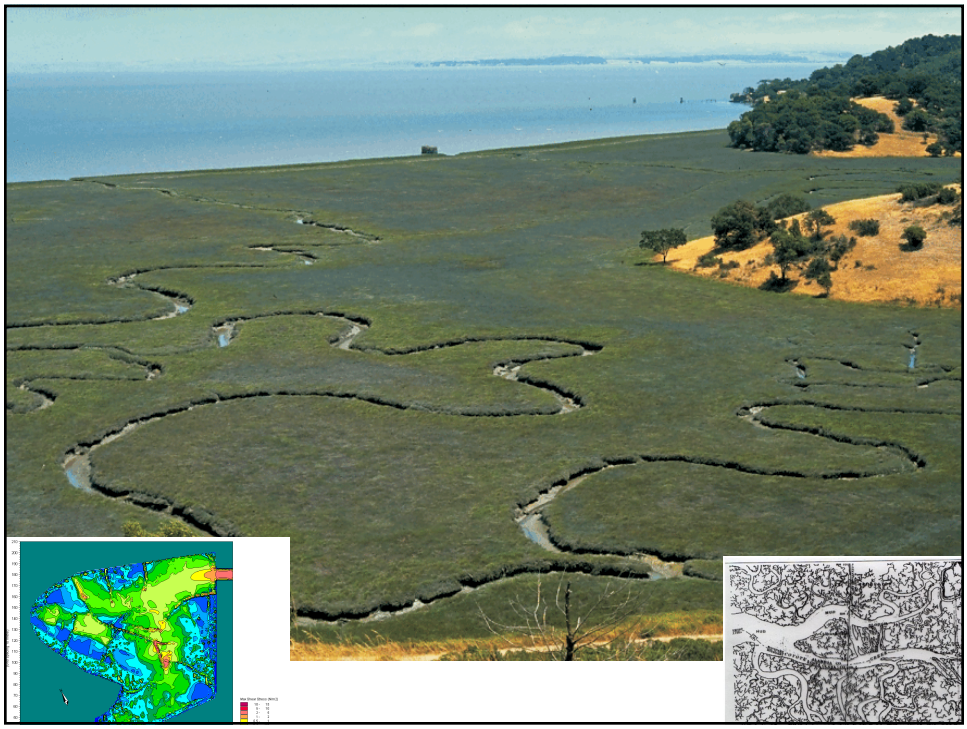

1998
Tidal Marsh
Restored Tidal Marsh
SFEI
AQUATIC SCIENCE CENTER

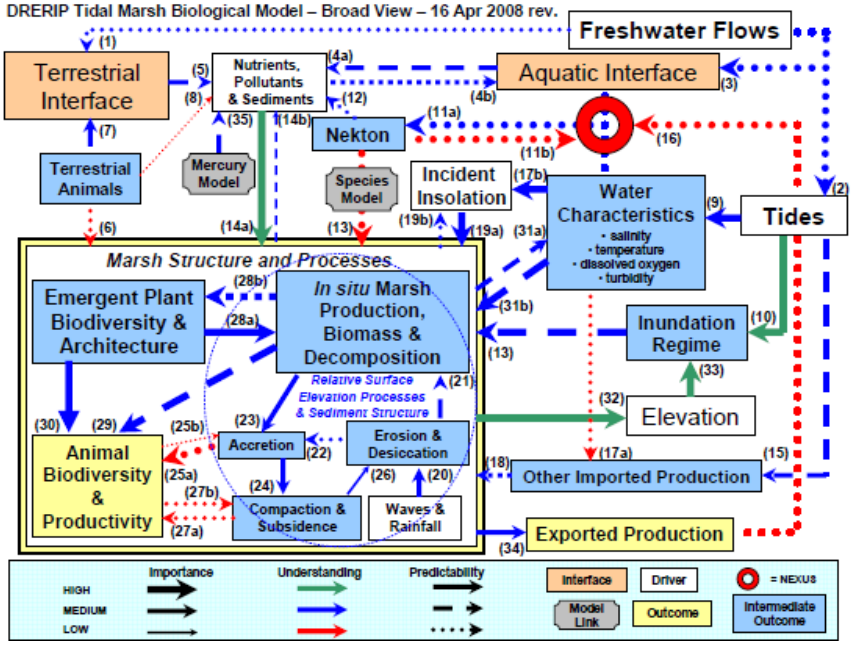

FUTURE
Existing Tidal Marsh
Restored Tidal Marsh
Restored Tidal Flat
Restored Diked Wetland
Restored Managed Pond
SFEI
AQUATIC SCIENCE CENTER


GLOBAL SEA LEVEL change SINCE 1800
Courtesy 3rd National Climate Assessment, 2014
7 ft
3.5 ft
0 ft
you are here
6.6 ft
4 ft
1 ft
1800
1900
1950
2050
2100


THE
Baylands
AND
Climate Change
WHAT WE CAN DO
BAYLANDS ECOSYSTEM HABITAT GOALS
SCIENCE UPDATE 2015
State of California
Coastal Conservancy
BAY AREA ECOSYSTEMS
CLIMATE CHANGE CONSORTIUM


WHAT WE CAN DO
• Restore complete systems, including processes
• Restore soon, in areas marshes are likely to persist
• Plan for the Baylands to migrate
Shira Bezalel
SFEI
AQUATIC SCIENCE CENTER





Kneib *et al.* 2008

WE HAVE *choices to make*

http://ian.umces.edu/work_with_us/environmental_report_card_production/

Can we learn from C.P. Snow?

(1) The objective must be clear and not too grandiloquently vast. A scientific committee set to advise on the welfare of all mankind is not likely to get very far. The objective of the Tizard Committee—to defend England in a foreseeable short-term future against air attack—is about as much as anyone can hope actually to cope with.

Delta Stewardship Council www.deltacouncil.ca.gov

Science and Society Transformed by Data

- Science and Scholarship are team sports
- Innovation and discovery will be driven by analysis
- Synthesis of diverse data streams
- Models encapsulate current knowledge

Tools change how we interact with one another, how we behave and therefore how we think.

www.wilsonminer.com

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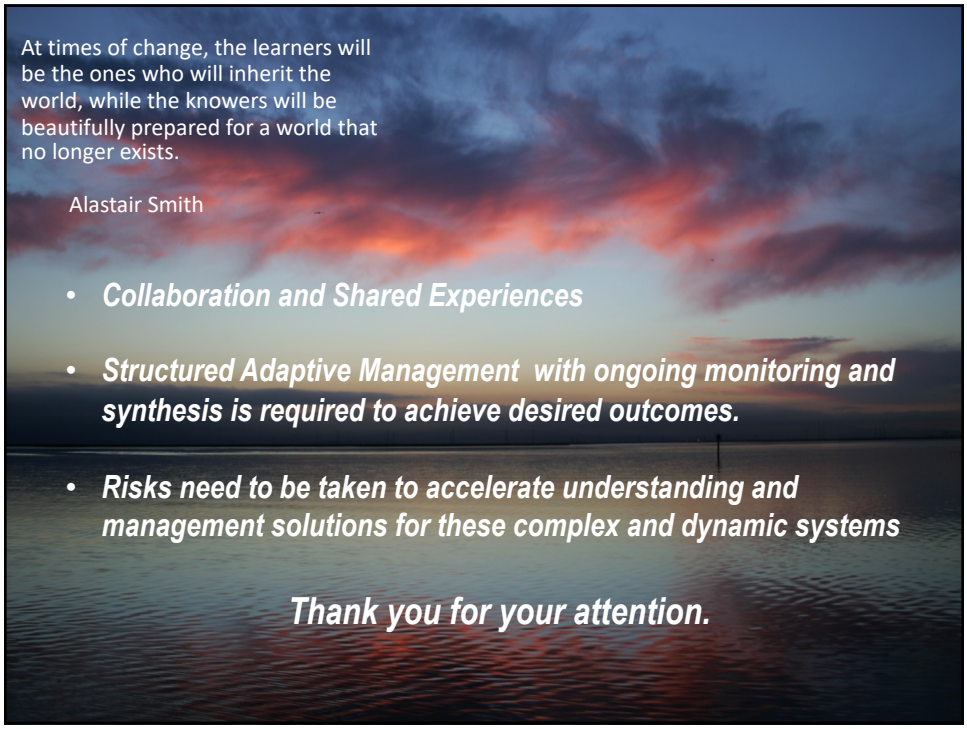
At times of change, the learners will be the ones who will inherit the world, while the knowers will be beautifully prepared for a world that no longer exists.
Alastair Smith
• Collaboration and Shared Experiences
• Structured Adaptive Management with ongoing monitoring and synthesis is required to achieve desired outcomes.
• Risks need to be taken to accelerate understanding and management solutions for these complex and dynamic systems
Thank you for your attention.