CALFED Independent Science Board

Water Quality Indicators
February 21, 2007

part 1: Overview
Ecosystem and Human Health

Water Quality Indicators - Overview

Review of draft Phase 1 Report (Sept. 2006)

- Base indicators on Program goals and *quantifiable* objectives
- Cover full range of beneficial uses
- Limited set of outcome indicators

Update: main work plan elements

- Evaluate a suite of water quality parameters
- Select indicators for causal factors (“driver”), intermediate outcomes, and “system outcomes”
- Incorporate monitoring

Questions and discussion

Indicators derive from Program goals and objectives

Provide good water quality for all beneficial uses.

Program Mission Statement

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Program Water Quality Goals for Ecosystem and Human Health

• Eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife and people.

• Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed. *Ecosystem Restoration Program, Goal 6.*

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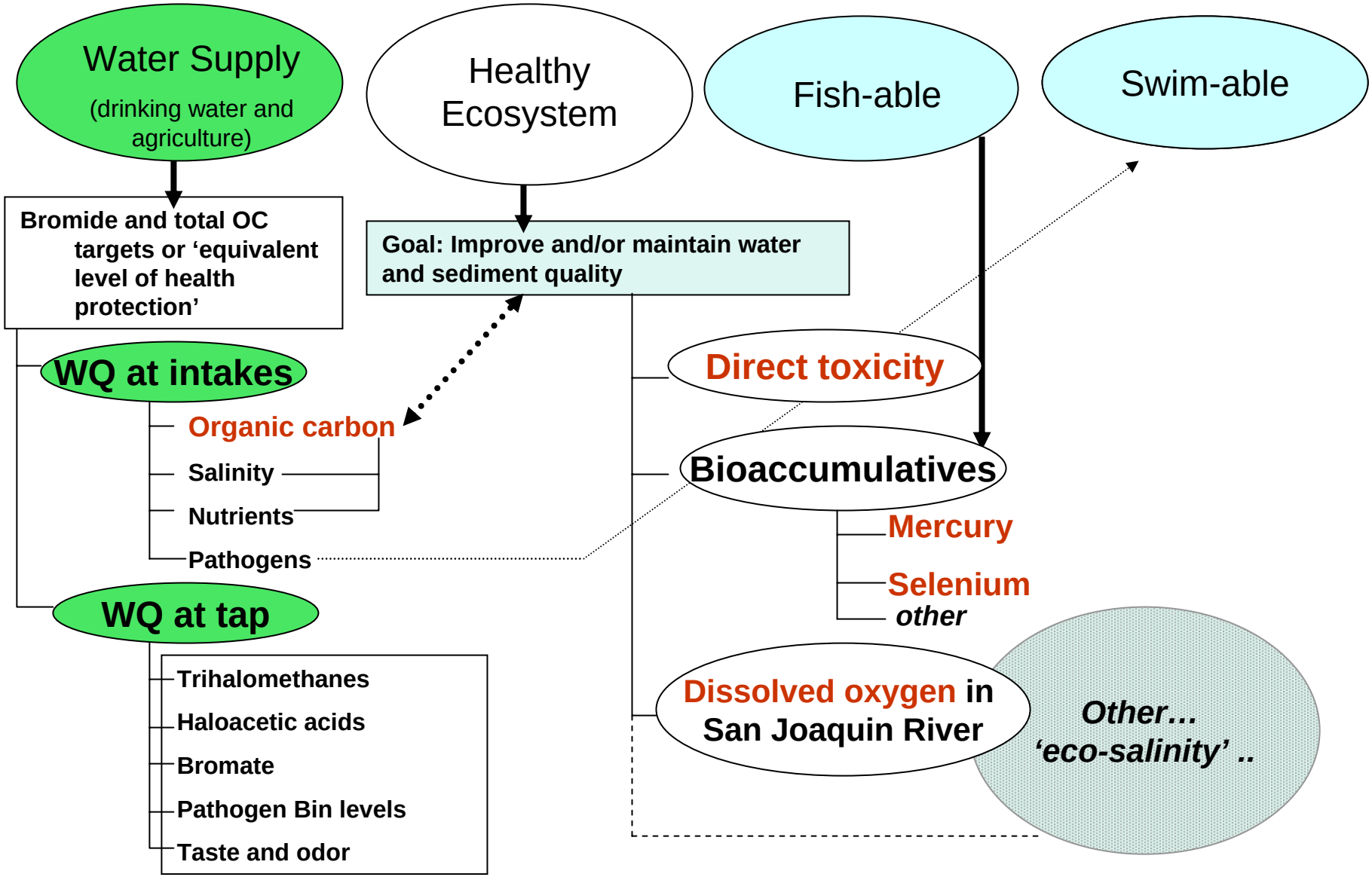
Objectives:

° **Reduce toxic contaminants**
- **-- Reduce direct toxicity**
- **-- Reduce bioaccumulatives**

° **Reduce oxygen-depleting substances**

Range of beneficial uses and water quality parameters



Toxicity objectives: • Identify toxic constituents and reduce toxicity to aquatic organisms • Reduce loadings of toxic contaminants • Conduct studies to identify causes of unknown toxicity	**Toxicity outcome indicators**: • Indications that toxicity can be attributed to known sources • No likely significant aquatic toxicity • Establish if toxicity is a significant factor in POD; if so, identify contaminants and sources	
Mercury objective: • Improve and/or maintain water and sediment quality to levels that do not adversely affect aquatic organisms, humans, and wildlife **Dissolved oxygen objective:** • Reduce oxygen-depleting substances	**Mercury outcome indicators**: • Mercury concentrations in tissue of representative "sport fish" • Public health benefits • Mercury concentrations in tissue of representative biosentinels ***Dissolved oxygen indicators pending***	
Drinking water objectives: • Maintain water quality at the Delta intakes for safe, reliable drinking supplies • Drinking water quality at the tap that meets drinking water targets	**DW outcome indicators**: • Intake water quality: organic carbon, salinity/bromide, nutrients, pathogens • Water quality "at the tap" for Delta providers: salinity, taste/odor, disinfection byproducts, treatment levels	

Proposed ecosystem and human health outcome indicators

from Draft Phase 1 Report

- **Toxicity**
  - Toxicity Identification Evaluations (TIE) indicate that sources of toxicity can be identified
  - Evidence of no likely significant toxicity to aquatic test organisms in water and sediment
  - Establish whether contaminants are a significant factor in the decline of Delta pelagic organisms and if so, identify contaminants and sources
  - *Conduct research on biomarkers*

Proposed outcome indicators, cont.

from Draft Phase 1 Report

Mercury (methylmercury)

- **Tissue concentrations in biosentinel species (birds, small fish, invertebrates)**
- **Mercury tissue concentrations in fish consumed by humans**
- **Metric to measure the effectiveness of outreach to reduce human exposure to mercury from eating contaminated fish**

The tissue concentration indicators track the Regional Water Board's proposed approach to objectives:

- ***Targets are protective values***
- ***Need characterization and control studies to understand methylation processes***

Need intermediate targets, in light of current limited understanding and complexity of management and control measures

Process to develop indicators: Phase 1 work plan (Dec. 2006+)

- ✓ Define a broader array of water quality parameters affecting the Delta *(Plan Activity 2.1).* Add:
  - Selenium
  - Dissolved oxygen in the lower San Joaquin River
  - Organic carbon
  - More specific investigation of toxicity (pyrethroids)

- ✓ Use conceptual models from "Delta Ecosystem Regional Ecosystem Restoration Implementation Plan" *(DRERIP)* to help define important "drivers," processes and intermediate outcomes, and end outcomes– and associated indicators. *(Activity 2.2)*
  - Where possible, identify quantitative targets and/or
  - define reference conditions

- ✓ Link indicator topics to monitoring data *(Activity 3)*
  - Select "informative" topics for preliminary indicator work
  - Identify monitoring gaps

Process to develop indicators: Phase 1 Work Plan, *cont.*

Work Plan activities should take advantage of complementary projects. For example:

- **Conduct comprehensive review and assessment** based on CALFED mercury projects and related work. Begins spring 2007.

- **Develop monitoring plans**
  - Comprehensive Monitoring, Assessment and Research Program
  - Coordinate with the State and Regional Water Board Programs

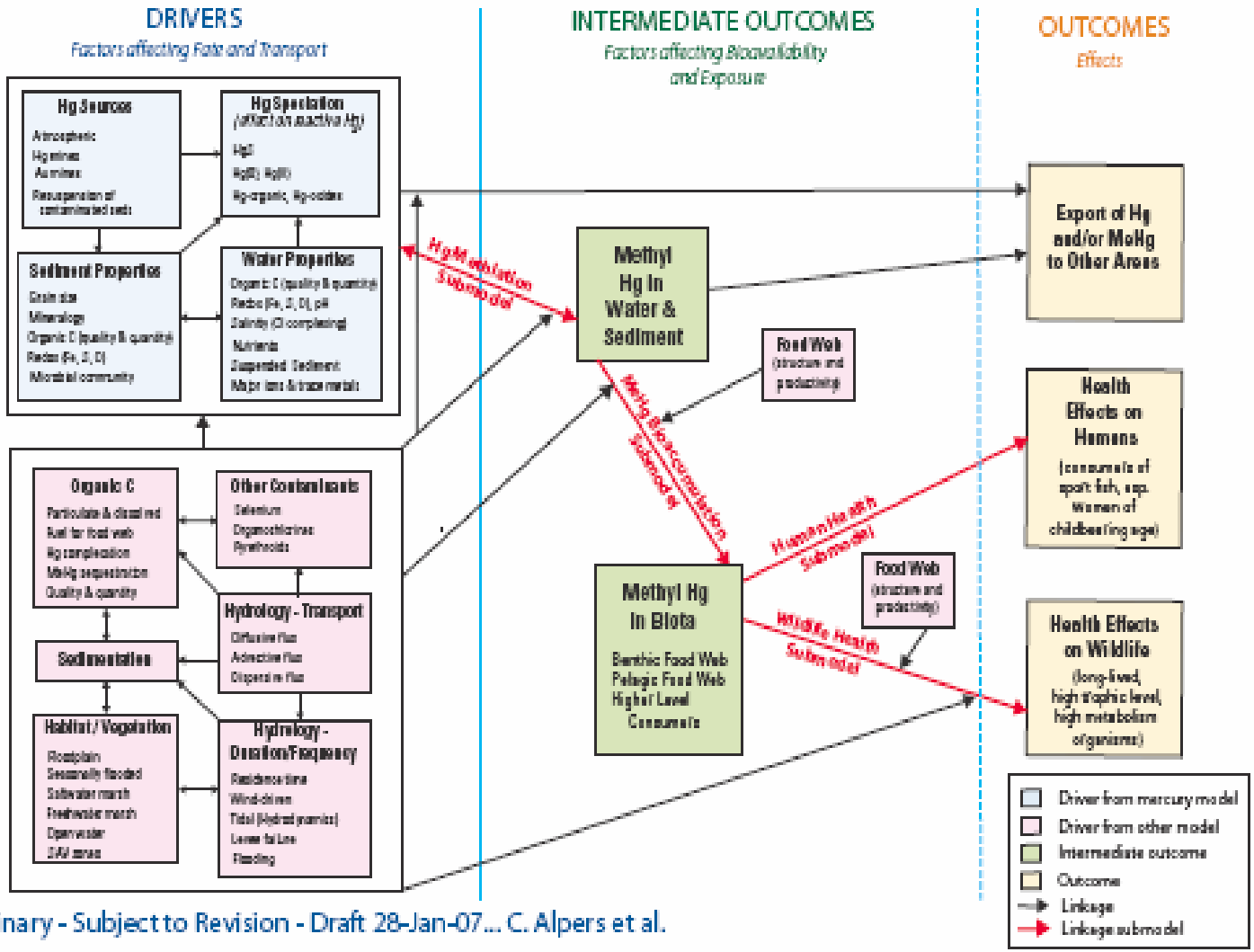
- **Provide guidance for wetland monitoring** and development of mercury management practices through experimental design in CALFED agency and other projects in the Delta.

- **Continue use of information from DRERIP**

Plans for developing mercury indicators

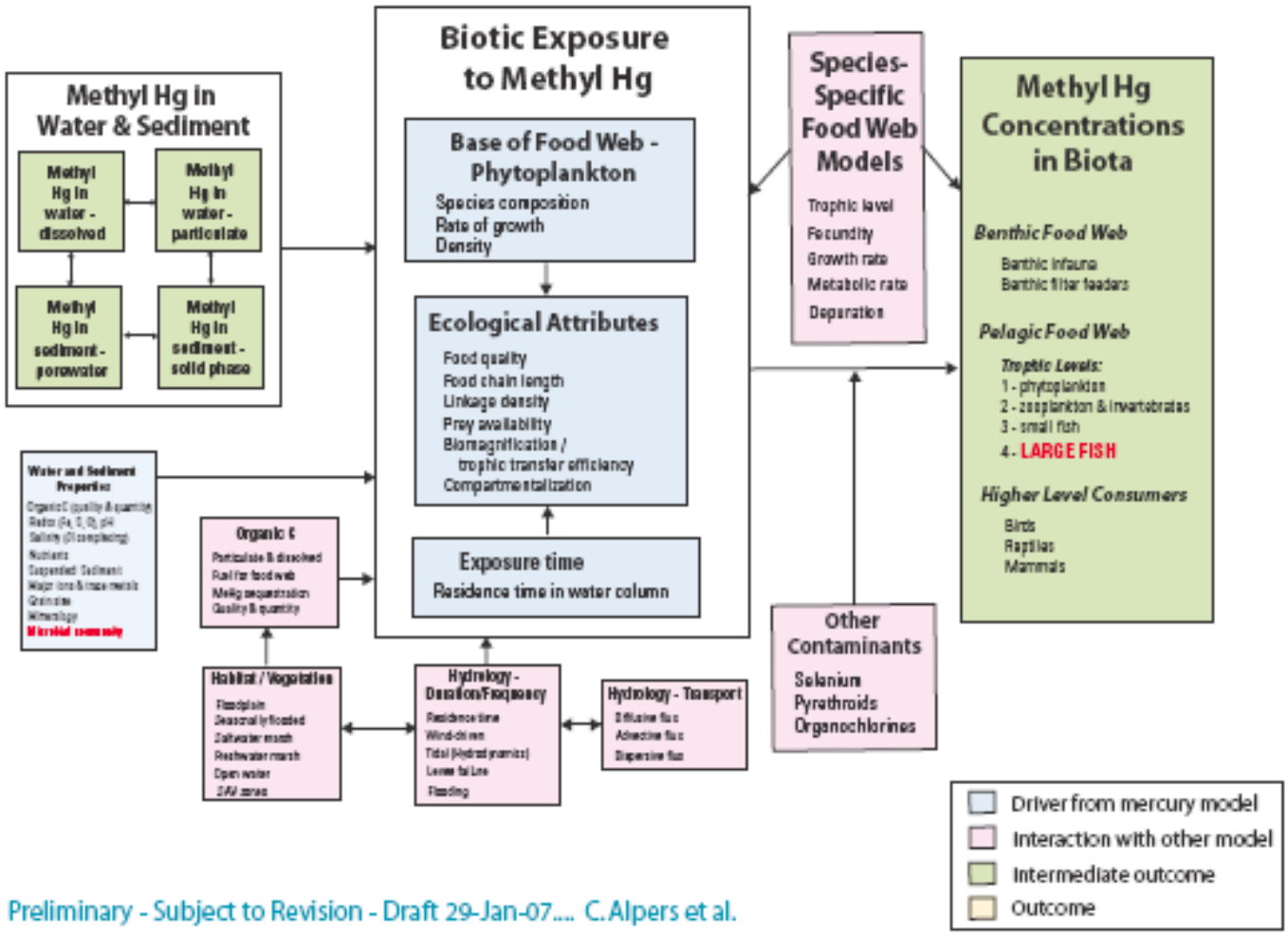
- ✓ **Learn from CALFED-funded mercury projects.**
  - Assessment of ecological and human health impacts of mercury in the Bay-Delta watershed
  - Biogeochemical mercury transformations and trophic transfer
  - Mass balance: transport, cycling and fate of mercury in the Delta and tributaries
  - Mercury cycling and release from wetlands
  - Mercury in birds and fish
  - Fish contamination monitoring, stakeholder involvement and risk communication
- ✓ **Use workshops to launch synthesis of research.**
- ✓ **Coordinate with Regional Water Board Basin Plan amendments/ TMDL to control total and methylmercury.**

Conceptual Model for Mercury in the Sacramento-San Joaquin Delta: Delta Regional Ecosystem Restoration Implementation Plan (DRERIP)



Preliminary - Subject to Revision - Draft 28-Jan-07... C. Alpers et al.

MERCURY CONCEPTUAL MODEL --- SUBMODEL #2 - BIOACCUMULATION



Preliminary - Subject to Revision - Draft 29-Jan-07.... C. Alpers et al.

The future…

- FINISH initial plan by June 2007 (Phase 1) *then*
- Begin development of indicators (Phase 2, *Work Plan activity 3.4 ff*)
  - Data gathering and analysis
  - Preliminary reporting
  - Plan to address data gaps through CMARP and other monitoring programs

….Continuous improvement….

Questions and Discussion

- Do we have an appropriate suite of water quality parameters and associated indicators?
  - In light of potential future changes in Delta management and
  - Uncontrollable factors (e.g., salinity changes with sea level rise)
- Are the selected water quality indicators linked to important ecosystem and other beneficial use effects?
- How do we make/measure connections between management actions and effects?
  - What forms of monitoring?
  - What analytical tools are available, and what are the associated data needs?

Status of Performance Measures for Drinking Water Quality

February 21, 2007

Independent Science Board

Lisa Holm, WQ Program

Water Quality Goals

Beneficial Use Framework for Objectives

Program Mission Statement:

Provide good water quality for all beneficial uses.

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Drinking water

Continuously improve source water quality that allows for municipal water suppliers to deliver safe, reliable, and affordable drinking water that meets and, where feasible, is better than applicable drinking water standards, in a cost effective way.

↓

Achieve either: (a) average concentrations at Clifton Court Forebay and other southern and central Delta drinking water intakes of 50 mg/L bromide and 3.0 mg/L total organic carbon, or (b) *an equivalent level of public health protection* using a cost-effective combination of alternative source waters, source control, and treatment technologies.

Drinking Water Quality

- Performance measures dependent on other ongoing assessment efforts:
  - Central Valley Drinking Water Policy
  - Final Program Assessment
  - Delta Conveyance Studies
  - Funded Projects
- Because of this, progress made on conceptual models, data collection, and assessment

Central Valley Drinking Water Policy

- Prioritization exercise on constituents of concern
- Developed conceptual models for:
  - Organic Carbon
  - Nutrients
  - Pathogens
- Continuing to refine organic carbon model
- Researching drinking water quality goals
- Future work on:
  - Drinking water treatment
  - Controllable sources
- Goal: Development of a Basin Plan Amendment by end of 2009

CALFED WQ “Final” Assessment

- System-wide look at drinking water quality:
  - Background on goals and interpretation
  - Assessment of watershed sources, transport to intakes and experiencing with controlling
  - Assessment of treated water quality, development of representative conceptual models of treated water quality
  - Initial economics evaluation
  - Integration with conveyance and storage studies

Final Assessment Goals

- Inform Stage 1 decision on conveyance by providing drinking water quality context
- Identify priorities for Stage 2 implementation of WQ Program, including initial development of performance measures, monitoring and research needs
- Technical work will also support Central Valley Drinking Water Policy (salinity and treatment conceptual models)

CALFED Conveyance Studies

- Through Delta Facility, Delta Cross Channel and Franks Tract studies focus on drinking water quality and fish impacts
- Primary constituent studied is salinity
- Conveyance Studies have significantly increased our understanding of Delta hydrodynamics

Funded Projects

- USGS assessment of in-Delta water quality, studies of organic carbon in Delta and State Water Project, watershed size investigations
- MWQI real-time (high frequency) samplers at key locations and research projects on urban runoff
- Other non-point source studies and demonstrations of source control

Performance Measure Development Process

- System-level conceptual models
- Tiered basin, watershed-level conceptual models
- Information/Data Assembly and Analysis
- Identification of Critical Performance Indicators
- Gap and Uncertainty Analysis

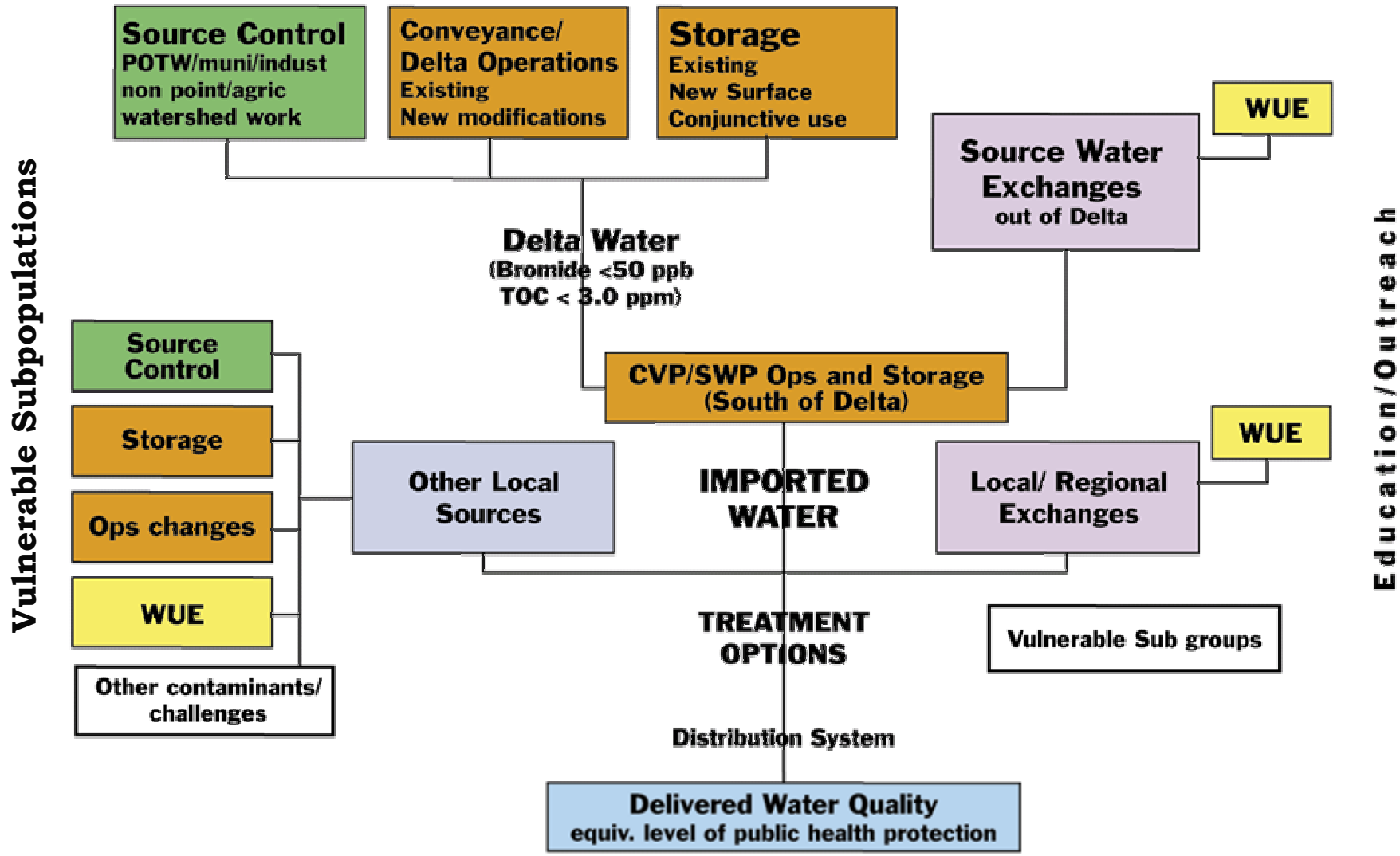
Multiple Barrier Principle

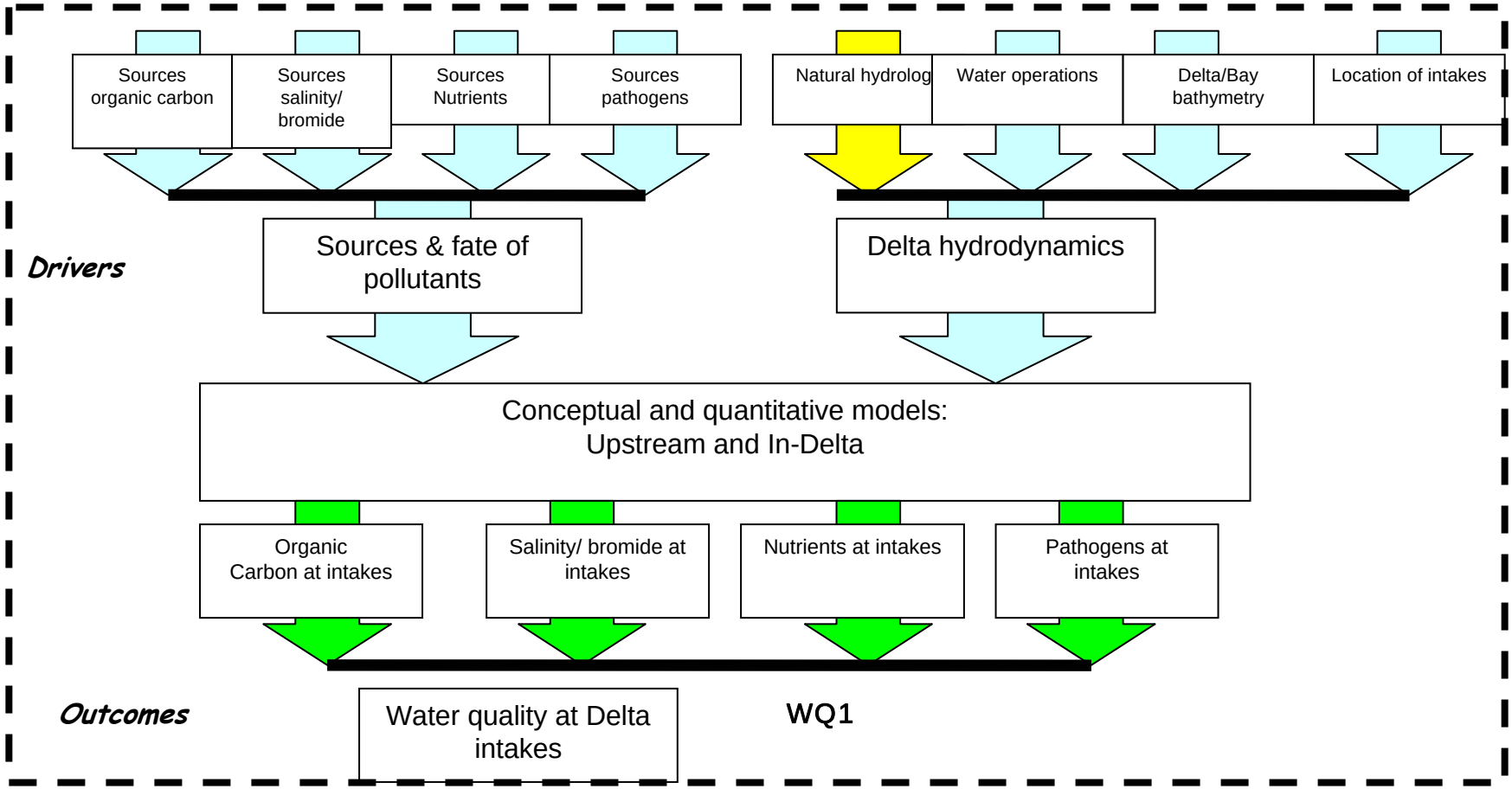
Source Protection

Treatment Effectiveness

Distribution Integrity

“Equivalent Level of Public Health Protection”



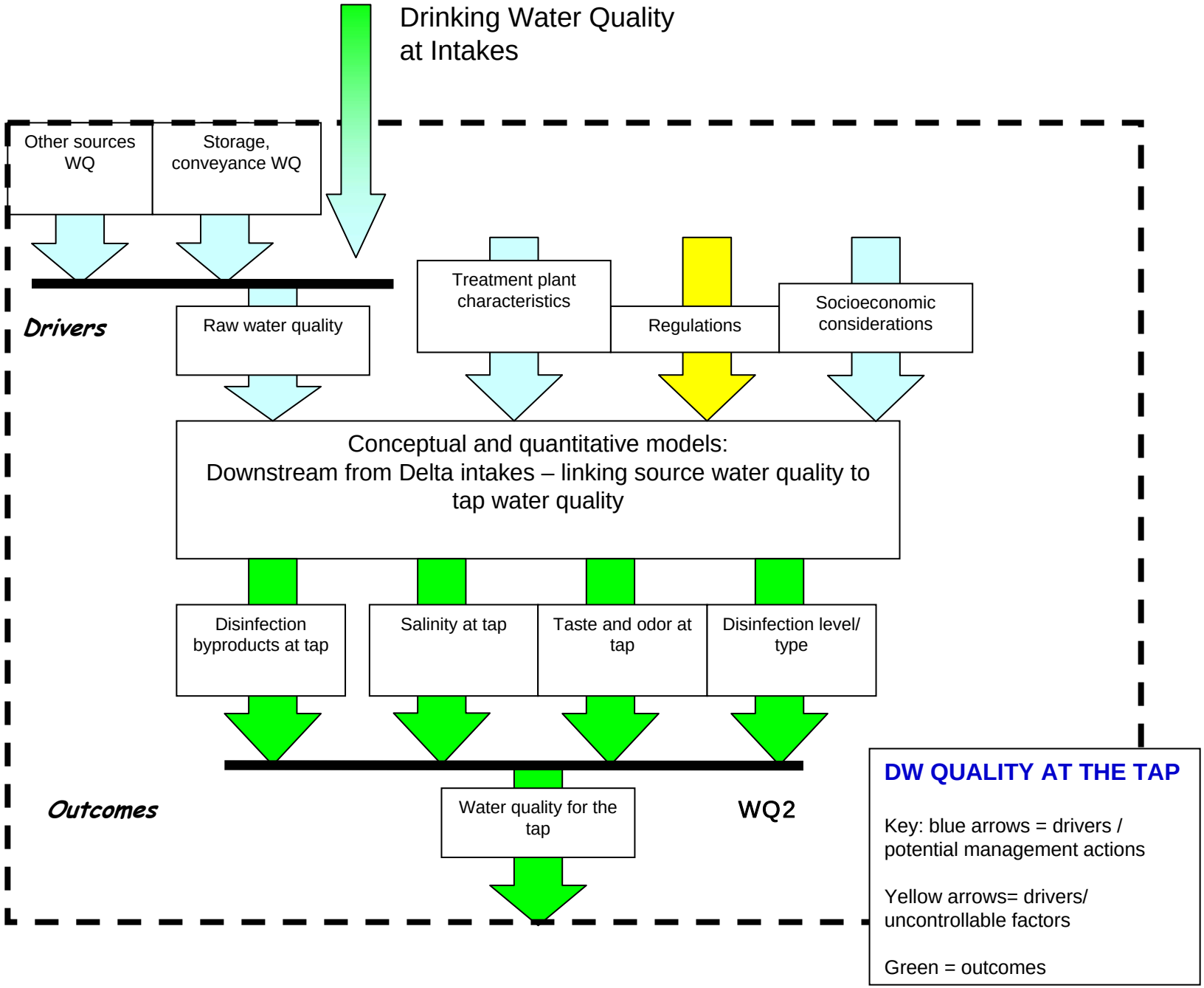


DRINKING WATER QUALITY AT THE INTAKES

Key: Blue arrows = drivers / potential management actions

Yellow arrows = drivers/ uncontrollable factors

Green = outcomes


Drinking Water Quality at Intakes
Other sources WQ
Storage, conveyance WQ
Drivers
Raw water quality
Treatment plant characteristics
Regulations
Socioeconomic considerations
Conceptual and quantitative models: Downstream from Delta intakes – linking source water quality to tap water quality
Disinfection byproducts at tap
Salinity at tap
Taste and odor at tap
Disinfection level/ type
Outcomes
Water quality for the tap
WQ2
DW QUALITY AT THE TAP
Key: blue arrows = drivers / potential management actions
Yellow arrows= drivers/ uncontrollable factors
Green = outcomes

Identified desired outcomes/values of treated water

Drivers

CONCEPTUAL MODEL

Outcomes/ Values

Public Health & Palatability

250 mg/L Cl
Maintain pathogen bin
5 mg/L Br issue
50 ug/L TTHM
40 ug/L HAA5

Treatment costs

$ per capita
$ per gallon treatment/ capital costs

Reliability & flexibility

Meet current regs
Risk of failure / ability to respond to emergencies
Likelihood of meeting regs
Able to meet future regulations before they take affect (aka meet benchmarks set by program)

Impacts on corrosion and recycling

Targets

Meet regulations 100% of time
Flexibility to respond to emergencies
Likelihood of meeting regs
Able to meet future regulations before they take affect (aka meet benchmarks set by program)

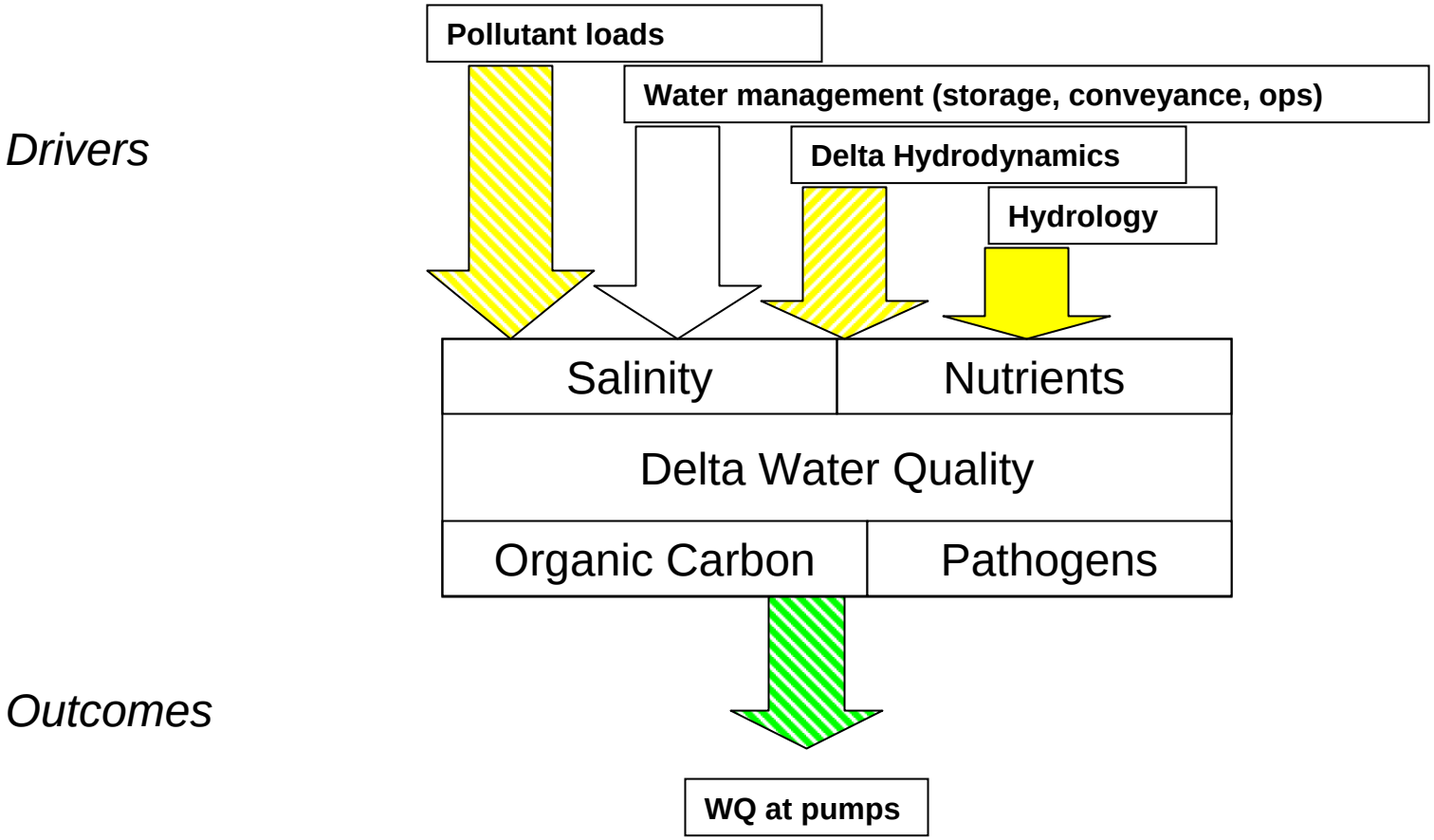
Impacts on corrosion and recycling

Make cost-efficient choices

Data Analysis

- Presentation of available data
- Variety of ways to look at data (time series, averaging schemes, geographical, ambient v. sources)
- Using statistical methods and numerical models to analyze and as filter
- Started with San Joaquin organic carbon in 2005, have since also started on Sacramento organic carbon, salinity, and drinking water treatment

Watershed Data Analysis

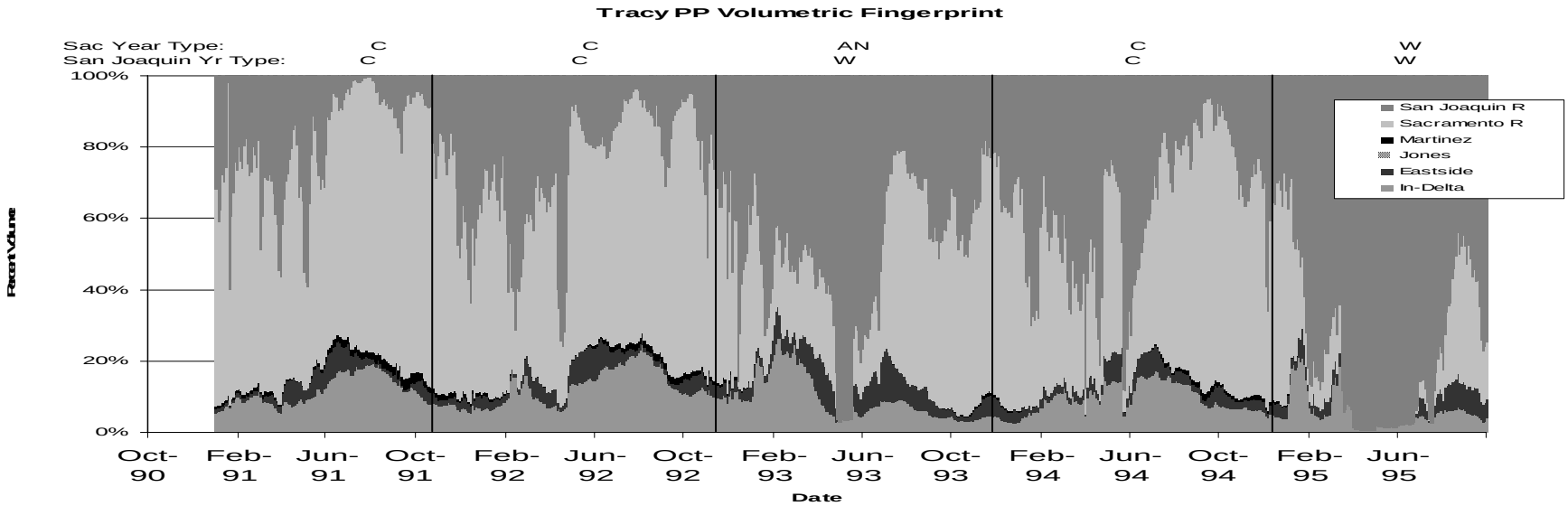

Drivers
Pollutant loads
Water management (storage, conveyance, ops)
Delta Hydrodynamics
Hydrology
Salinity
Nutrients
Delta Water Quality
Organic Carbon
Pathogens
Outcomes
WQ at pumps

Primary Analyses Questions

- When is export water quality a problem?
- What do we mean by “average”?
- What are the trends at the intakes?
- What is the source of the problems?
- What can we do about the problem?

Hydrodynamics

- Driver of transport to intakes
  - Natural processes (rainfall, tides)
  - Anthropogenic processes (supply operations, structures)
- Conceptual model developing within DRERIP process
- Use of DSM2 to produce 16-year volumetric fingerprints at Delta intakes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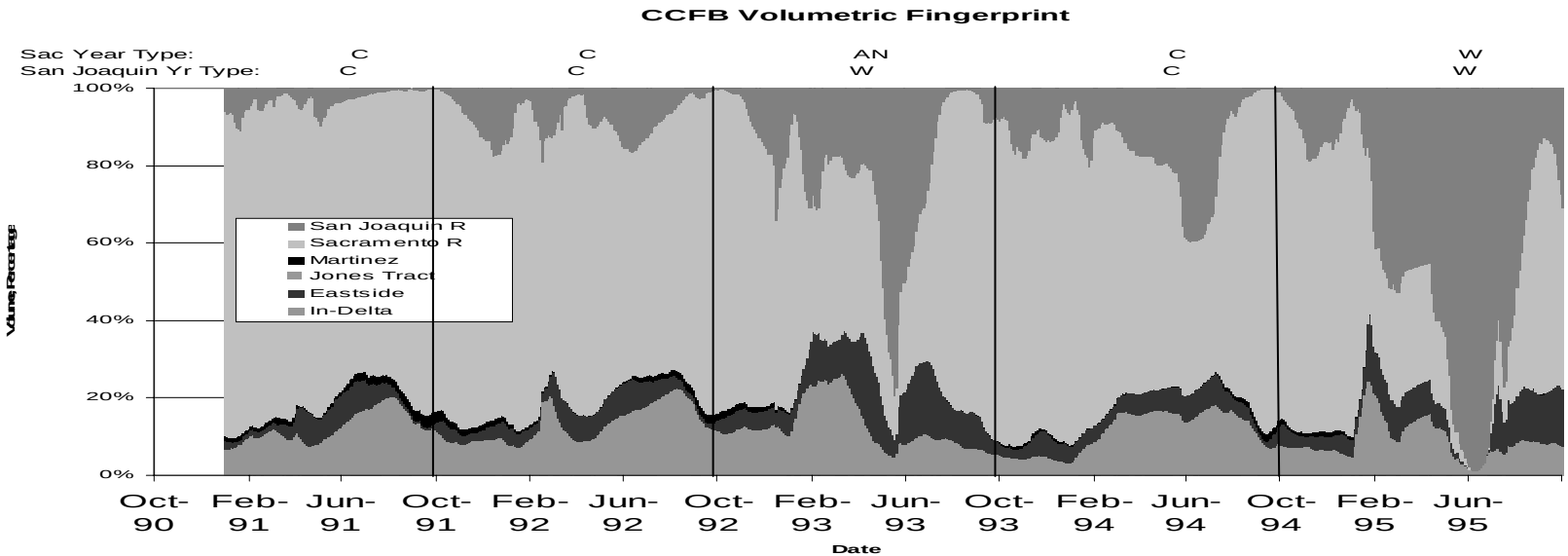
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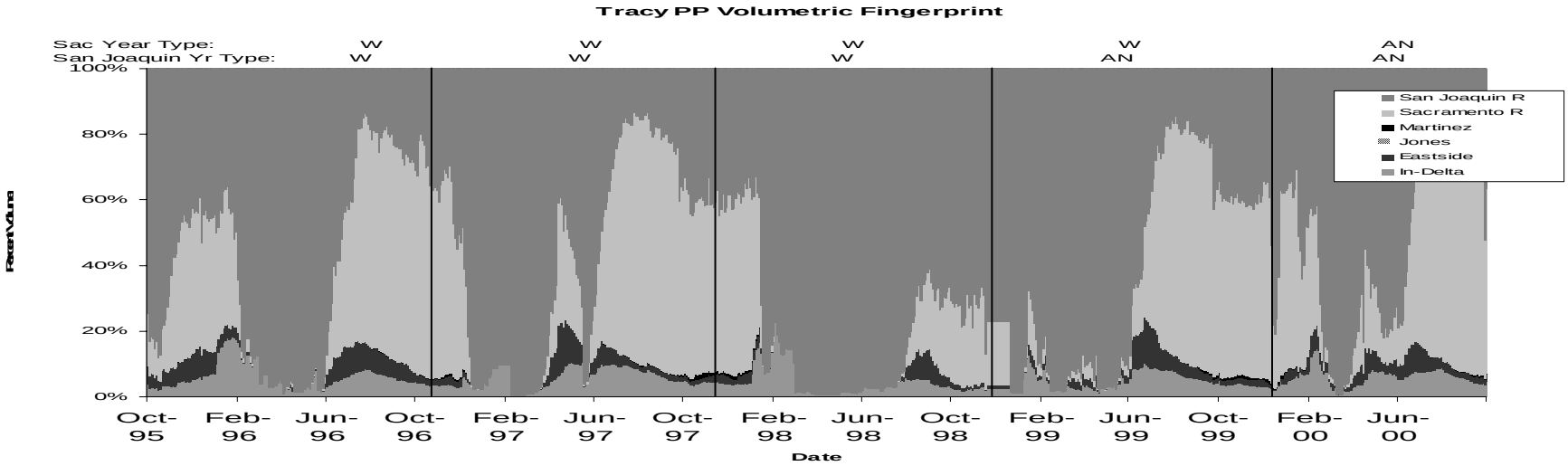
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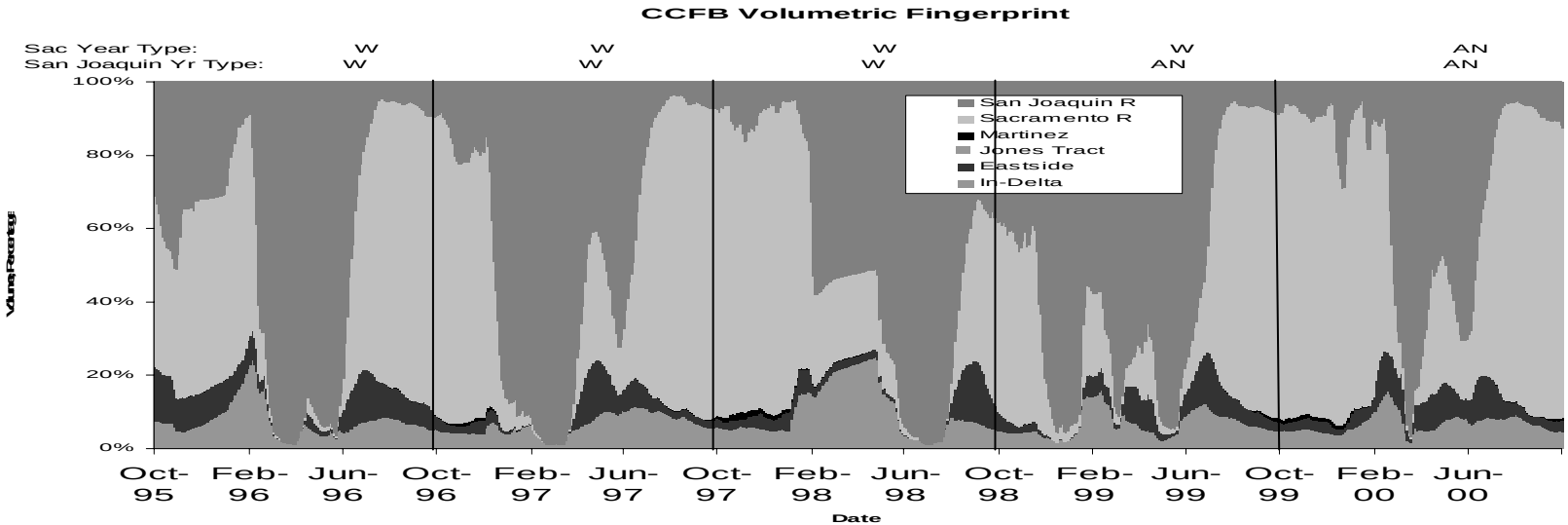
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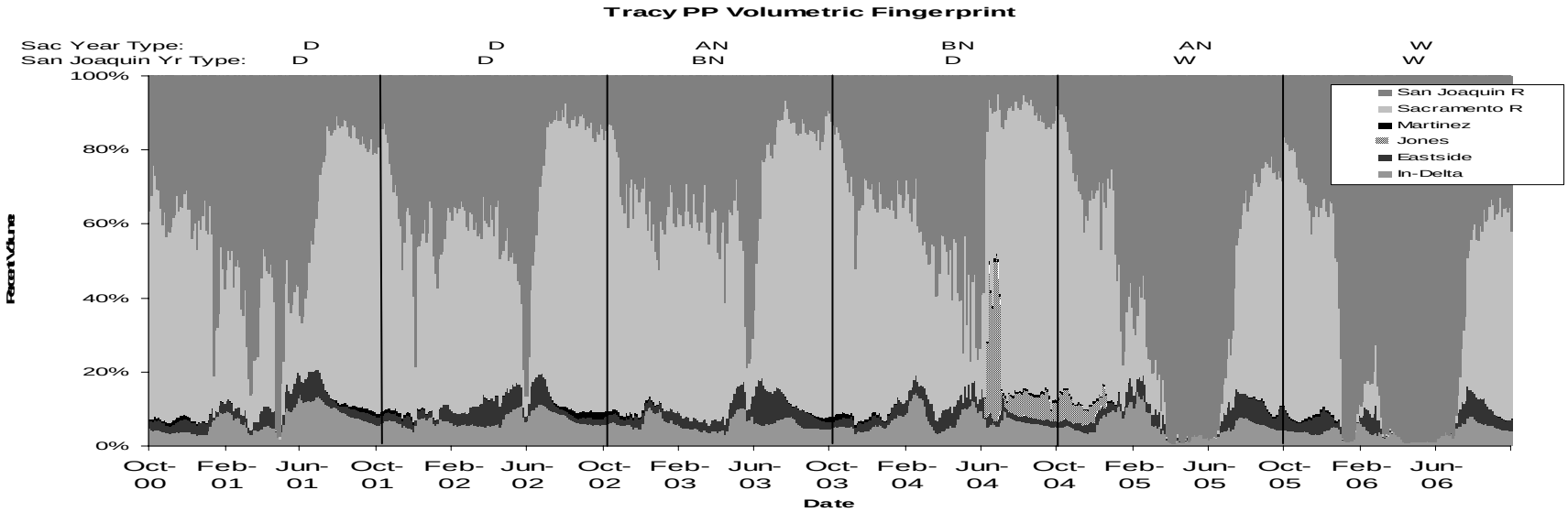
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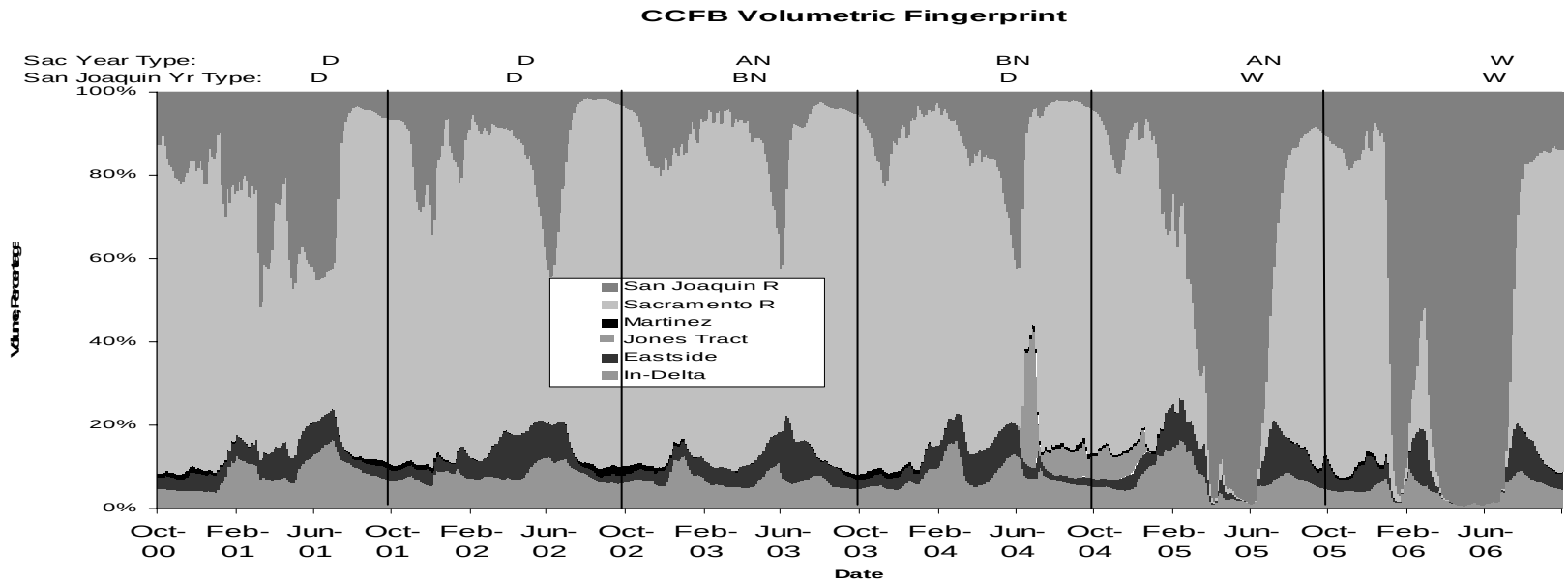
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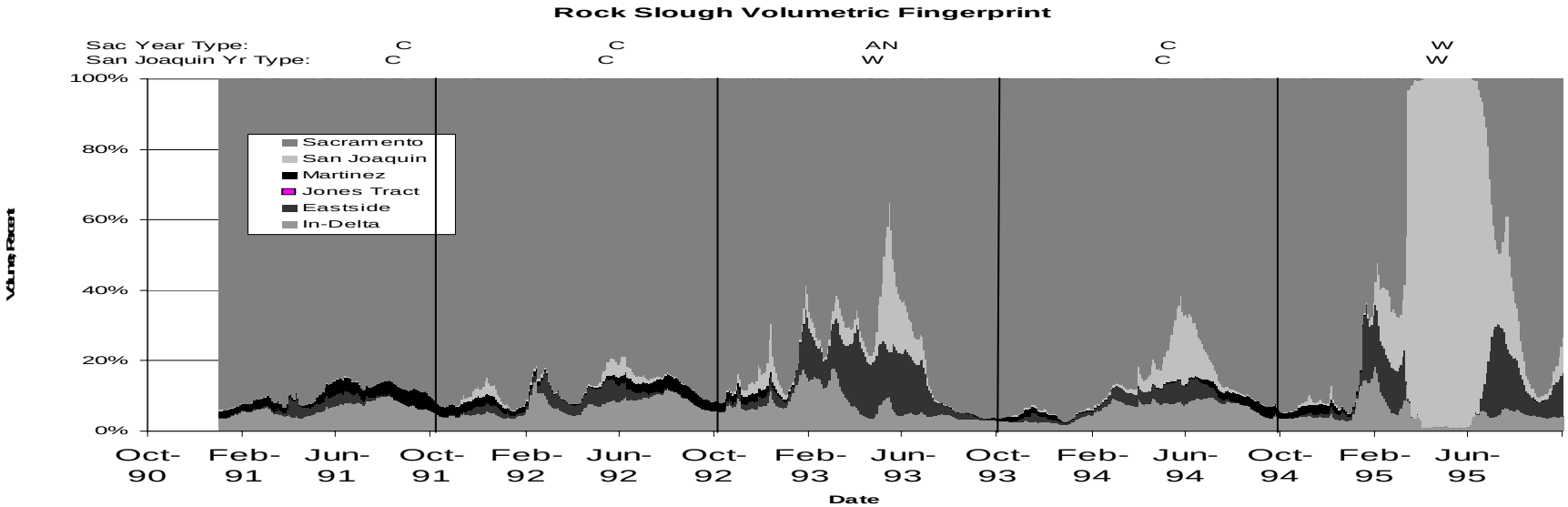
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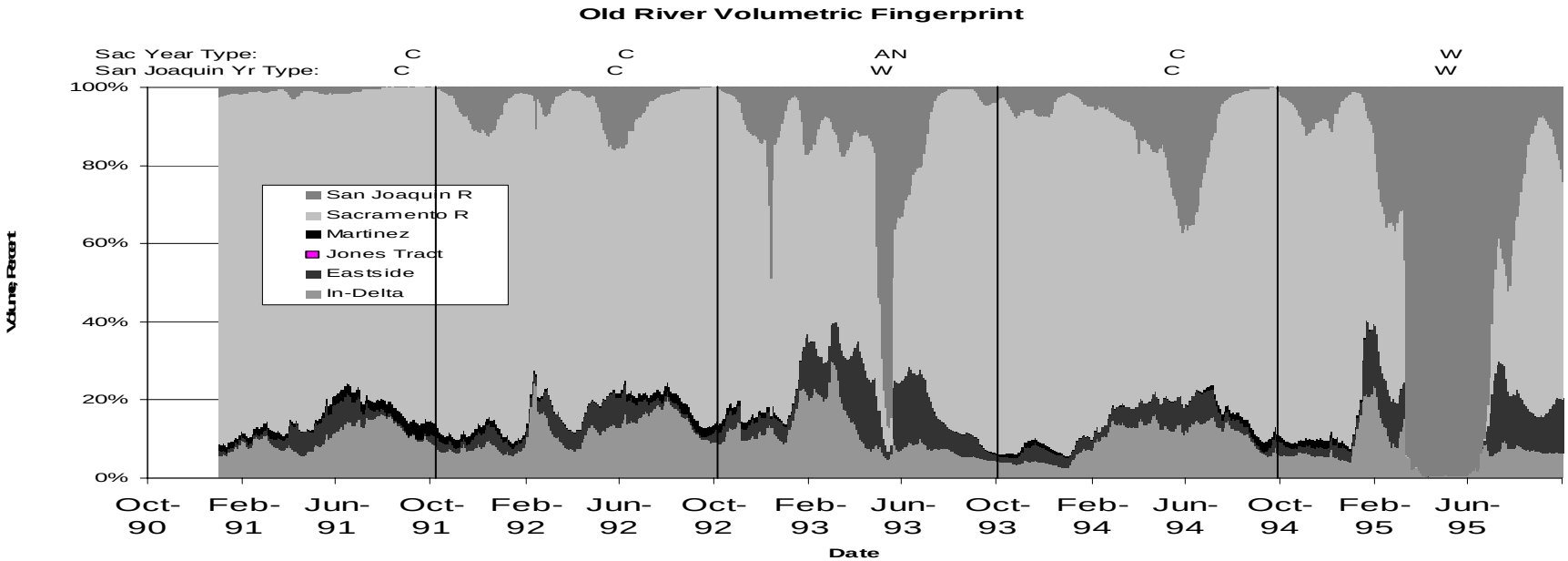
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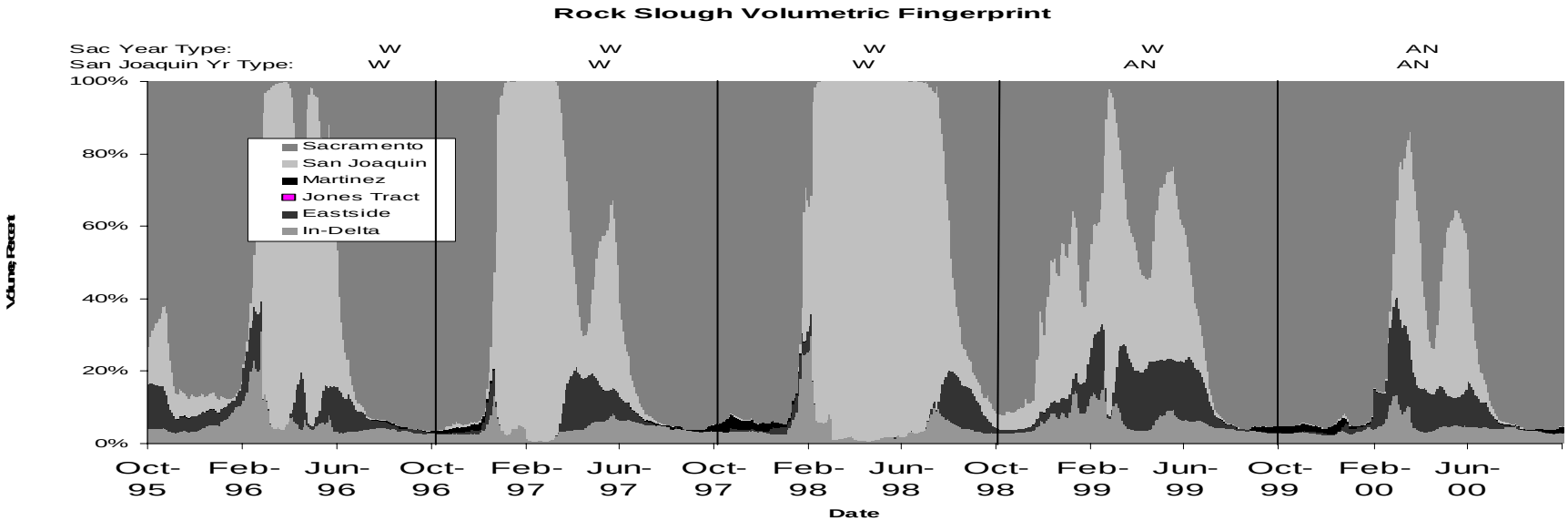
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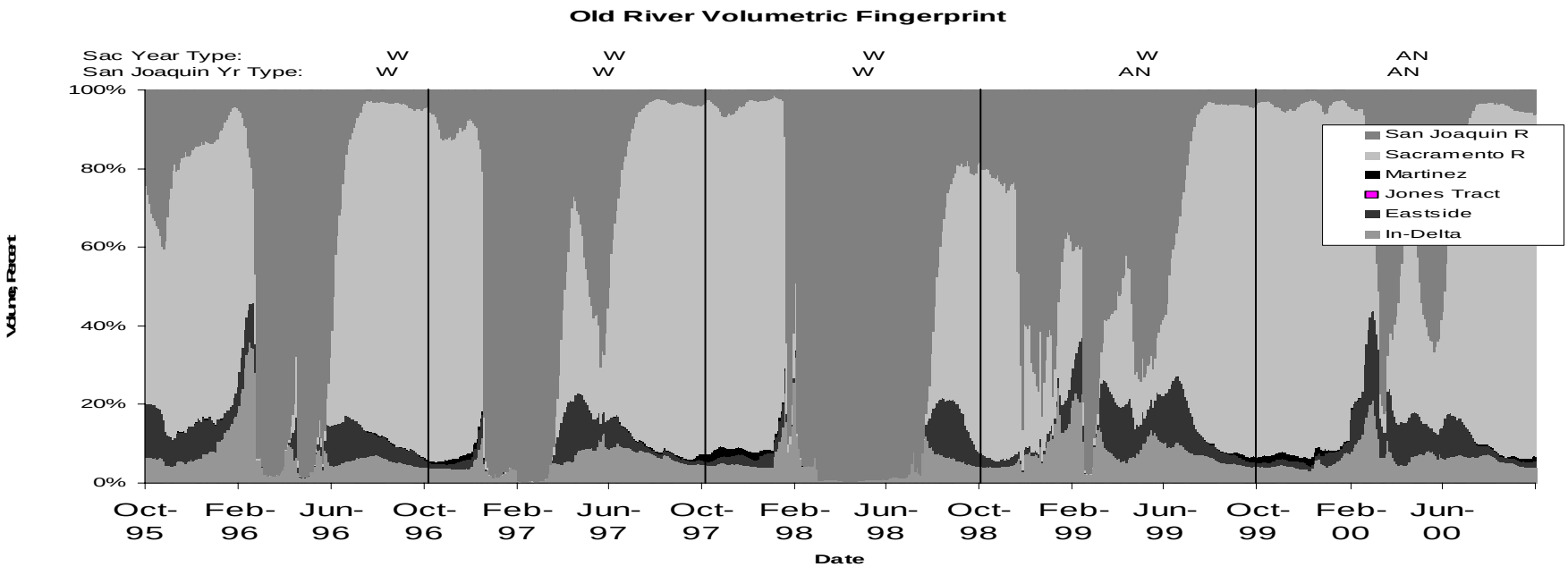
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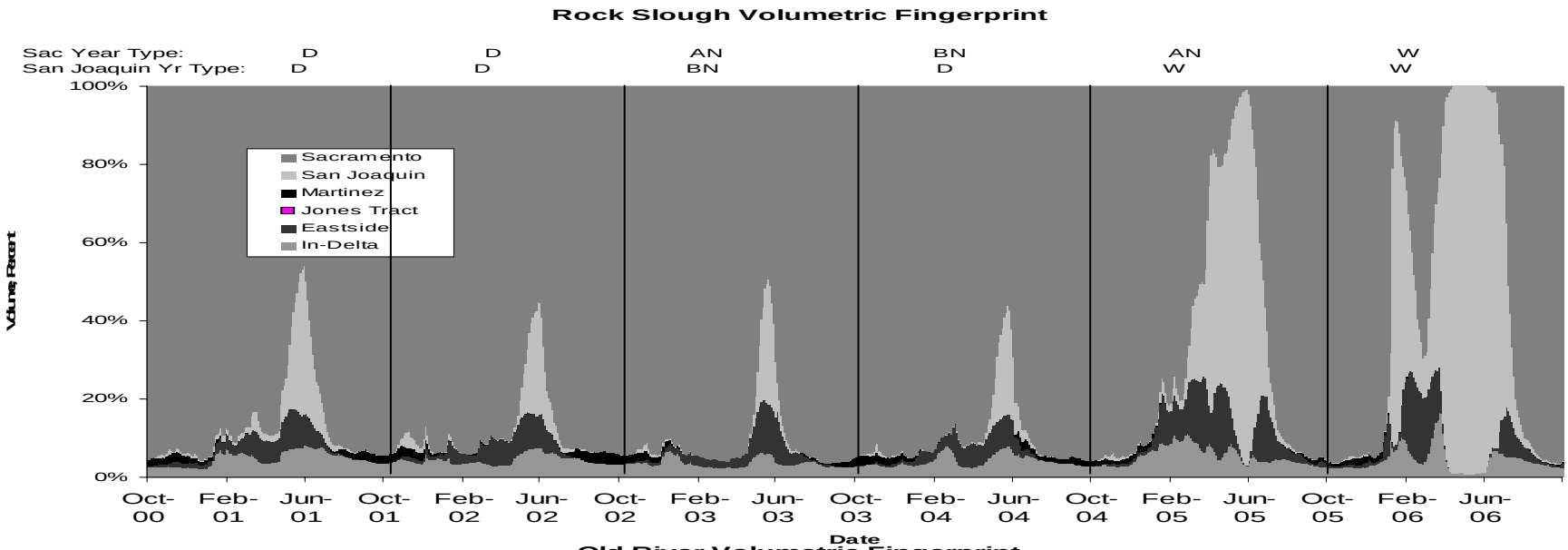
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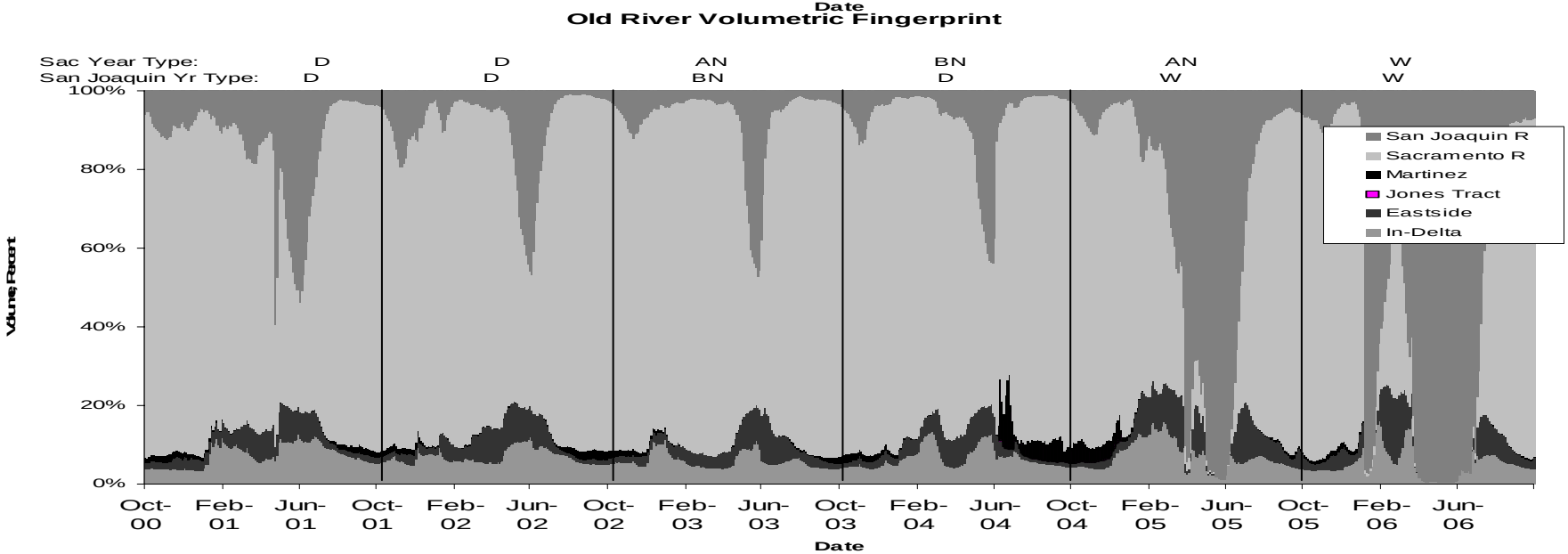
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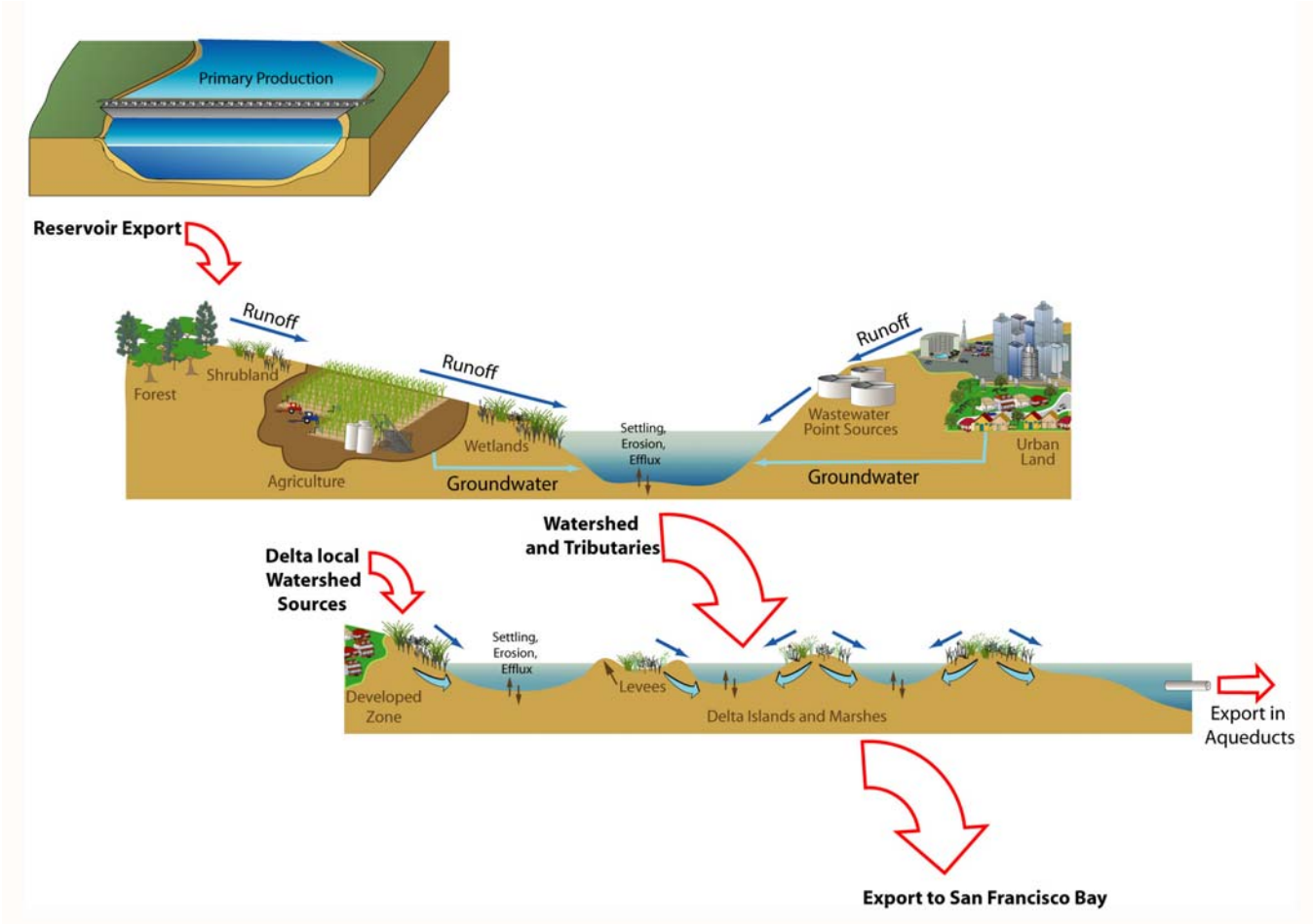
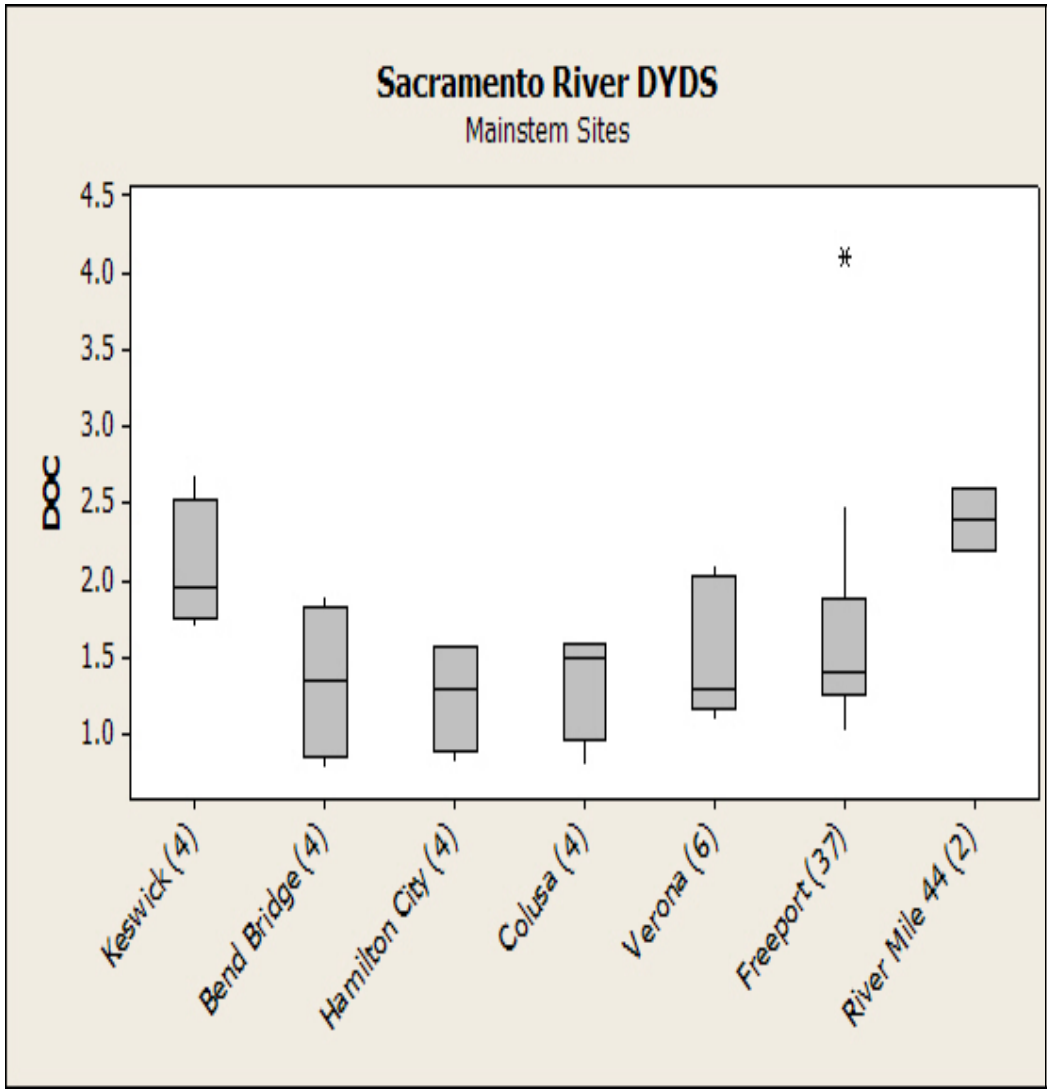
Organic Carbon

Organic Carbon cycling in the Central Valley, Delta

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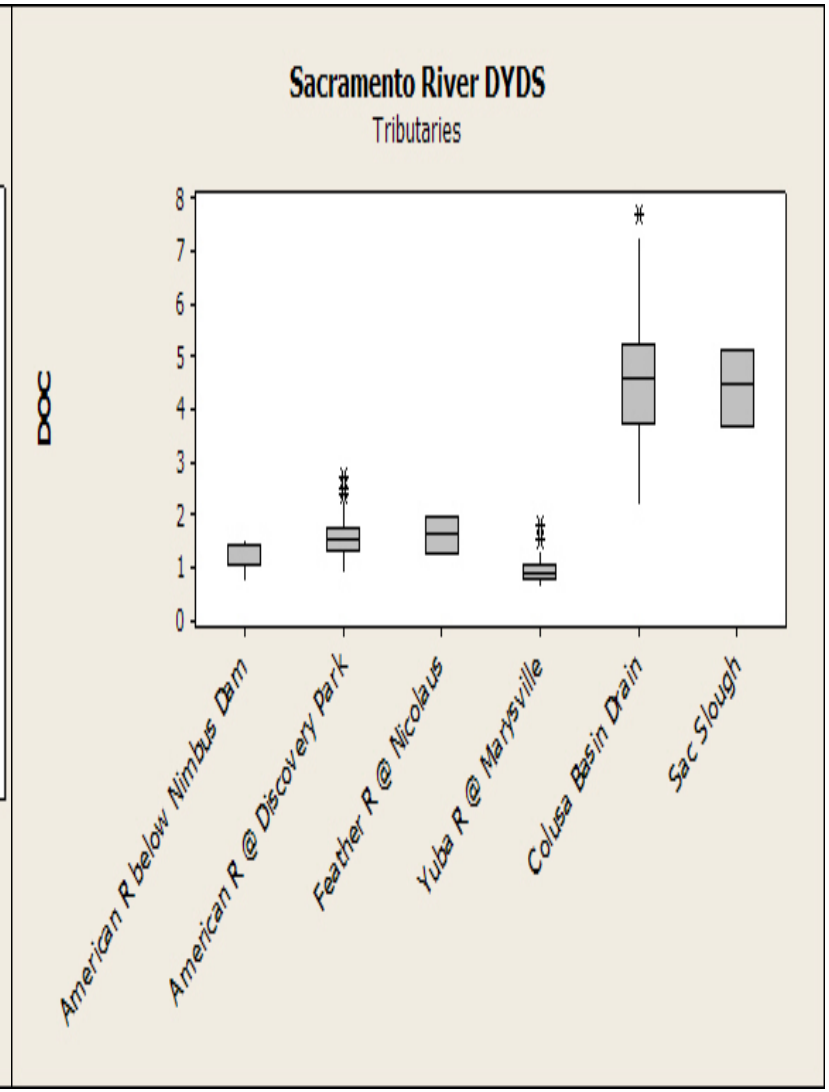
Colusa (4)
Verona (6)
Freeport (37)
River Mile 44 (2)


Sacramento River DYDS
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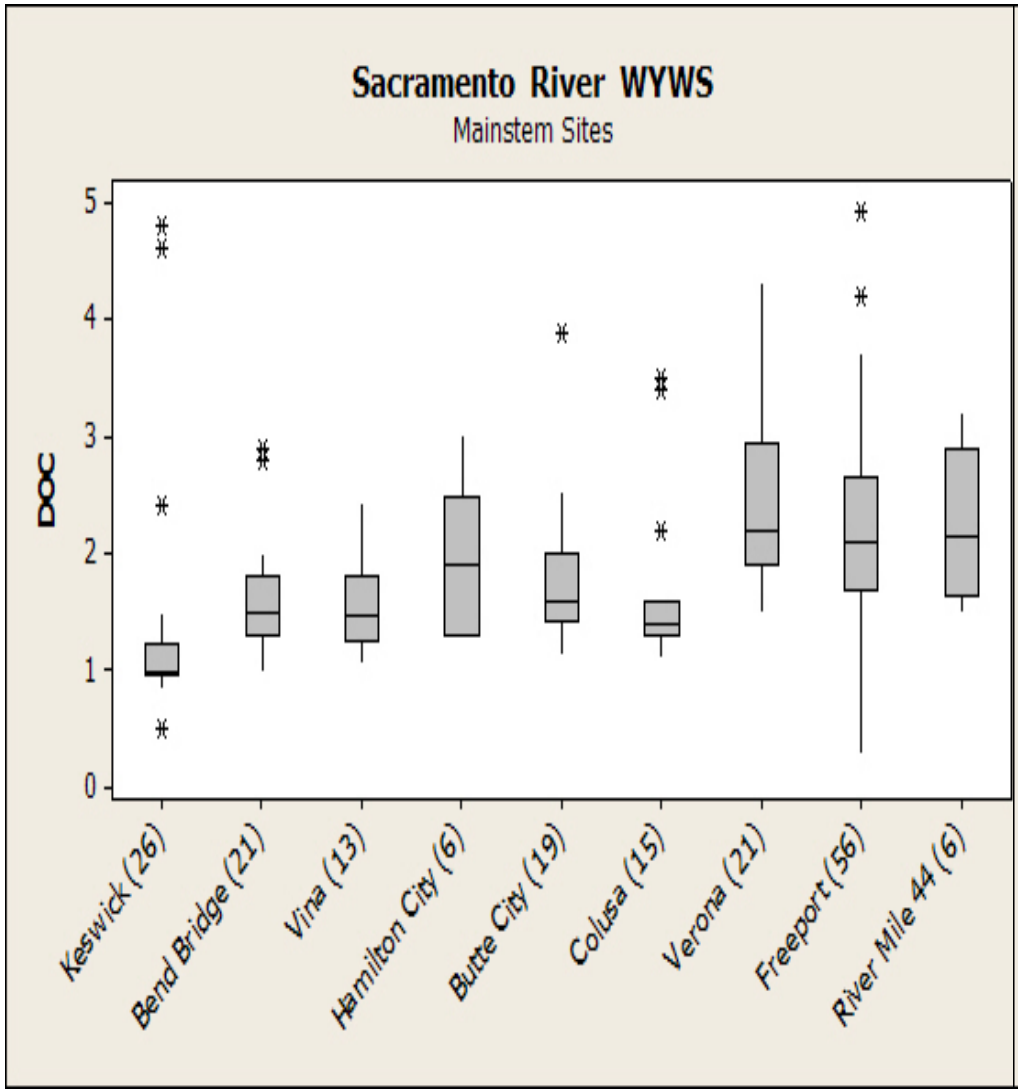
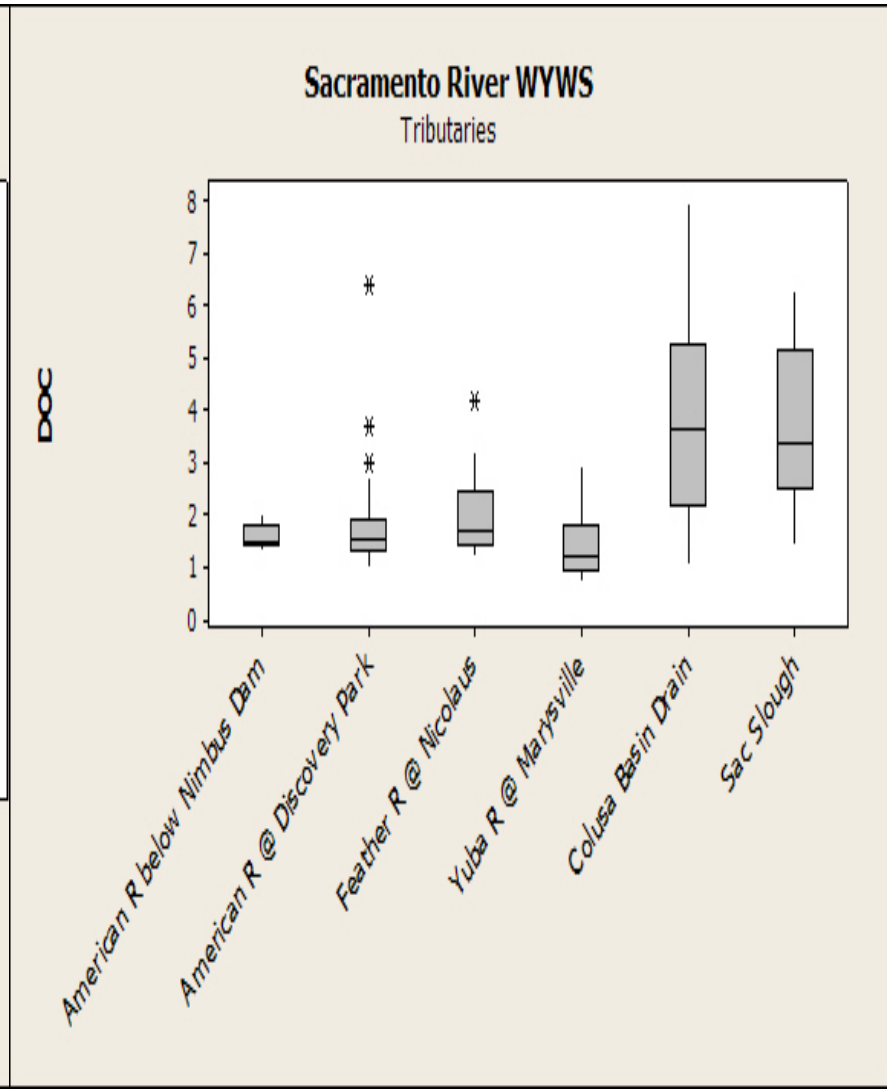
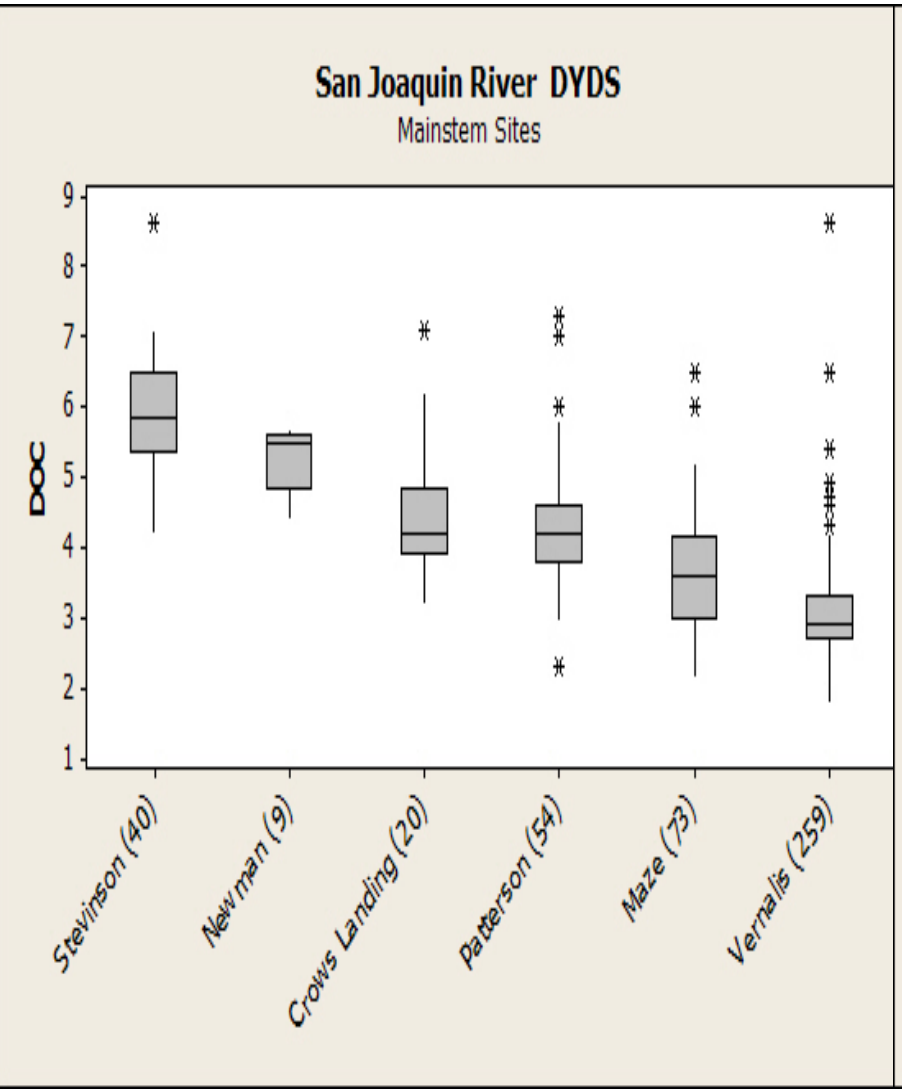
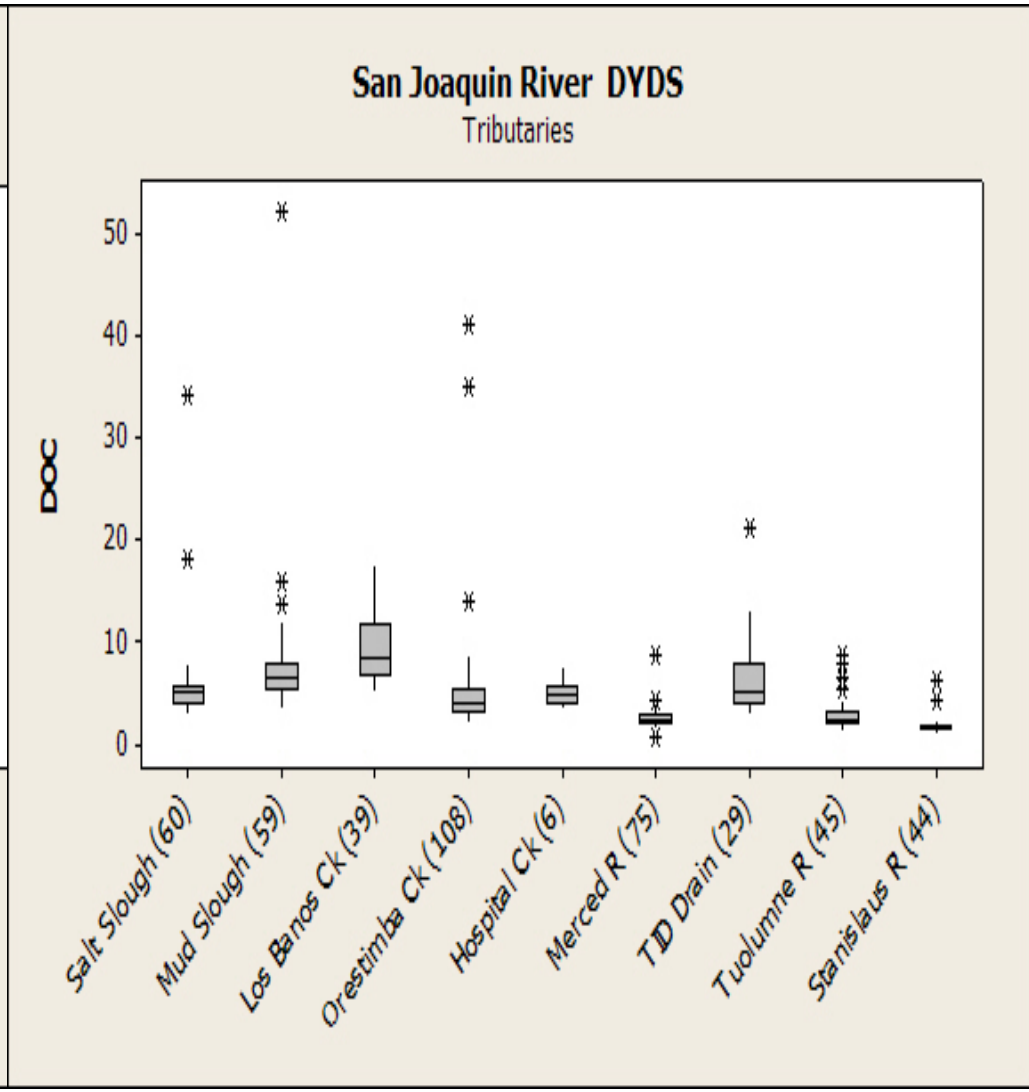
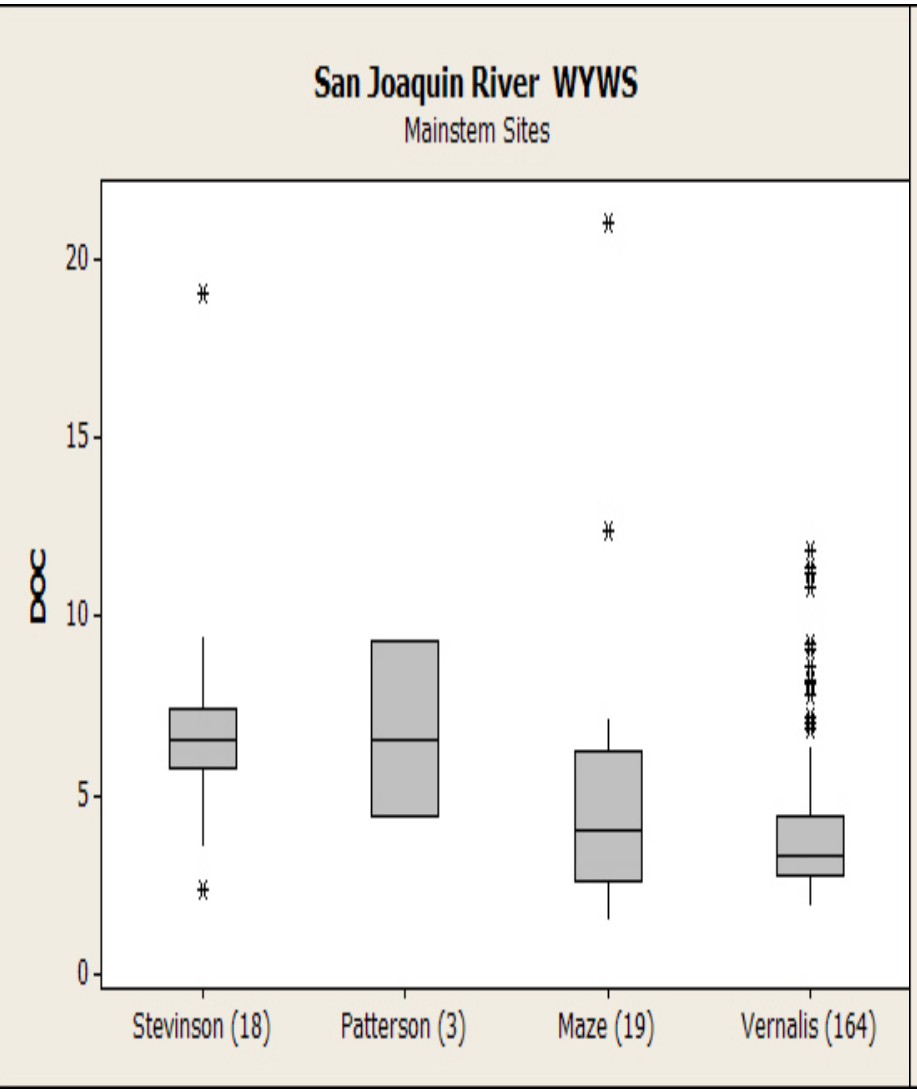
American R below Nimbus Dam
American R @ Discovery Park
Feather R @ Nicolaus
Yuba R @ Marysville
Colusa Basin Drain
Sac Slough

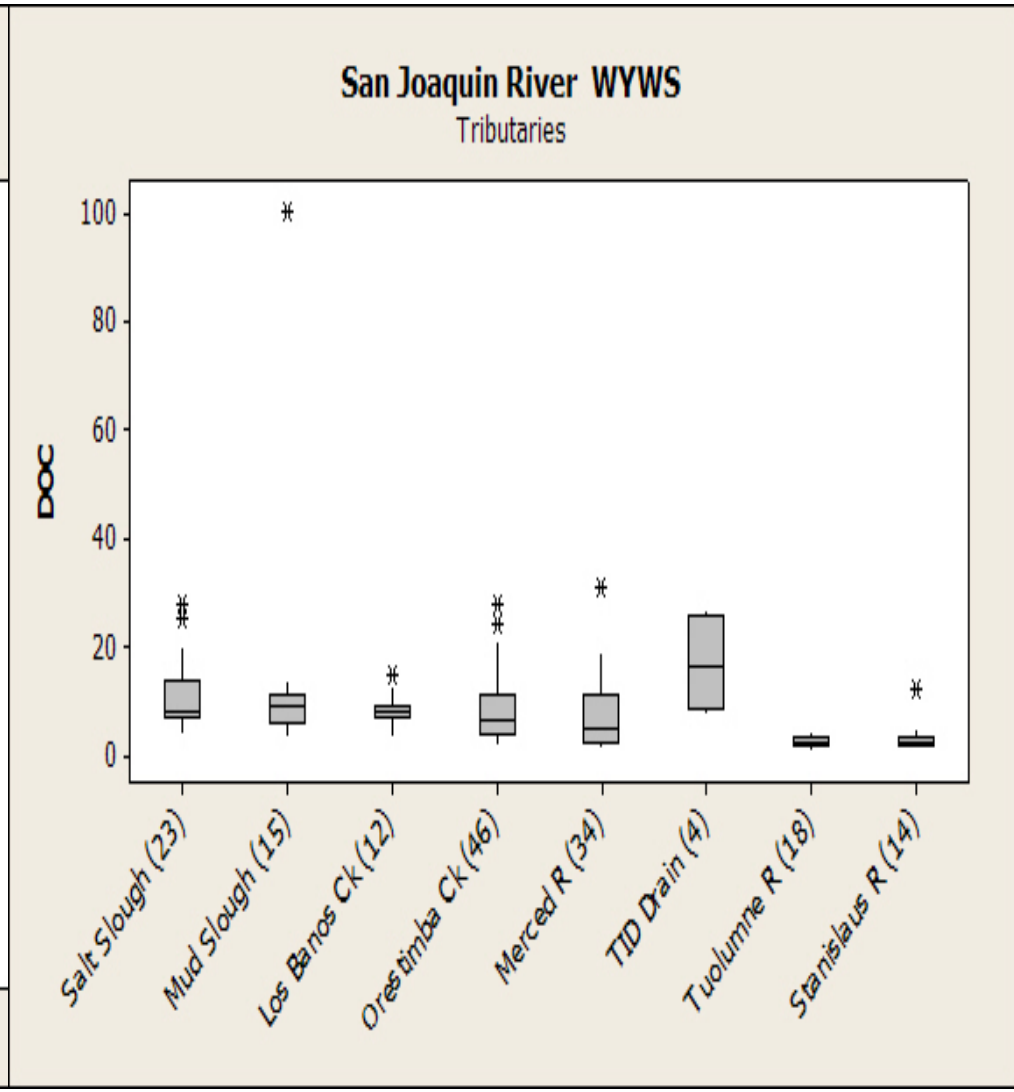

Sacramento River WYWS
Mainstem Sites
DOC
0
1
2
3
4
5
Keswick (26)
Bend Bridge (21)
Vina (13)
Hamilton City (6)
Butte City (19)
Colusa (15)
Verona (21)
Freeport (56)
River Mile 44 (6)


Sacramento River WYWS
Tributaries
DOC
0
1
2
3
4
5
6
7
8
American R below Nimbus Dam
American R @ Discovery Park
Feather R @ Nicolaus
Yuba R @ Marysville
Colusa Basin Drain
Sac Slough

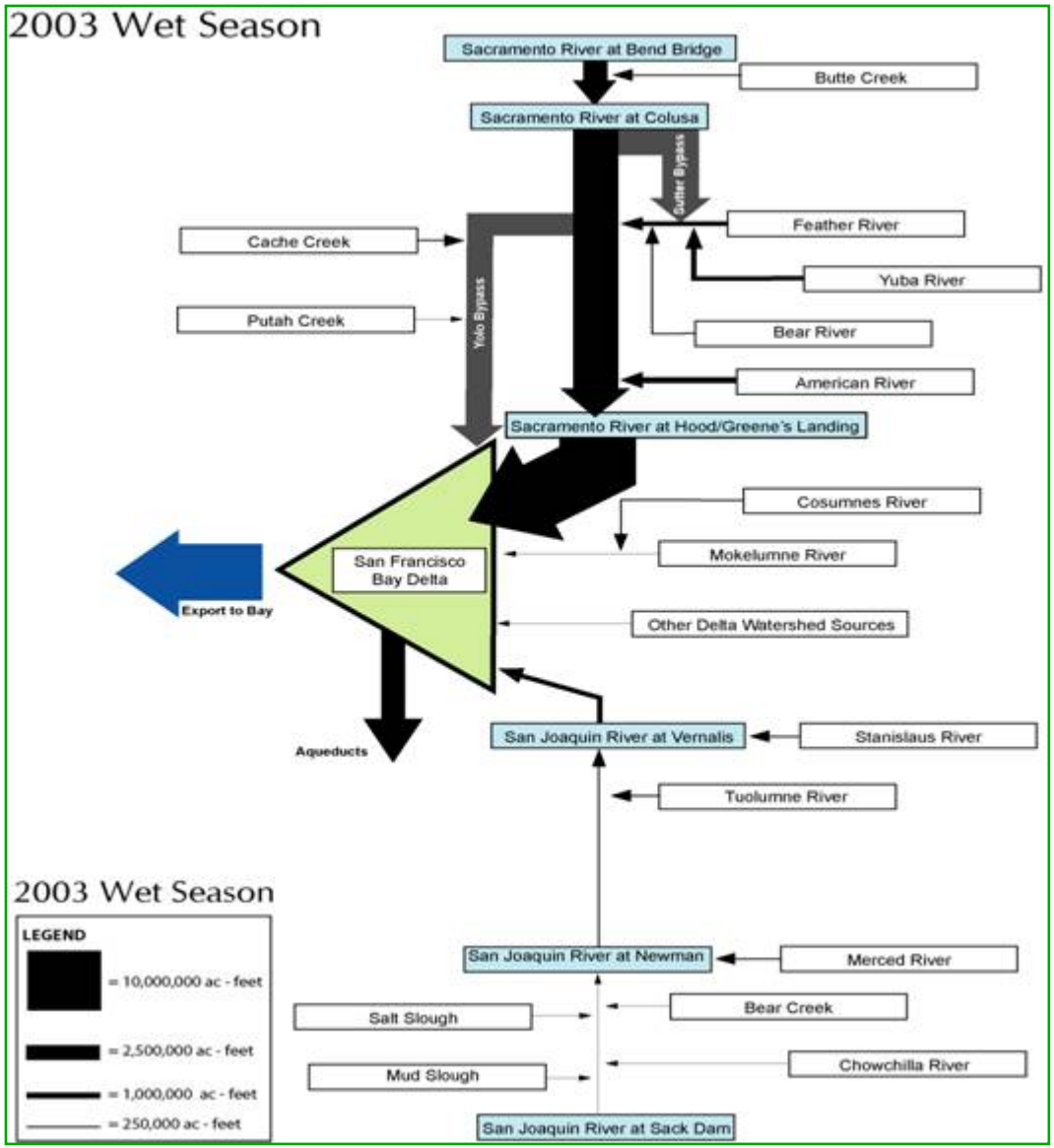

San Joaquin River DYDS
Mainstem Sites
DOC
9
8
7
6
5
4
3
2
1
Stevinson (40)
Newman (9)
Crows Landing (20)
Patterson (54)
Maze (73)
Vernalis (259)

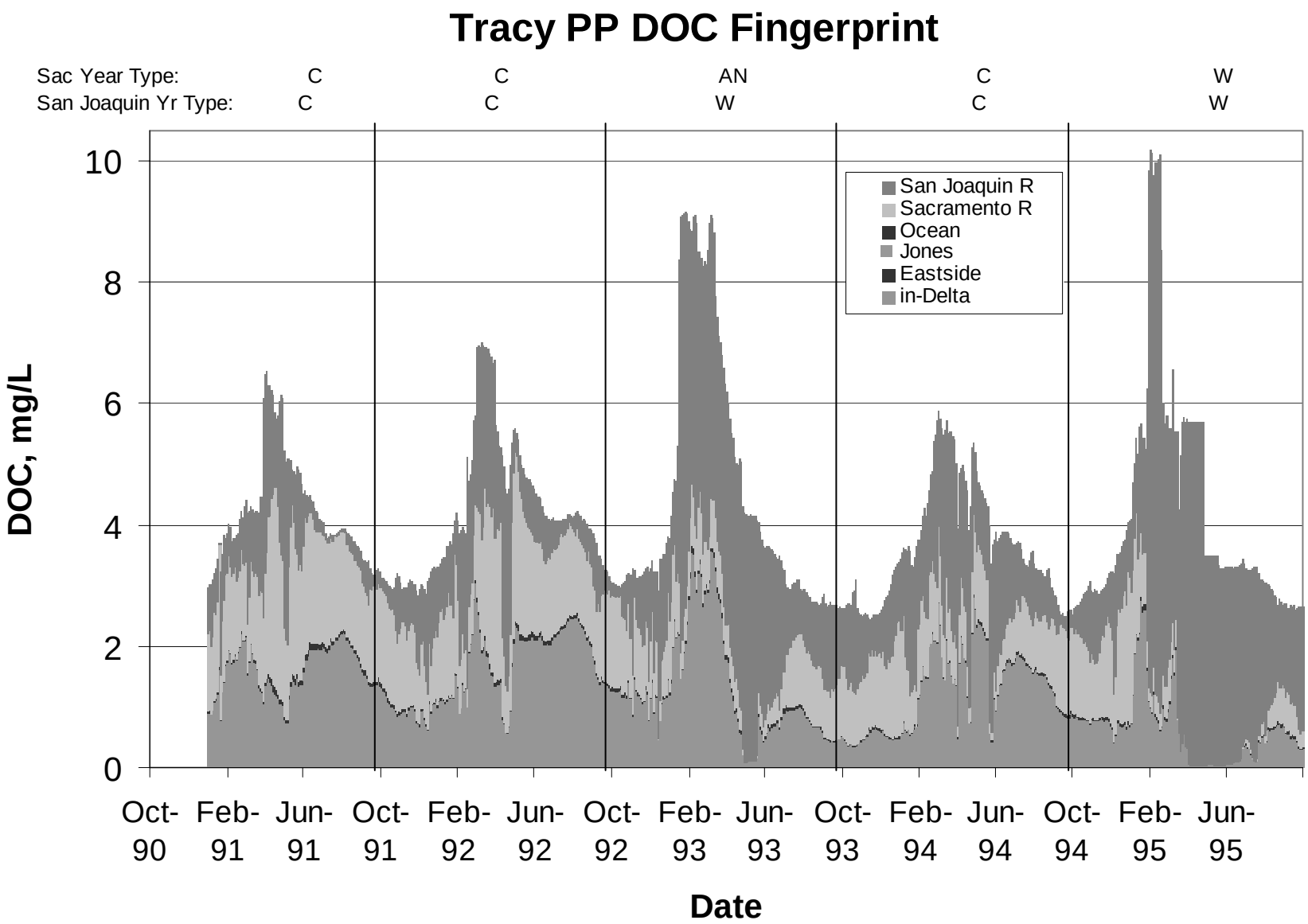

San Joaquin River DYDS
Tributaries
DOC
50
40
30
20
10
0
Salt Slough (60)
Mud Slough (59)
Los Banos Ck (39)
Orestimba Ck (108)
Hospital Ck (6)
Merced R (75)
TID Drain (29)
Tuolumne R (45)
Stanislaus R (44)

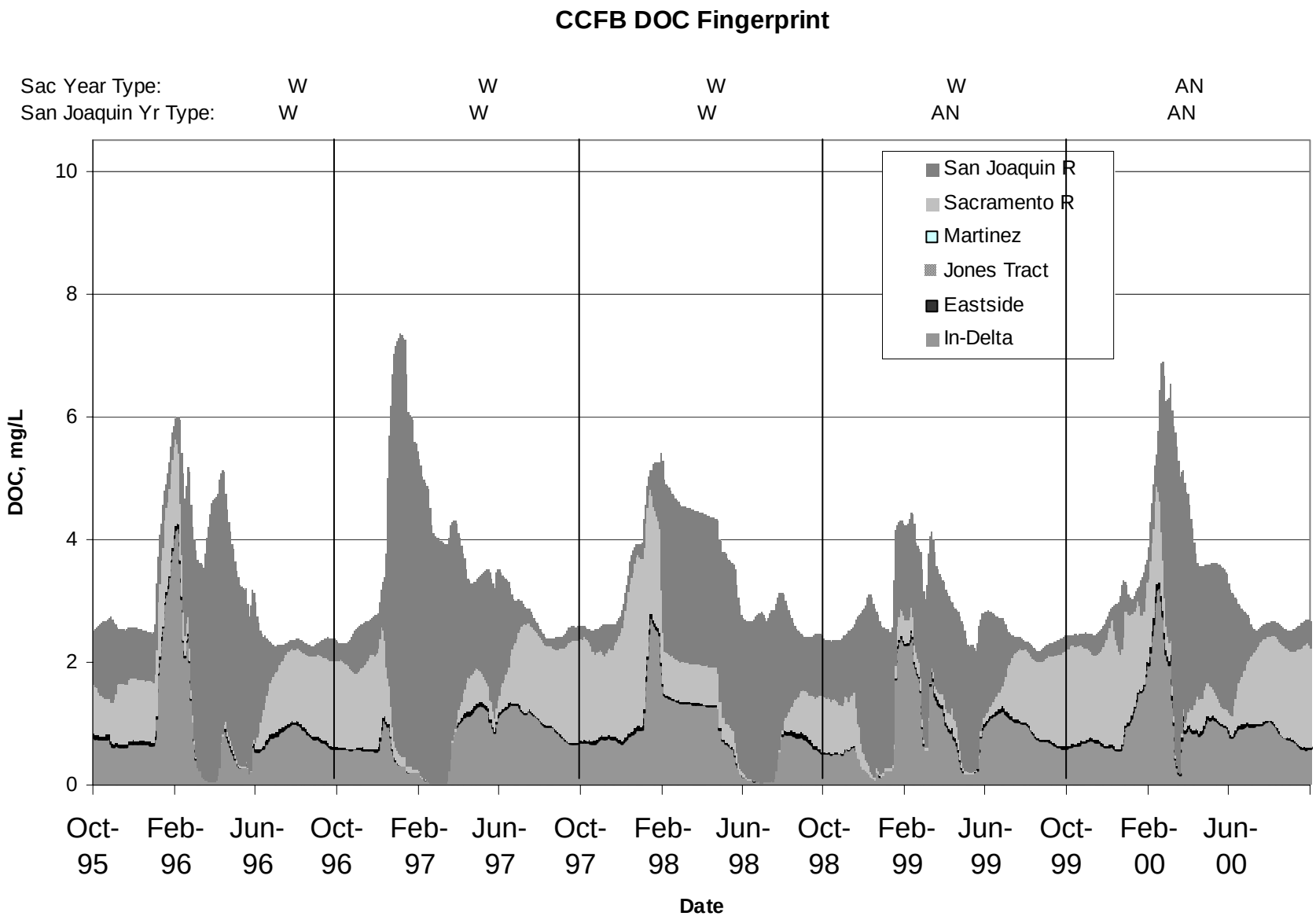

San Joaquin River WYWS
Mainstem Sites
DOC
0
5
10
15
20
Stevinson (18)
Patterson (3)
Maze (19)
Vernalis (164)

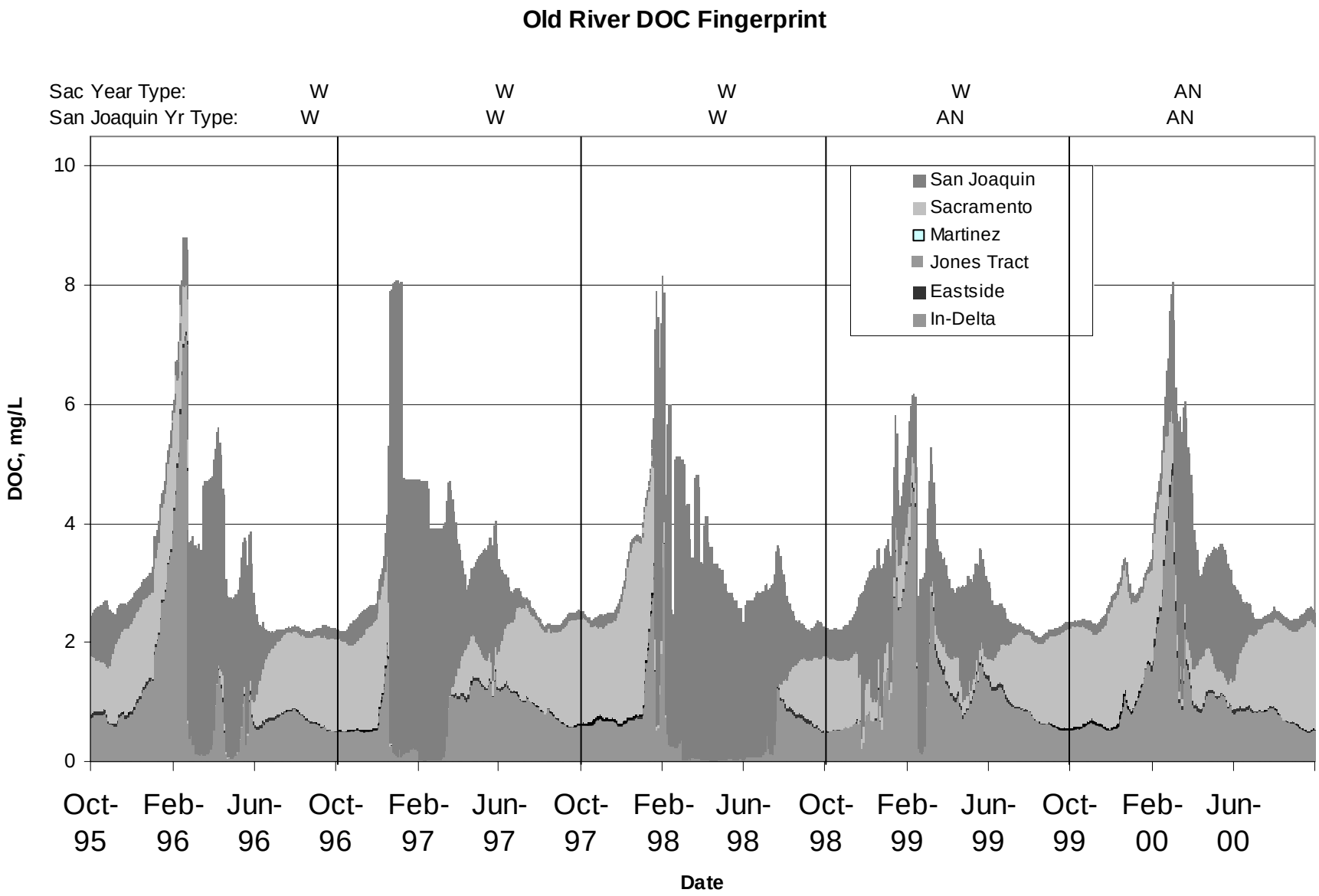

San Joaquin River WYWS
Tributaries
DOC
0
20
40
60
80
100
Salt Slough (23)
Mud Slough (15)
Los Banos Ck (12)
Orestimba Ck (46)
Merced R (34)
TID Drain (4)
Tuolumne R (18)
Stanislaus R (14)

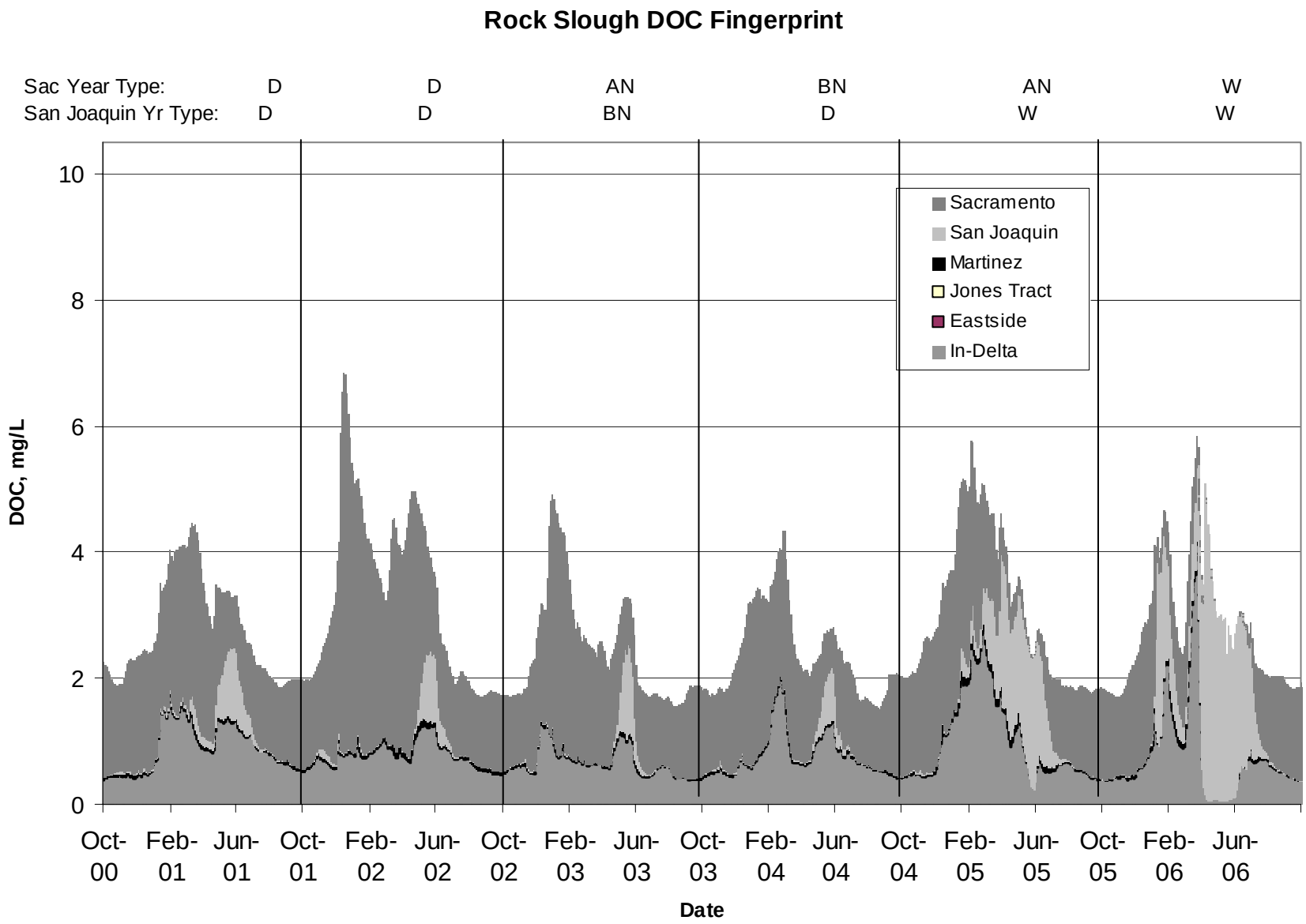
Flows in the Wet Season of 2003




Tracy PP DOC Fingerprint
Sac Year Type: C C AN C W
San Joaquin Yr Type: C C W C W
San Joaquin R
Sacramento R
Ocean
Jones
Eastside
in-Delta
DOC, mg/L
0
2
4
6
8
10
Oct-90
Feb-91
Jun-91
Oct-91
Feb-92
Jun-92
Oct-92
Feb-93
Jun-93
Oct-93
Feb-94
Jun-94
Oct-94
Feb-95
Jun-95
Date


CCFB DOC Fingerprint
Sac Year Type: W W W W AN
San Joaquin Yr Type: W W W AN AN
San Joaquin R
Sacramento R
Martinez
Jones Tract
Eastside
In-Delta
DOC, mg/L
0
2
4
6
8
10
Oct-95
Feb-96
Jun-96
Oct-96
Feb-97
Jun-97
Oct-97
Feb-98
Jun-98
Oct-98
Feb-99
Jun-99
Oct-99
Feb-00
Jun-00
Date


Old River DOC Fingerprint
Sac Year Type:
W
W
W
W
AN
San Joaquin Yr Type:
W
W
W
AN
AN
San Joaquin
Sacramento
Martinez
Jones Tract
Eastside
In-Delta
DOC, mg/L
0
2
4
6
8
10
Oct-95
Feb-96
Jun-96
Oct-96
Feb-97
Jun-97
Oct-97
Feb-98
Jun-98
Oct-98
Feb-99
Jun-99
Oct-99
Feb-00
Jun-00
Date


Rock Slough DOC Fingerprint
Sac Year Type: D D AN BN AN W
San Joaquin Yr Type: D D BN D W W
Sacramento
San Joaquin
Martinez
Jones Tract
Eastside
In-Delta
DOC, mg/L
0
2
4
6
8
10
Oct-00
Feb-01
Jun-01
Oct-01
Feb-02
Jun-02
Oct-02
Feb-03
Jun-03
Oct-03
Feb-04
Jun-04
Oct-04
Feb-05
Jun-05
Oct-05
Feb-06
Jun-06
Date

Next steps

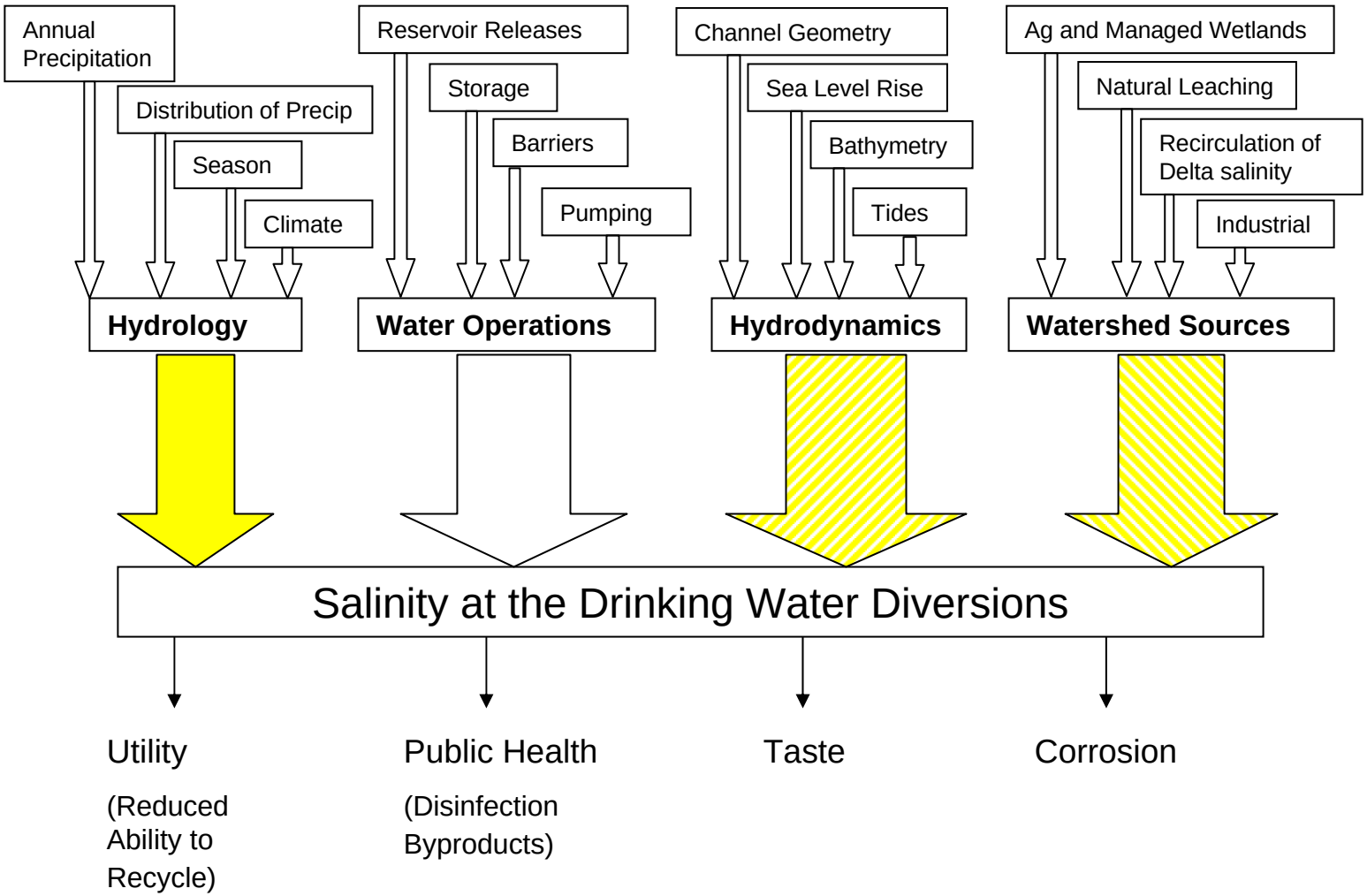
- Significance comparisons between sites to prioritize sub watersheds
- Exploration of drivers
- Investigate data on sources (vs. ambient)
- DWR spreadsheet model of SJ OC, focus on loading at heads of tributaries
- Continue working with DRERIP and funded projects
- CALFED consultant work on controllability

Performance Measures

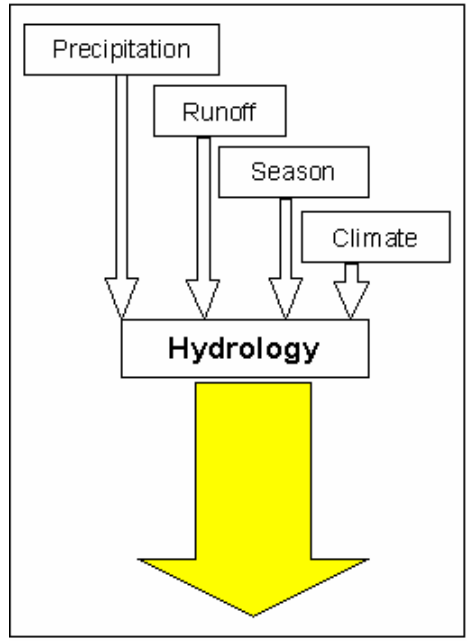
- Potential locations for all watershed measures:
  - Intakes
  - Tributaries (Hood, Vernalis)
  - Subwatersheds (Smaller river inputs)
  - Identified potential controllable sources

Salinity and Bromide

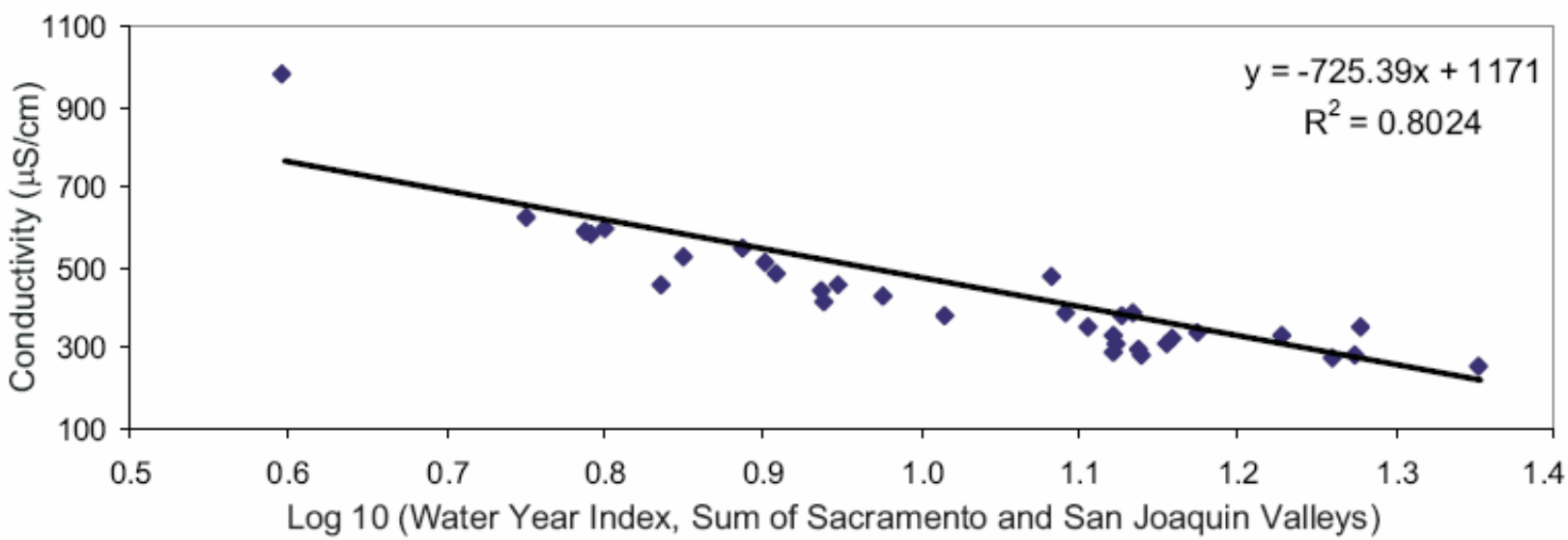
Delta Drinking Water Quality - Salinity



Hydrology



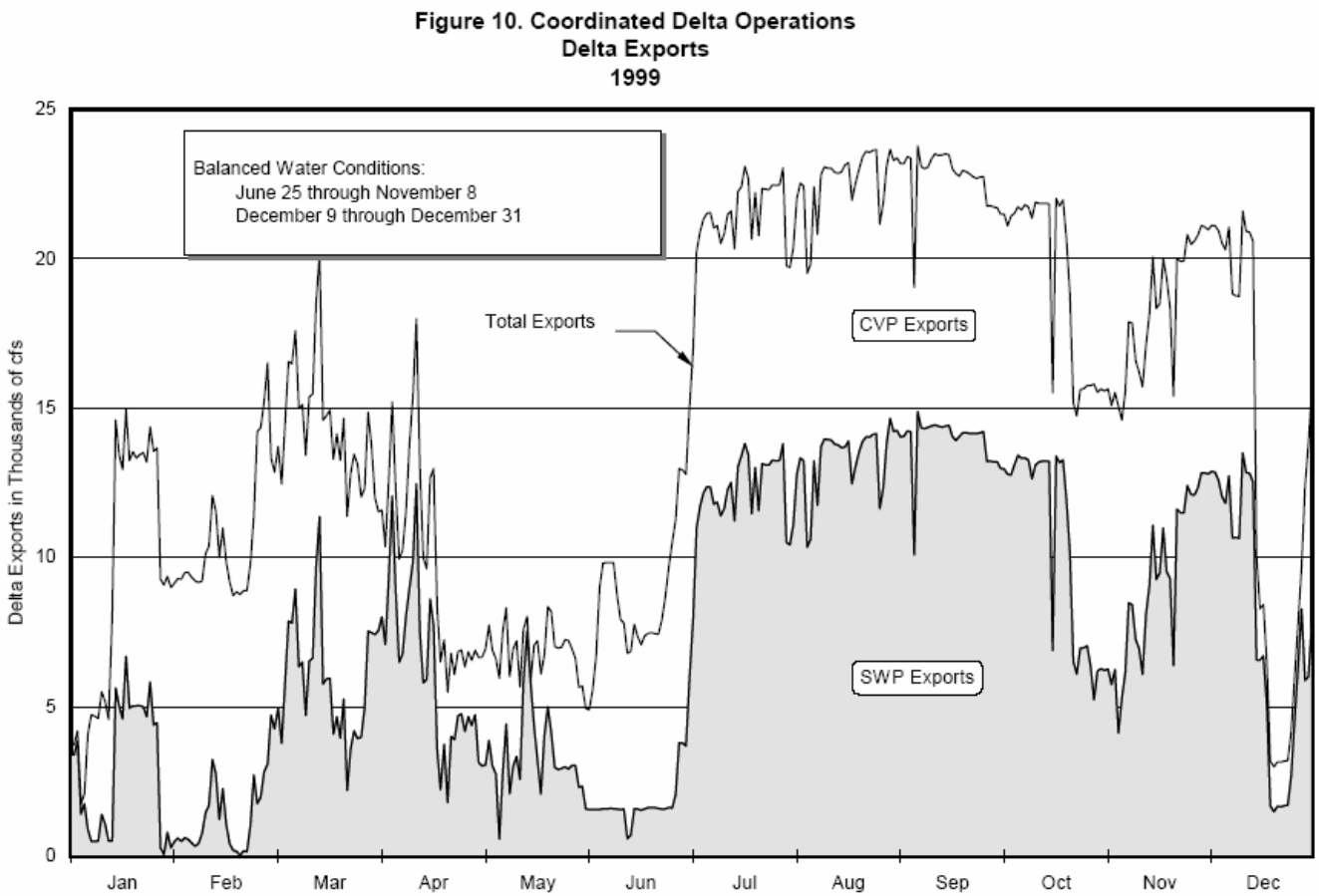
The amount of water flowing into the Delta is the single most important determinant of salinity at the export pumps and the amount of inflow is largely determined by hydrology.

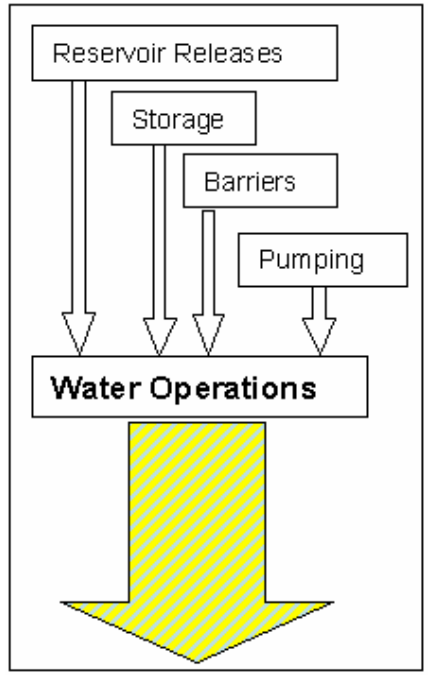


DWR

Water Operations

During periods of low natural inflow, the combination of reservoir releases, barrier operations, and Delta diversion pumping govern salinity.

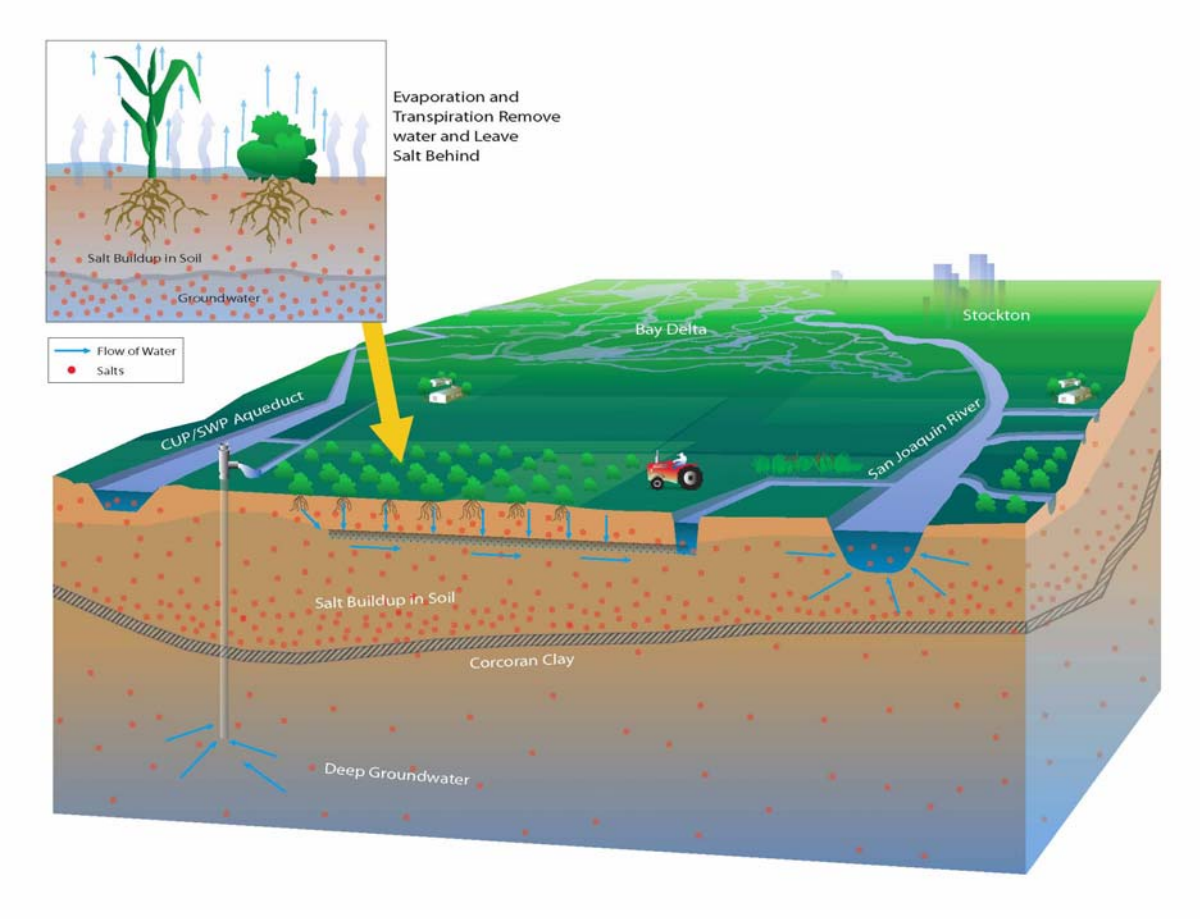


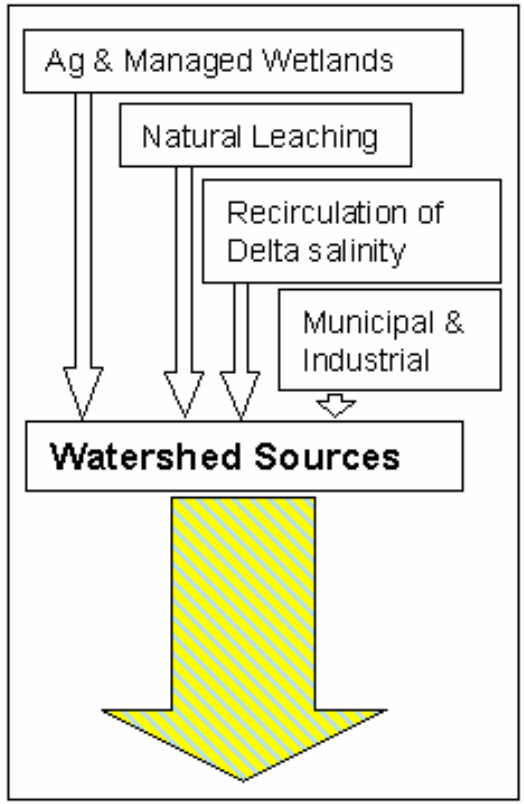


DWR, 2003

Watershed Sources

Included here are salts added through material inputs to agricultural, municipal, industrial, and natural processes.

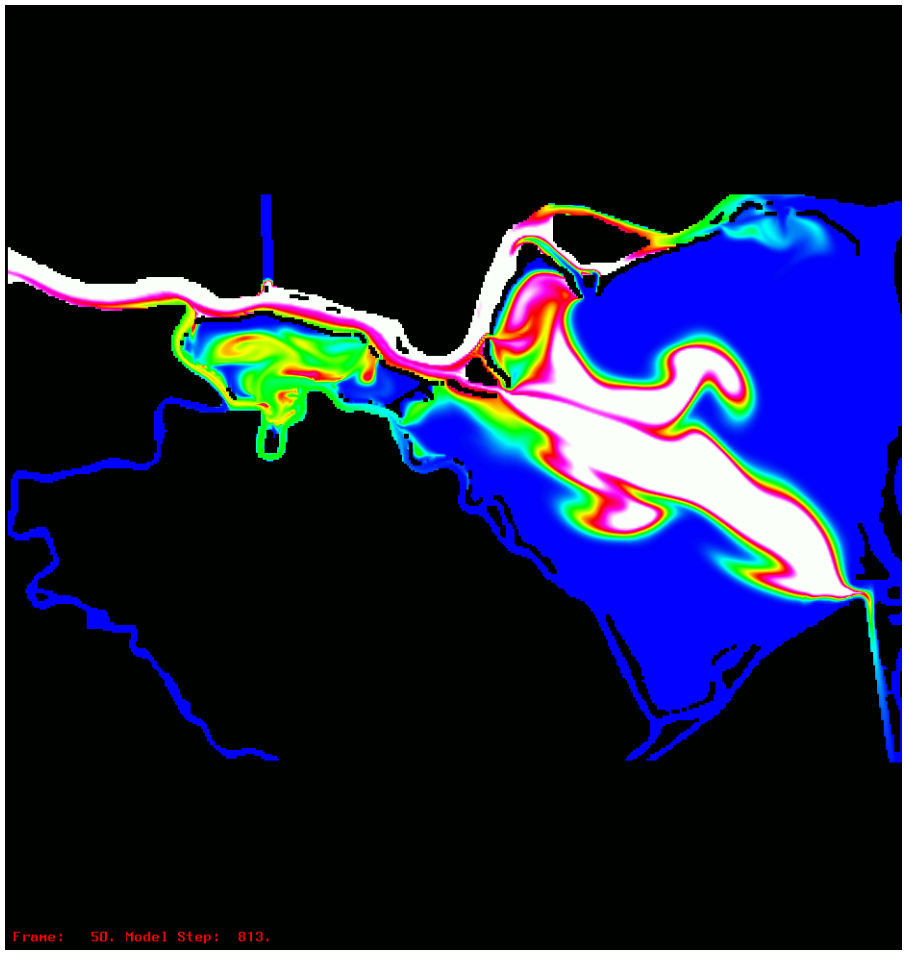


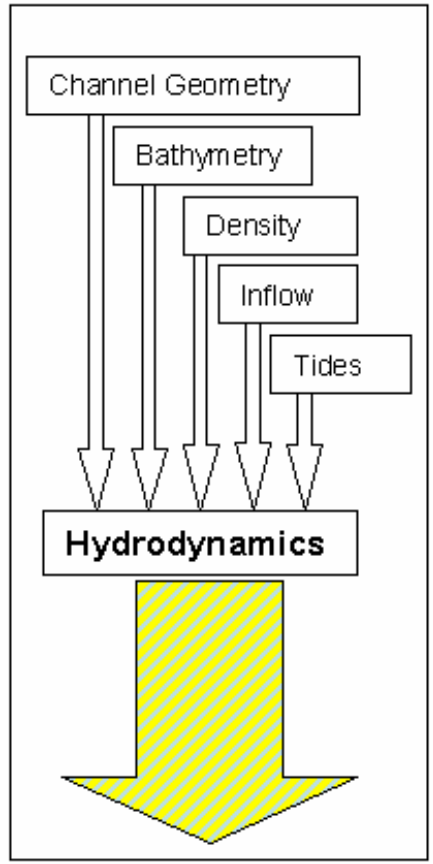


Tetratech, 2006

Hydrodynamics

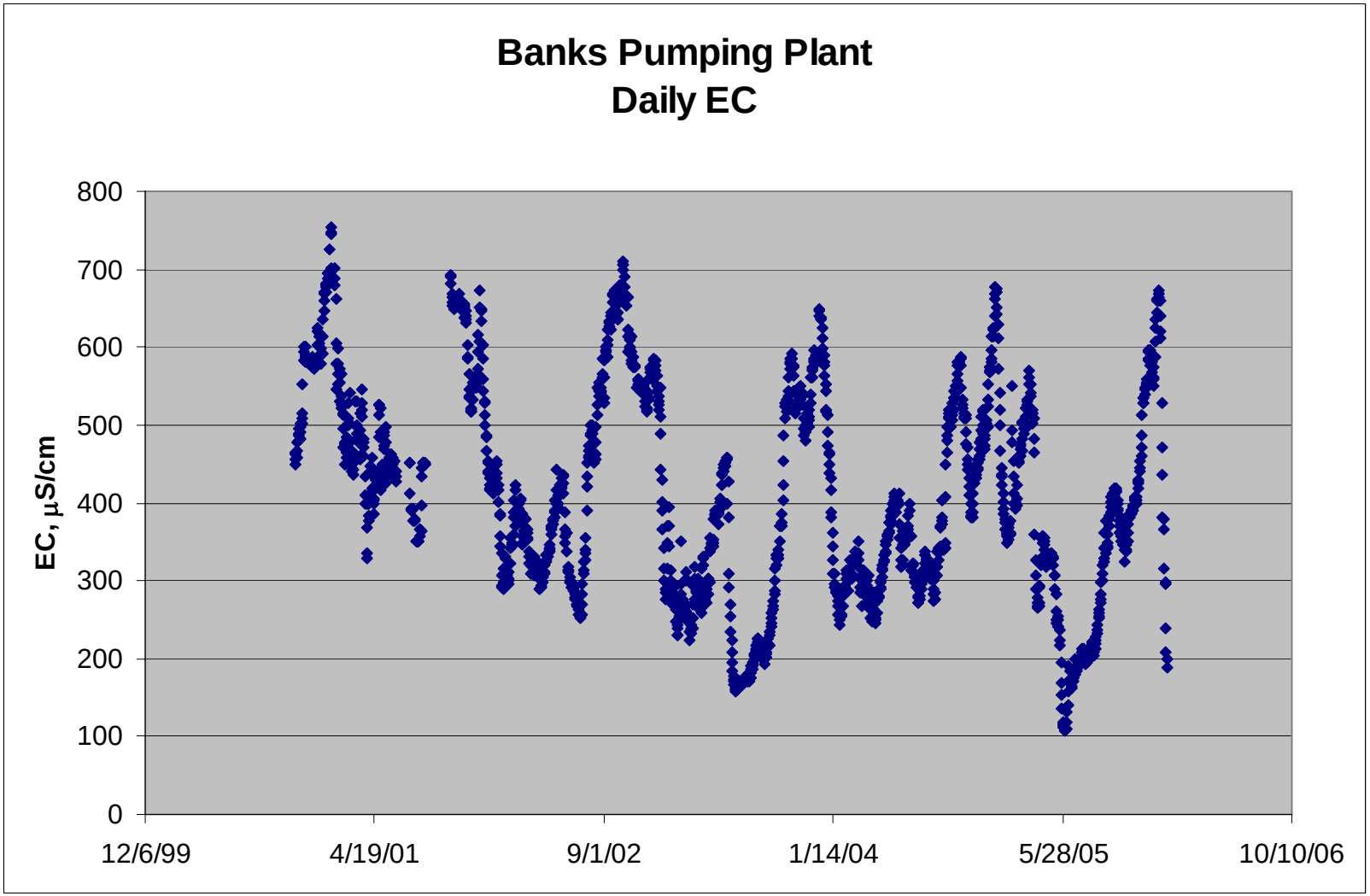
Hydrodynamics includes the major physical features, properties, and processes that govern the movement of water within the Delta and Bay.



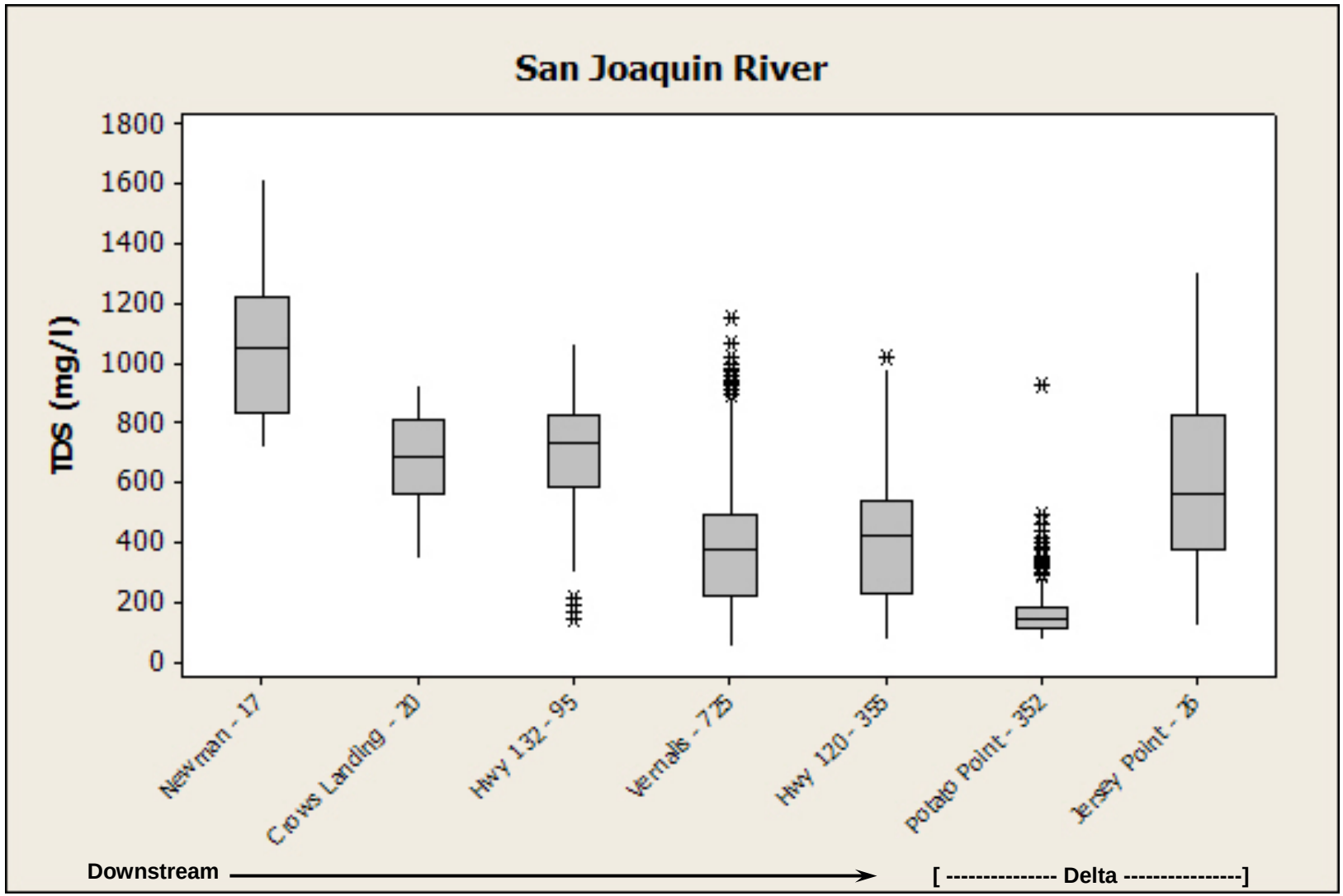


USGS, DWR, and RMA

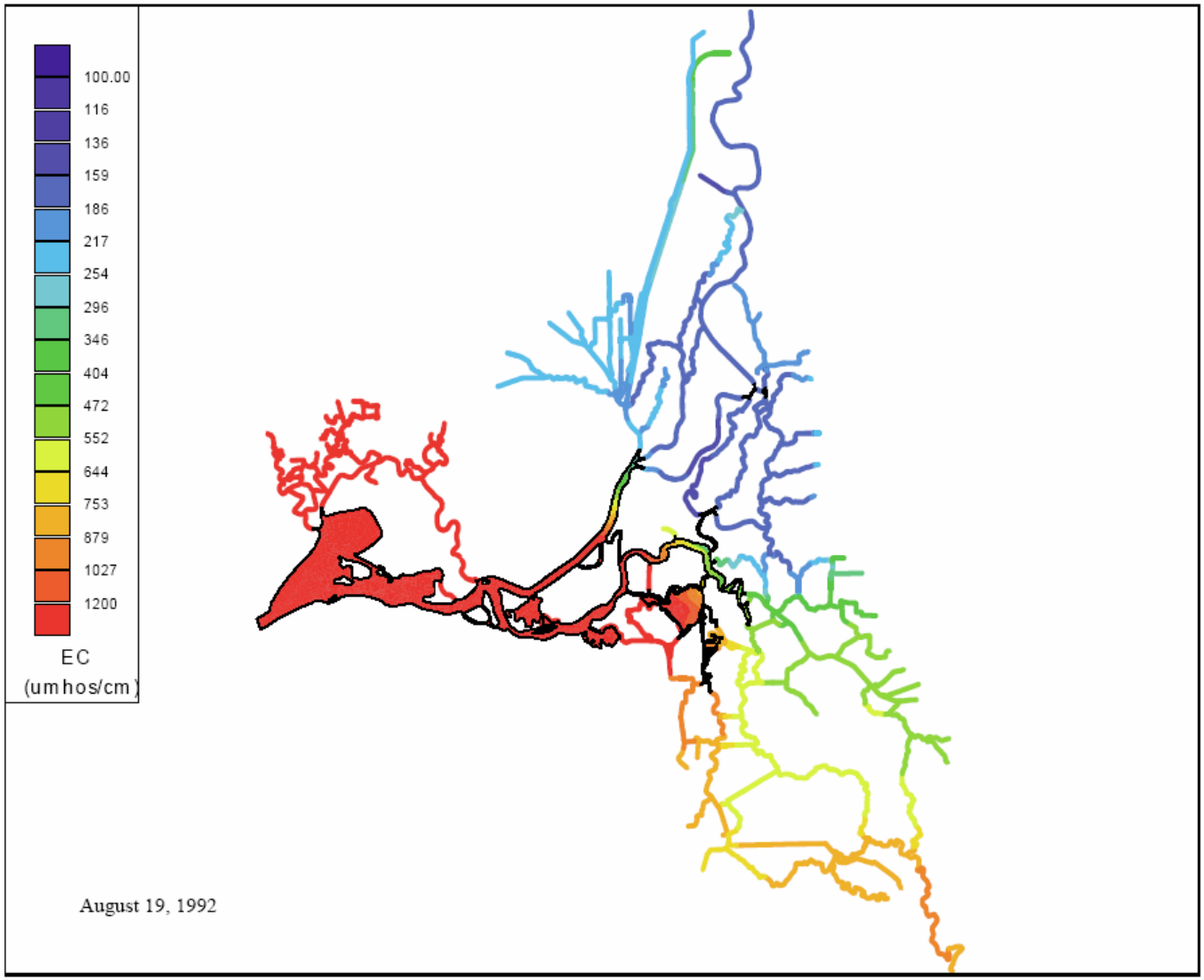
Characterizing salinity



Characterizing salinity



Characterizing salinity



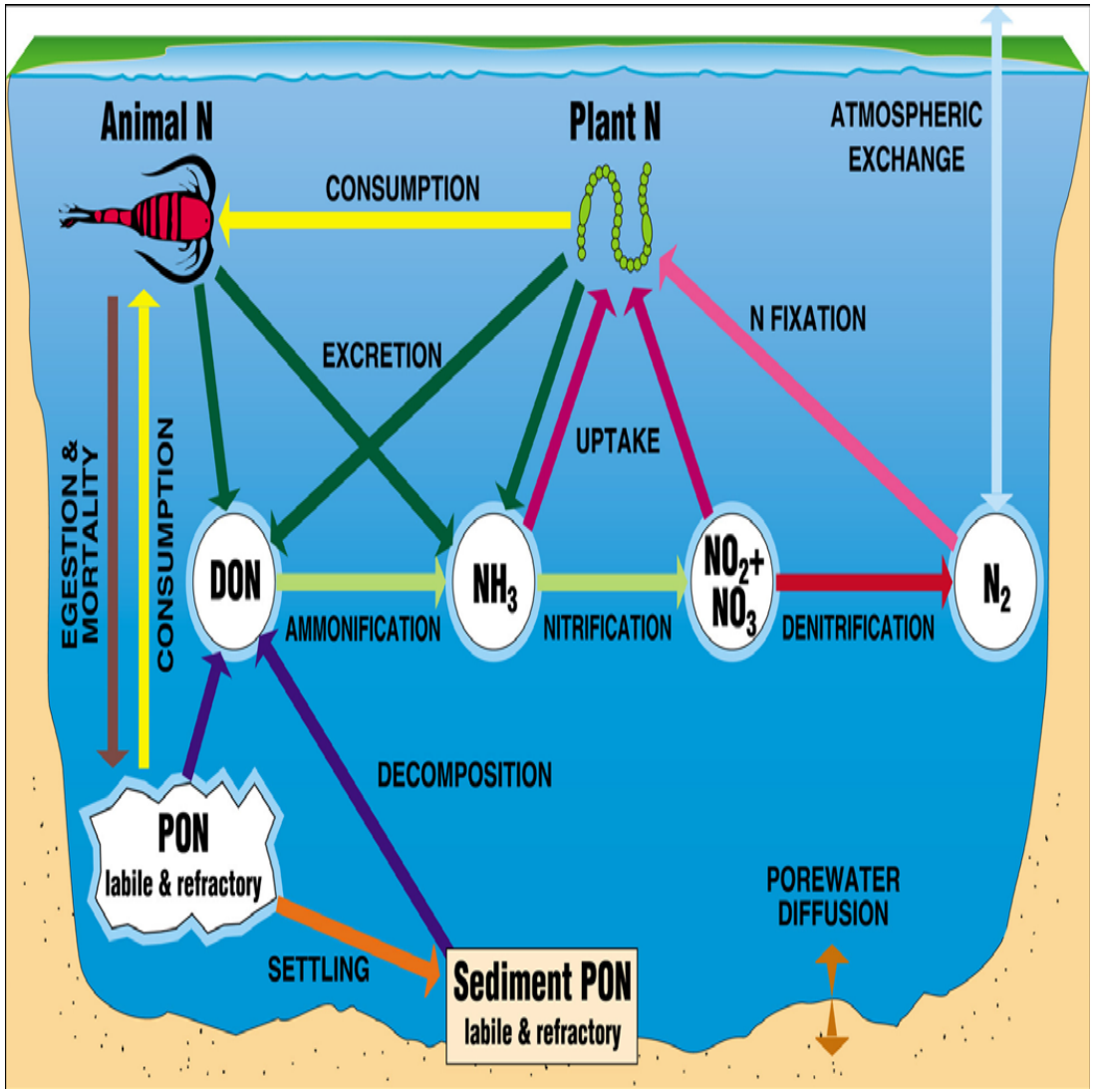
RMA, 2006

Next steps

- Work with DRERIP team on write up of Hydrodynamics/Salinity conceptual models
- Add more explicit bromide analysis
- Solicit input for data analysis direction (in watersheds)
- Investigate data on sources (vs. ambient)
- Finish salinity conceptual model
- Potentially use modeling sensitivity runs to further explore drivers and potential actions

Nutrients

Conceptual Model



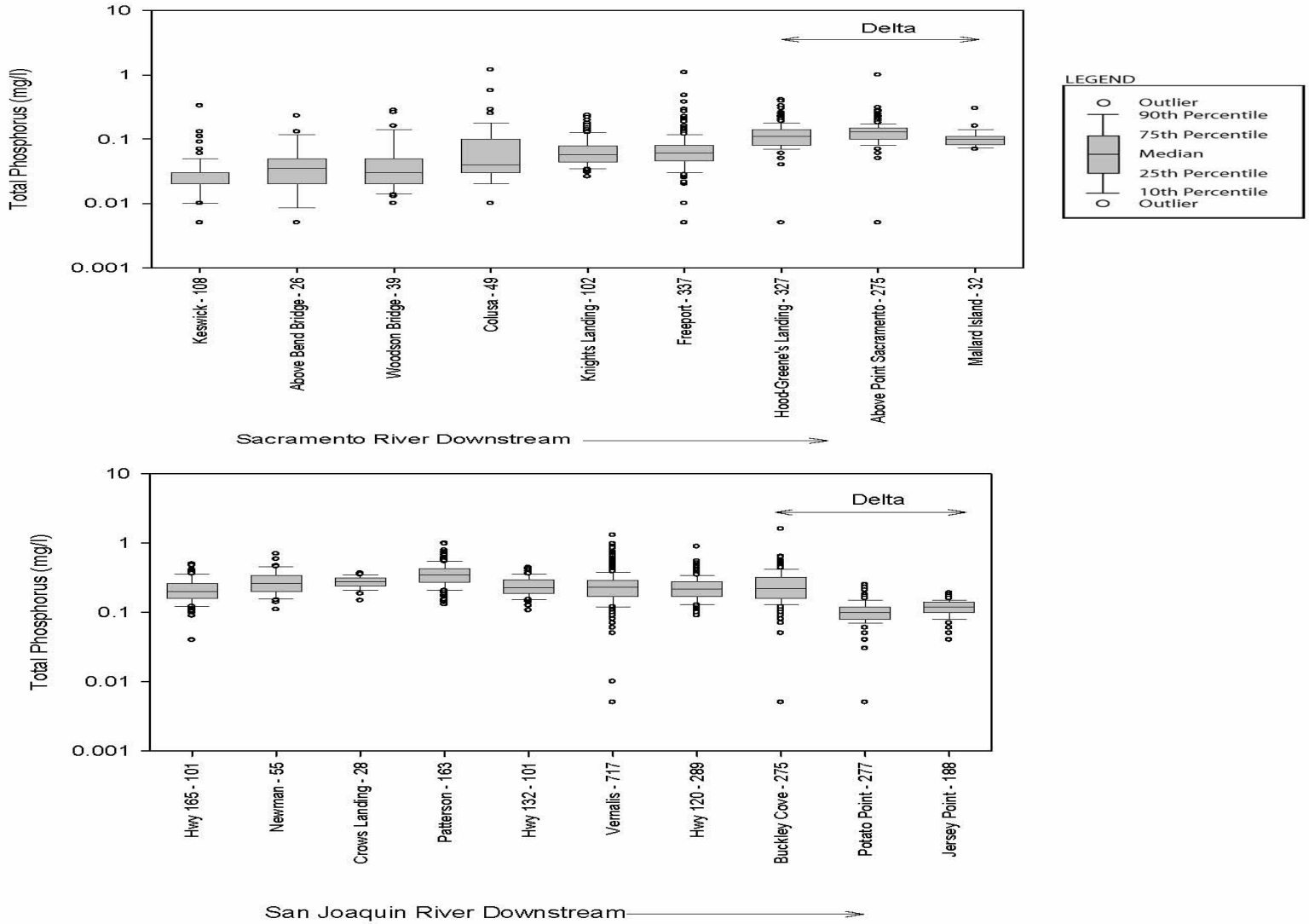
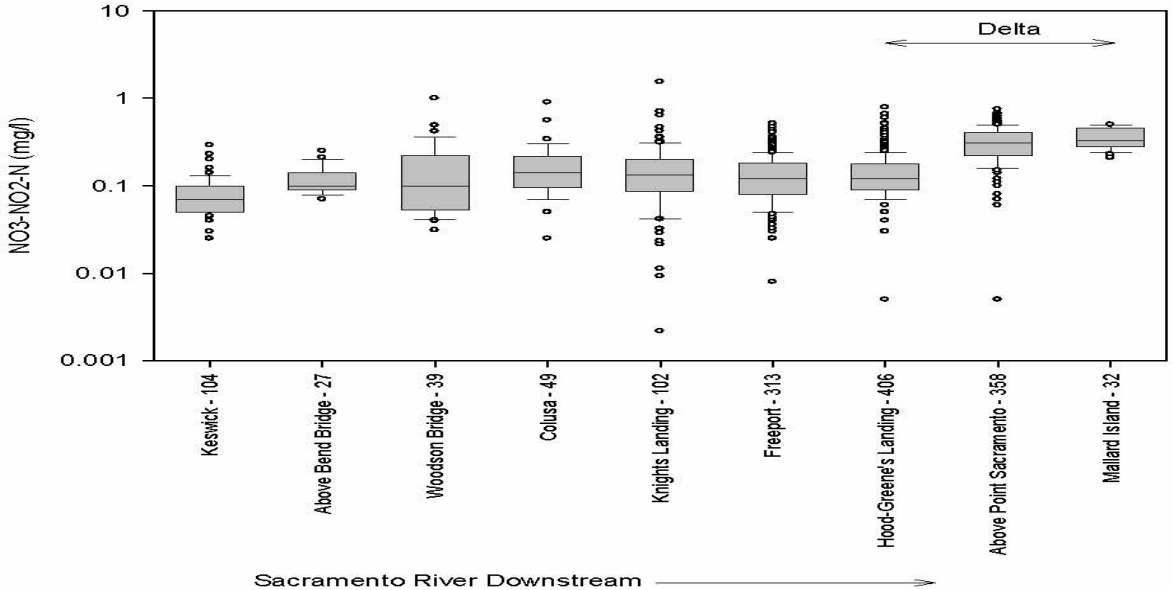
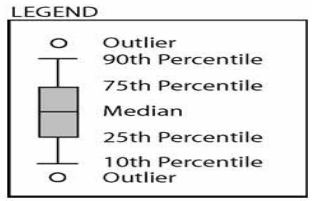
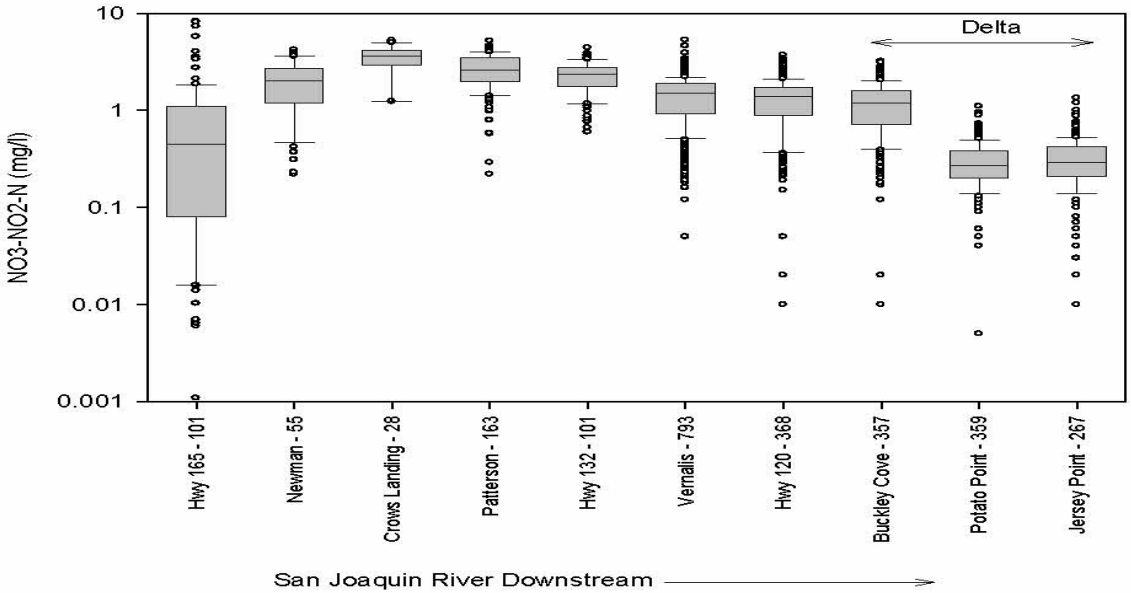
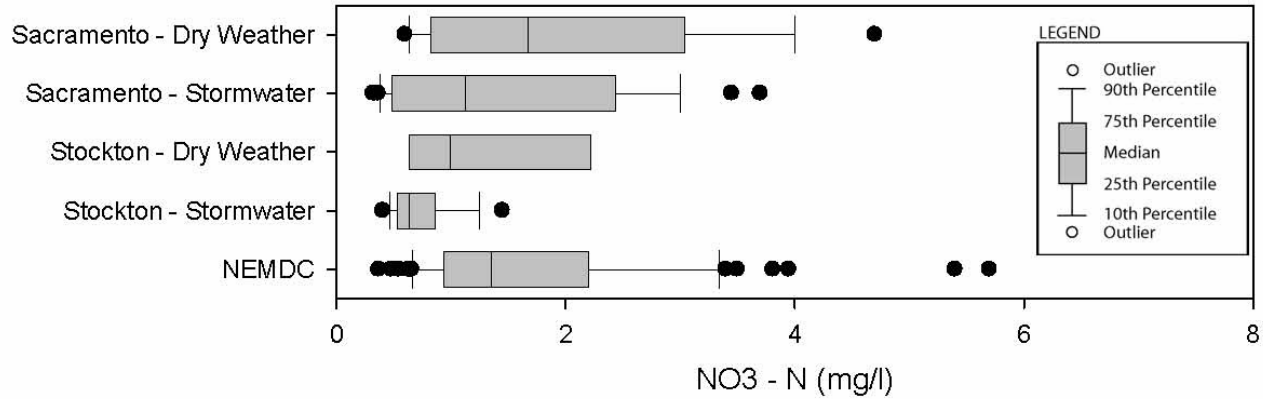


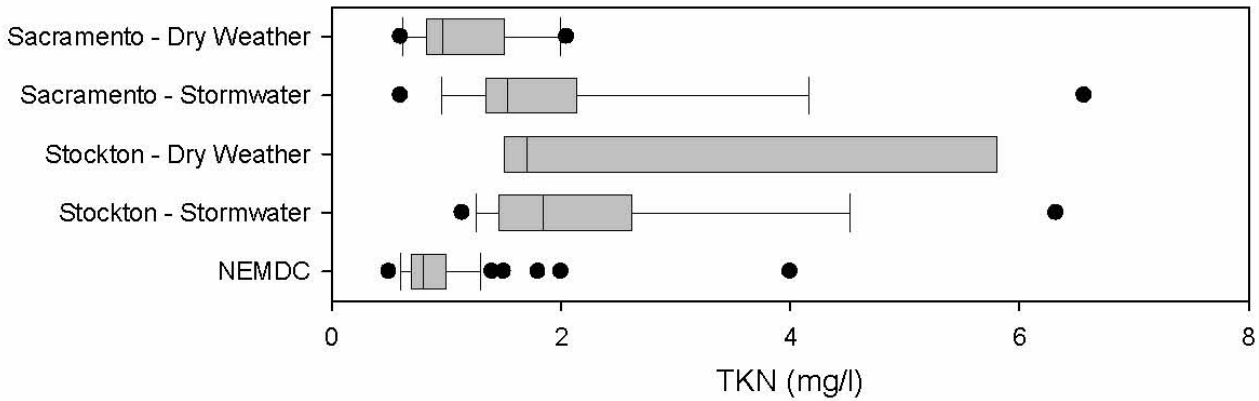
Figure 3-26. TP at various locations in the Sacramento and San Joaquin Rivers. The number of data points is shown after each station name.

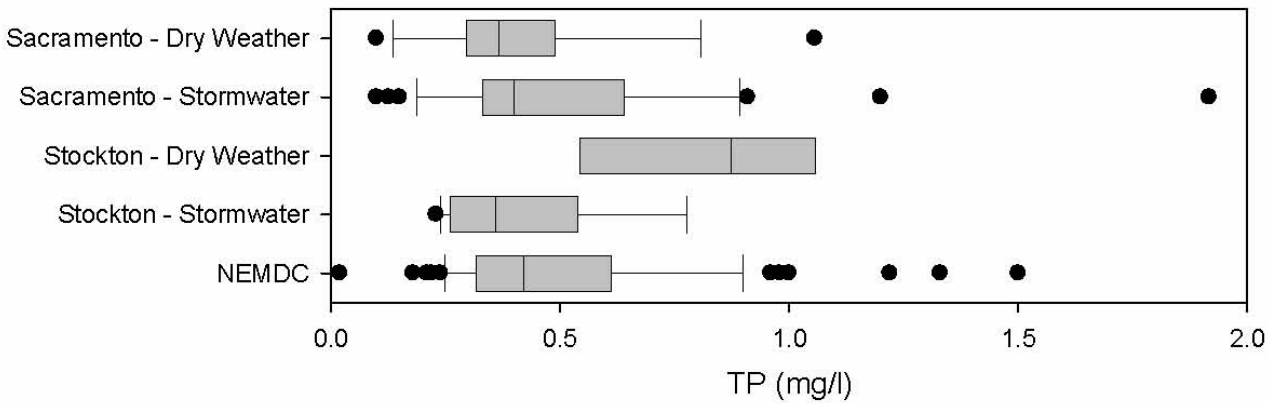

NO3-NO2-N (mg/l)
10
1
0.1
0.01
0.001
Delta
Keswick - 104
Above Bend Bridge - 27
Woodson Bridge - 39
Colusa - 49
Knights Landing - 102
Freeport - 313
Hood-Greene's Landing - 406
Above Point Sacramento - 358
Mallard Island - 32
Sacramento River Downstream

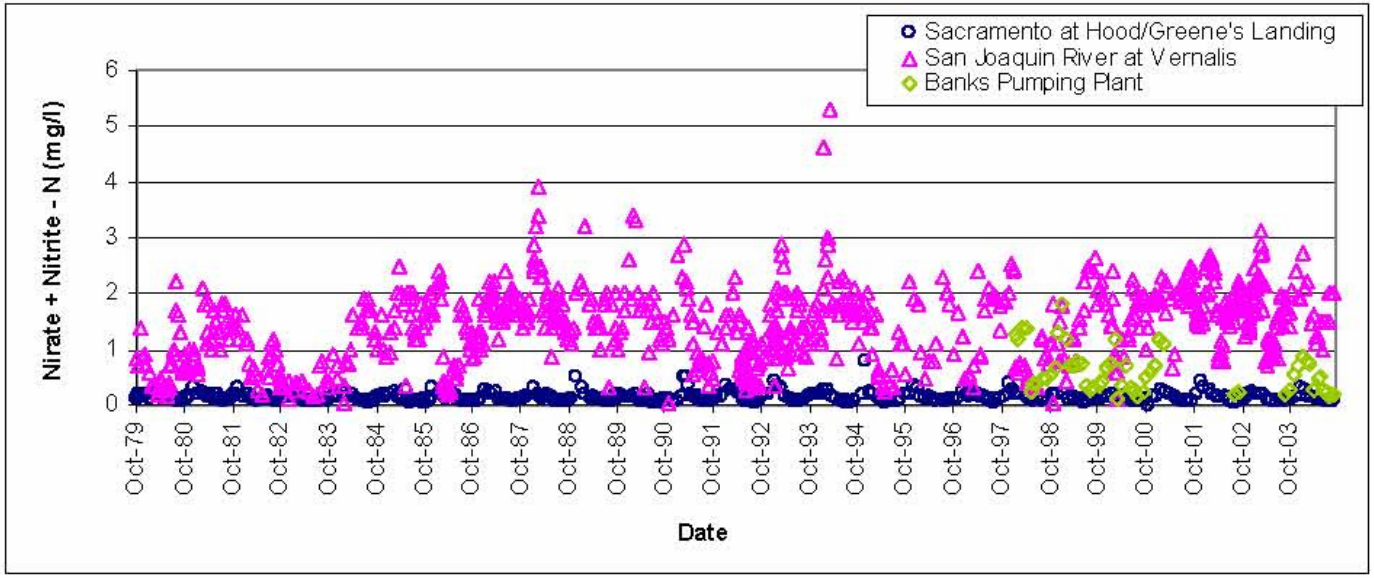

LEGEND
Outlier
90th Percentile
75th Percentile
Median
25th Percentile
10th Percentile
Outlier

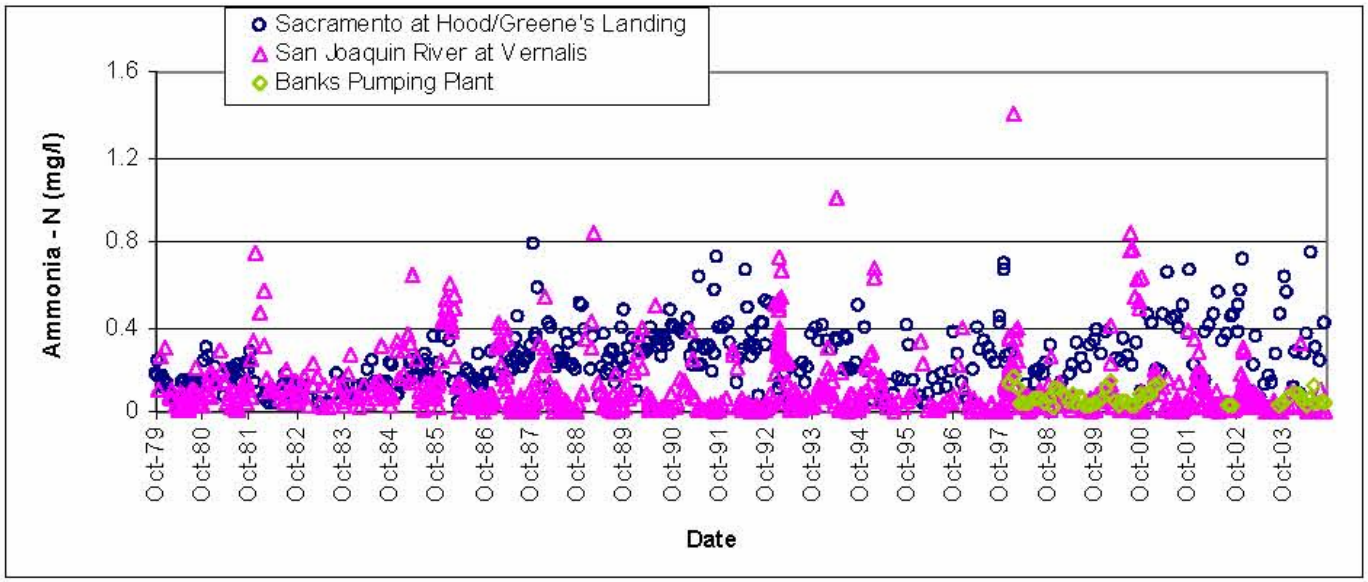

NO3-NO2-N (mg/l)
10
1
0.1
0.01
0.001
Delta
Hwy 165 - 101
Newman - 55
Crows Landing - 28
Patterson - 163
Hwy 132 - 101
Vernalis - 793
Hwy 120 - 368
Buckley Cove - 357
Potato Point - 359
Jersey Point - 267
San Joaquin River Downstream


Sacramento - Dry Weather
Sacramento - Stormwater
Stockton - Dry Weather
Stockton - Stormwater
NEMDC
LEGEND
Outlier
90th Percentile
75th Percentile
Median
25th Percentile
10th Percentile
Outlier
0
2
4
6
8
NO3 - N (mg/l)


Sacramento - Dry Weather
Sacramento - Stormwater
Stockton - Dry Weather
Stockton - Stormwater
NEMDC
0
2
4
6
8
TKN (mg/l)


Sacramento - Dry Weather
Sacramento - Stormwater
Stockton - Dry Weather
Stockton - Stormwater
NEMDC
0.0
0.5
1.0
1.5
2.0
TP (mg/l)


Sacramento at Hood/Greene's Landing
San Joaquin River at Vernalis
Banks Pumping Plant
Nirate + Nitrite - N (mg/l)
0
1
2
3
4
5
6
Oct-79
Oct-80
Oct-81
Oct-82
Oct-83
Oct-84
Oct-85
Oct-86
Oct-87
Oct-88
Oct-89
Oct-90
Oct-91
Oct-92
Oct-93
Oct-94
Oct-95
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Date


Sacramento at Hood/Greene's Landing
San Joaquin River at Vernalis
Banks Pumping Plant
Ammonia - N (mg/l)
0
0.4
0.8
1.2
1.6
Oct-79
Oct-80
Oct-81
Oct-82
Oct-83
Oct-84
Oct-85
Oct-86
Oct-87
Oct-88
Oct-89
Oct-90
Oct-91
Oct-92
Oct-93
Oct-94
Oct-95
Oct-96
Oct-97
Oct-98
Oct-99
Oct-00
Oct-01
Oct-02
Oct-03
Date

Next steps

- Work with DO project’s work on nutrient modeling
- Determine monitoring and research needs, using treatment work to direct
- CALFED consultant work on controllability (in parallel with organic carbon)

Pathogens

Conceptual Model

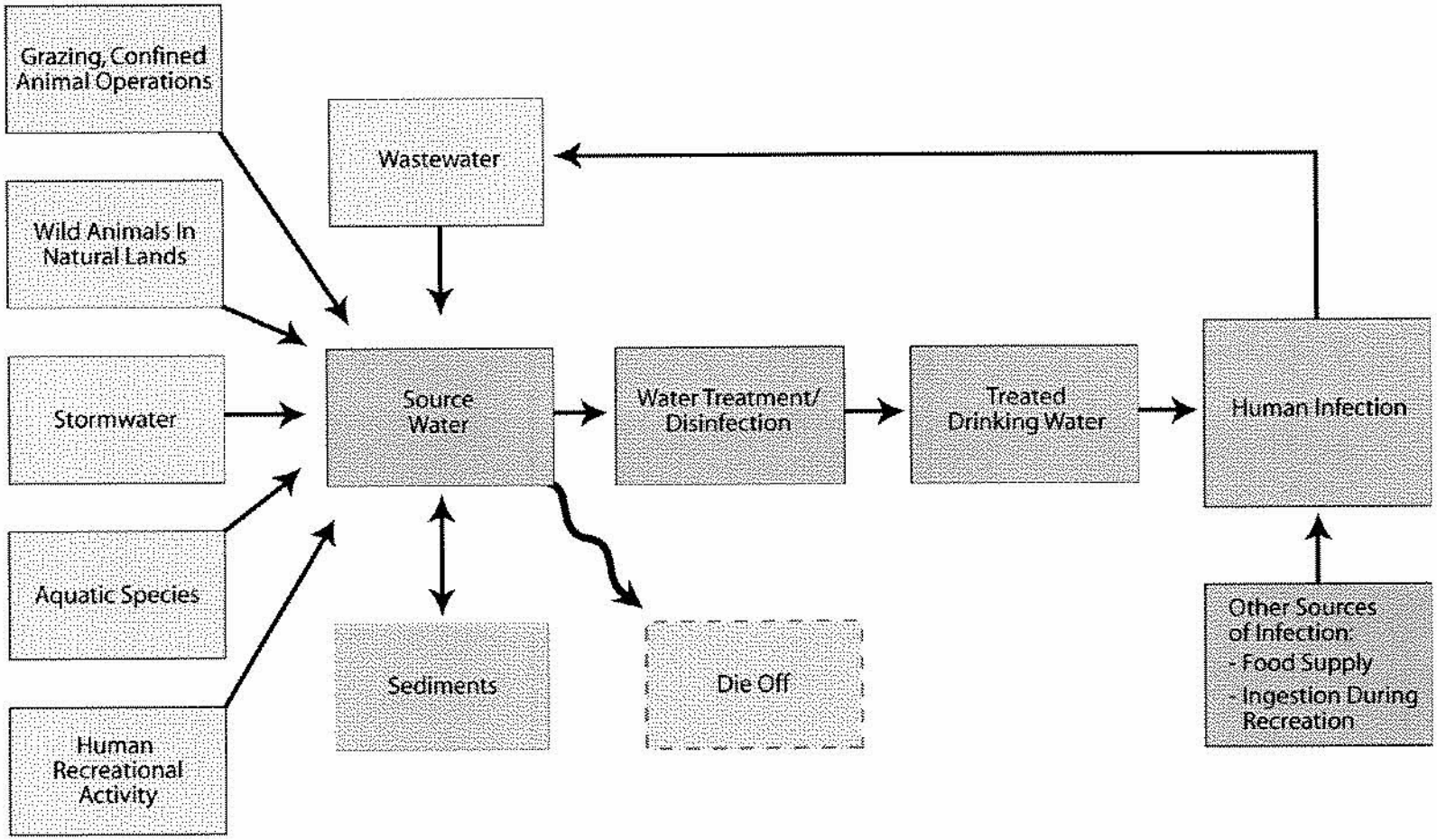
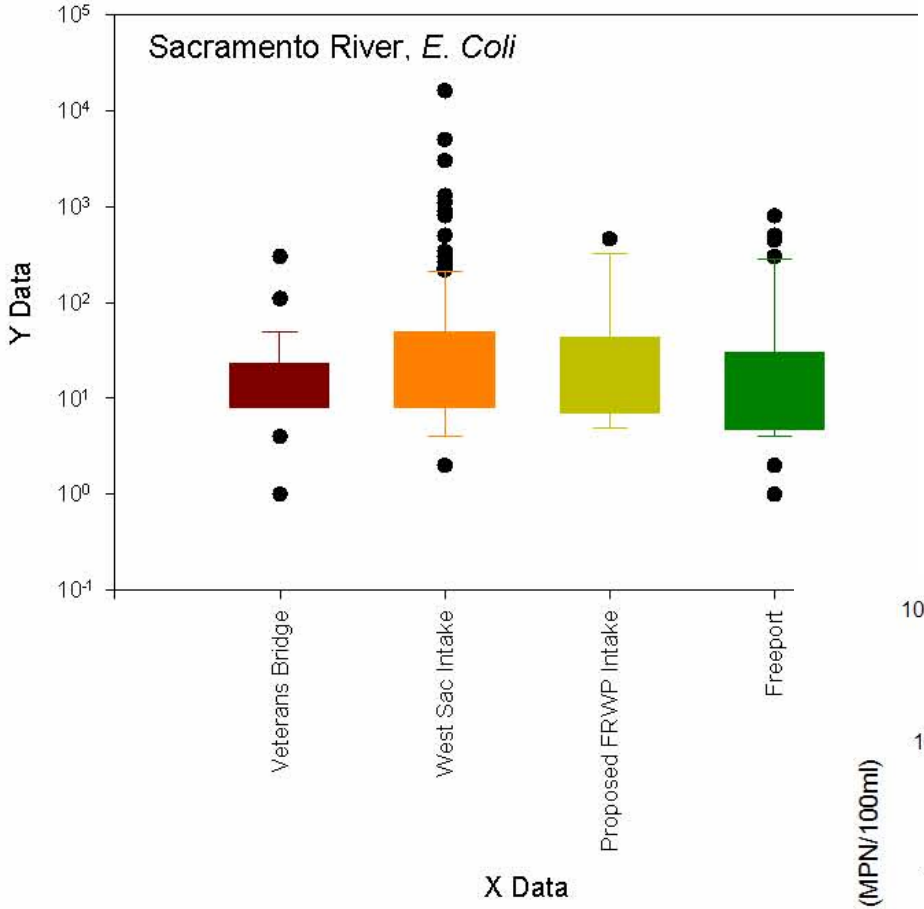
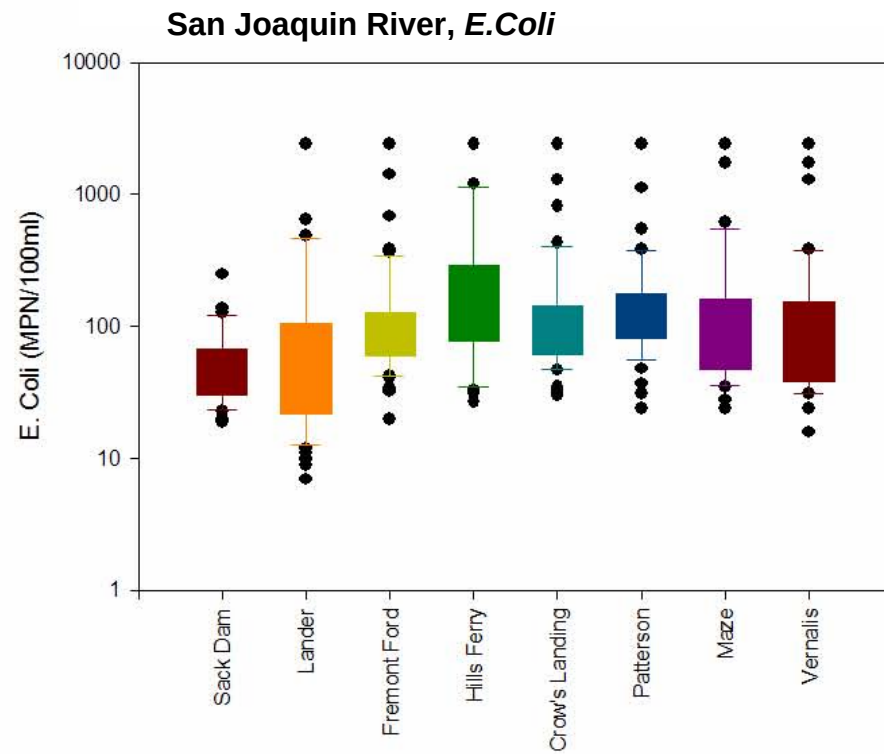


Figure 2-1 Schematic of pathogen contamination of drinking waters.

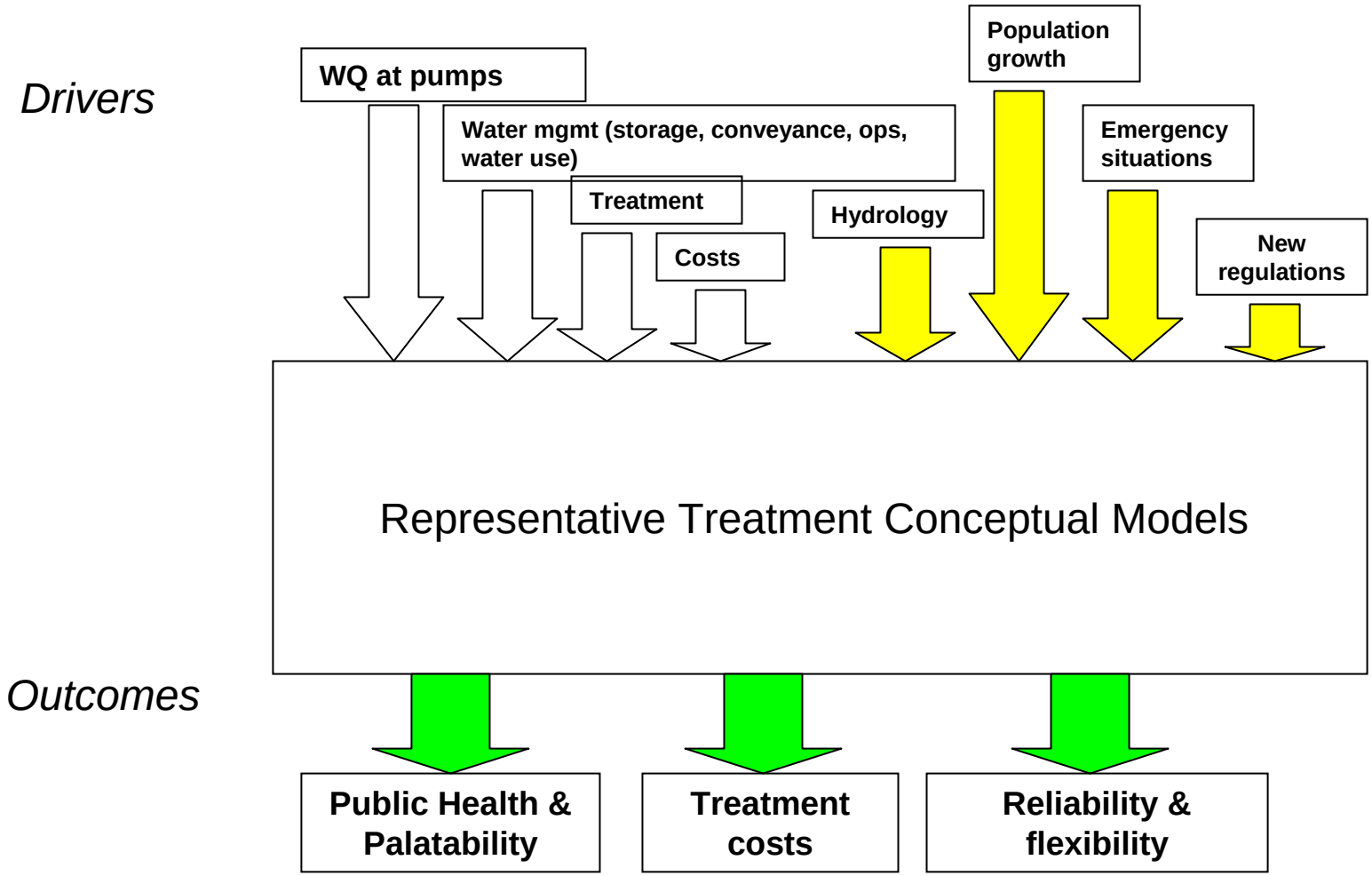
DRAFT


Sacramento River, *E. Coli*
Y Data
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
Veterans Bridge
West Sac Intake
Proposed FRWP Intake
Freeport
X Data


San Joaquin River, *E.Coli*
E. Coli (MPN/100ml)
10000
1000
100
10
1
Sack Dam
Lander
Fremont Ford
Hills Ferry
Crow's Landing
Patterson
Maze
Vernalis

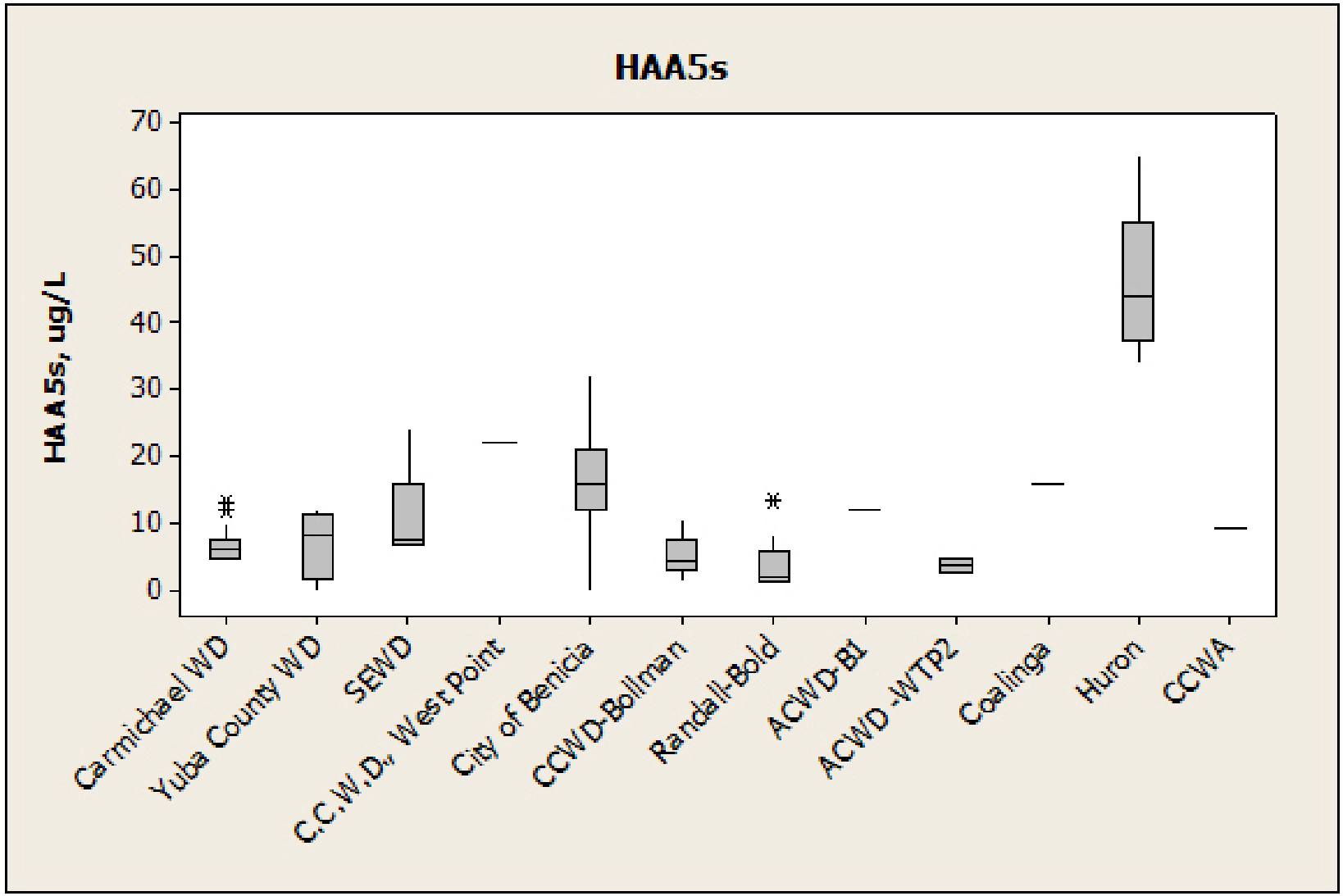
DRAFT

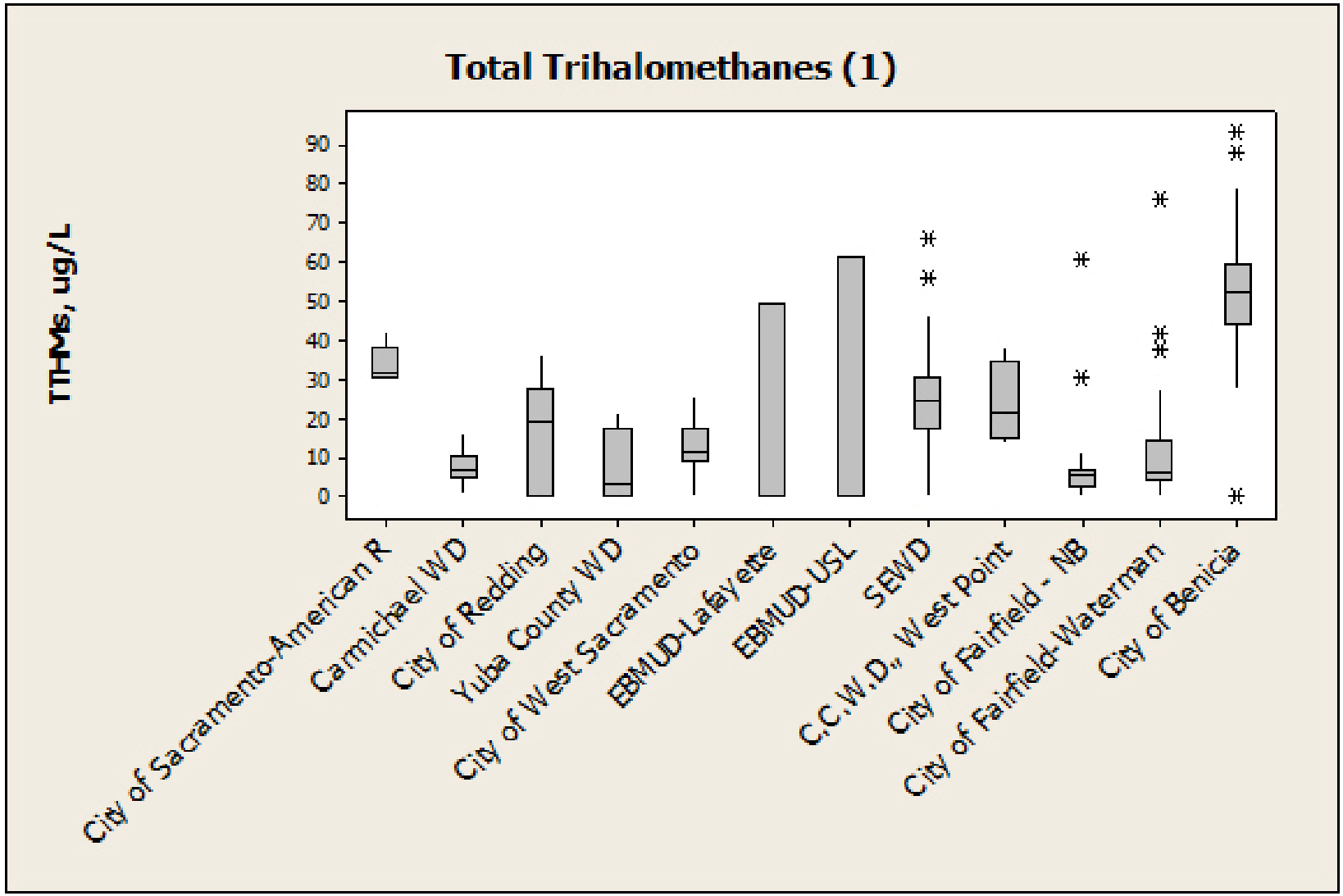
Drinking Water Treatment

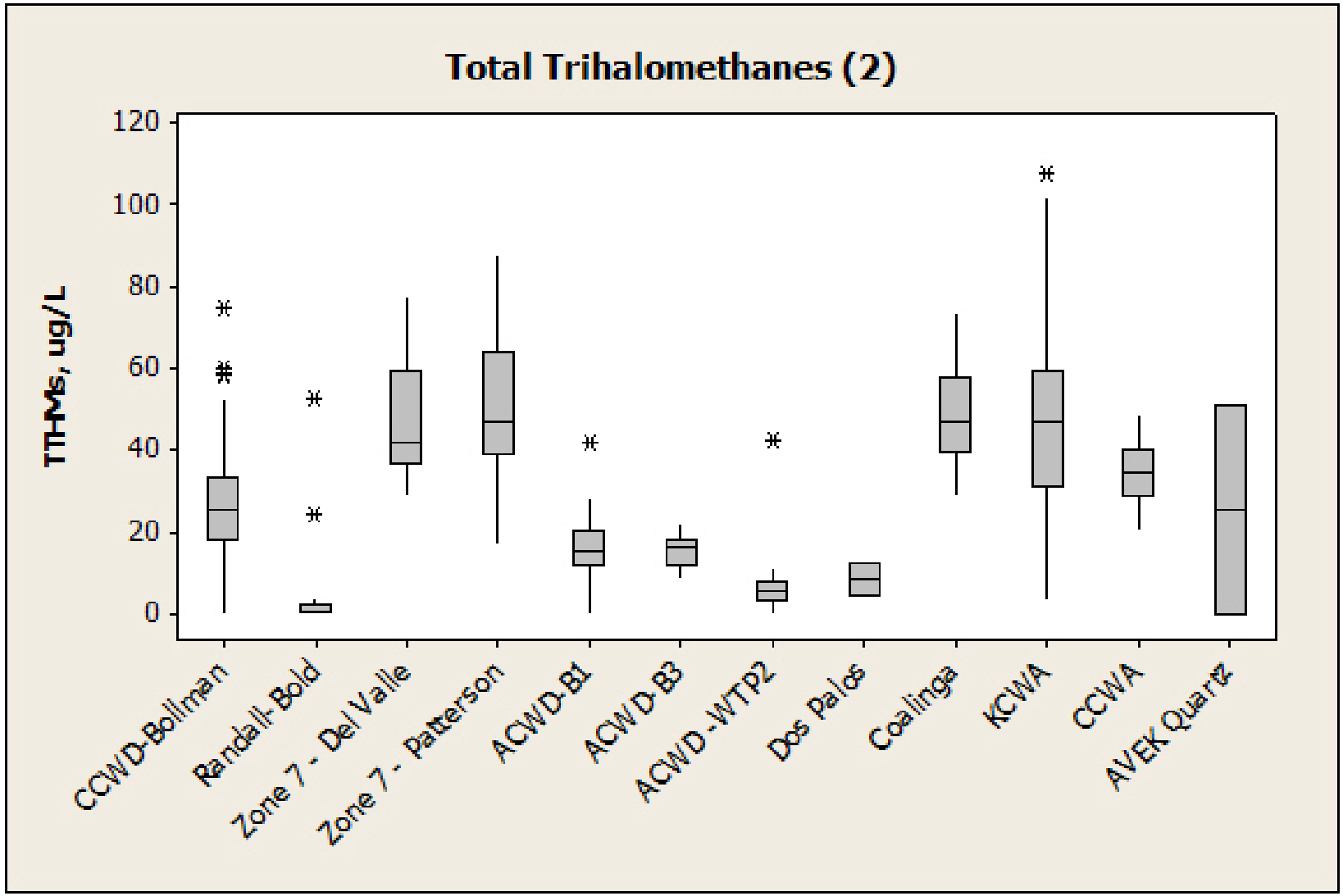

Drivers
WQ at pumps
Water mgmt (storage, conveyance, ops, water use)
Treatment
Costs
Hydrology
Population growth
Emergency situations
New regulations
Representative Treatment Conceptual Models
Outcomes
Public Health & Palatability
Treatment costs
Reliability & flexibility

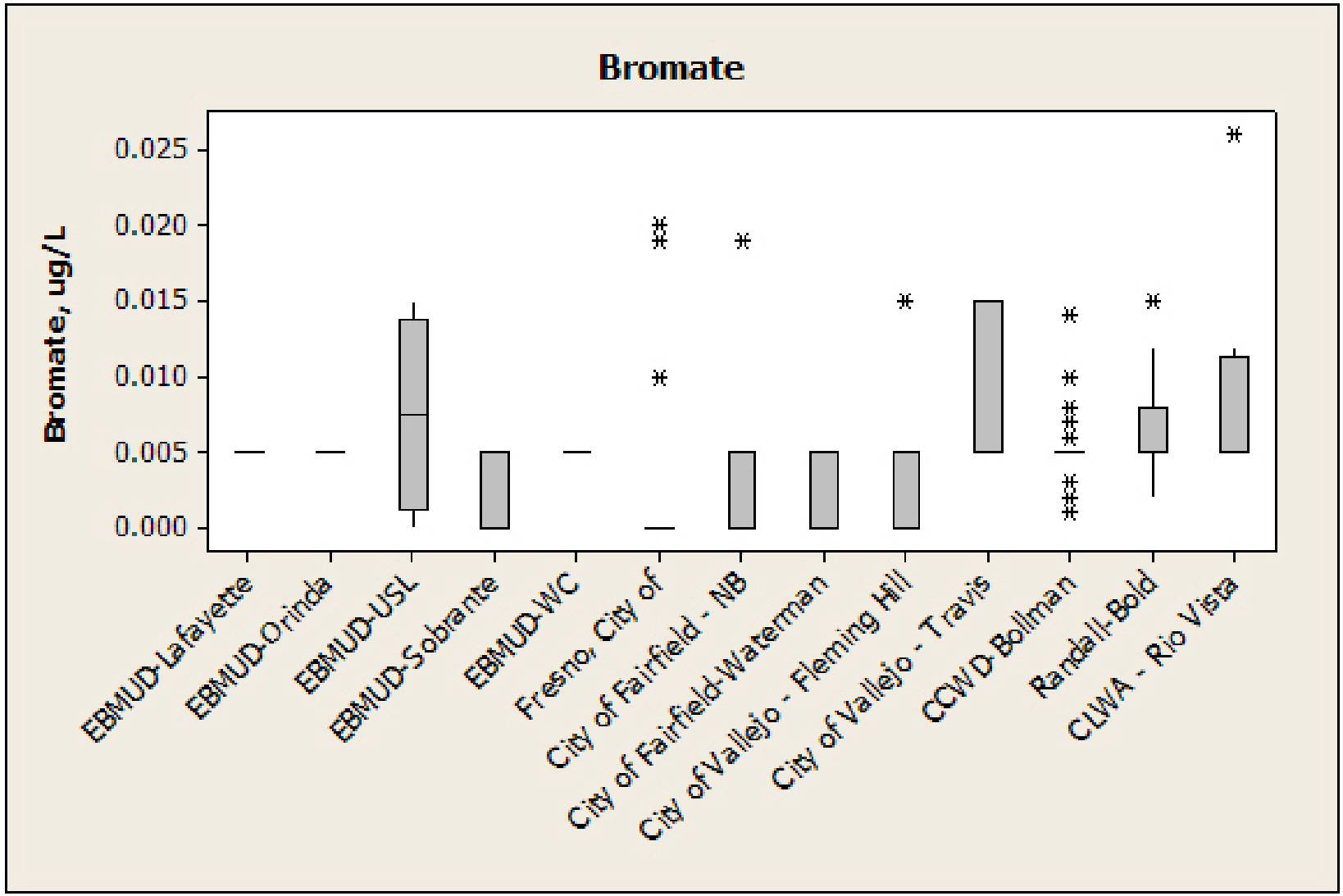
Representative Treatment Plants

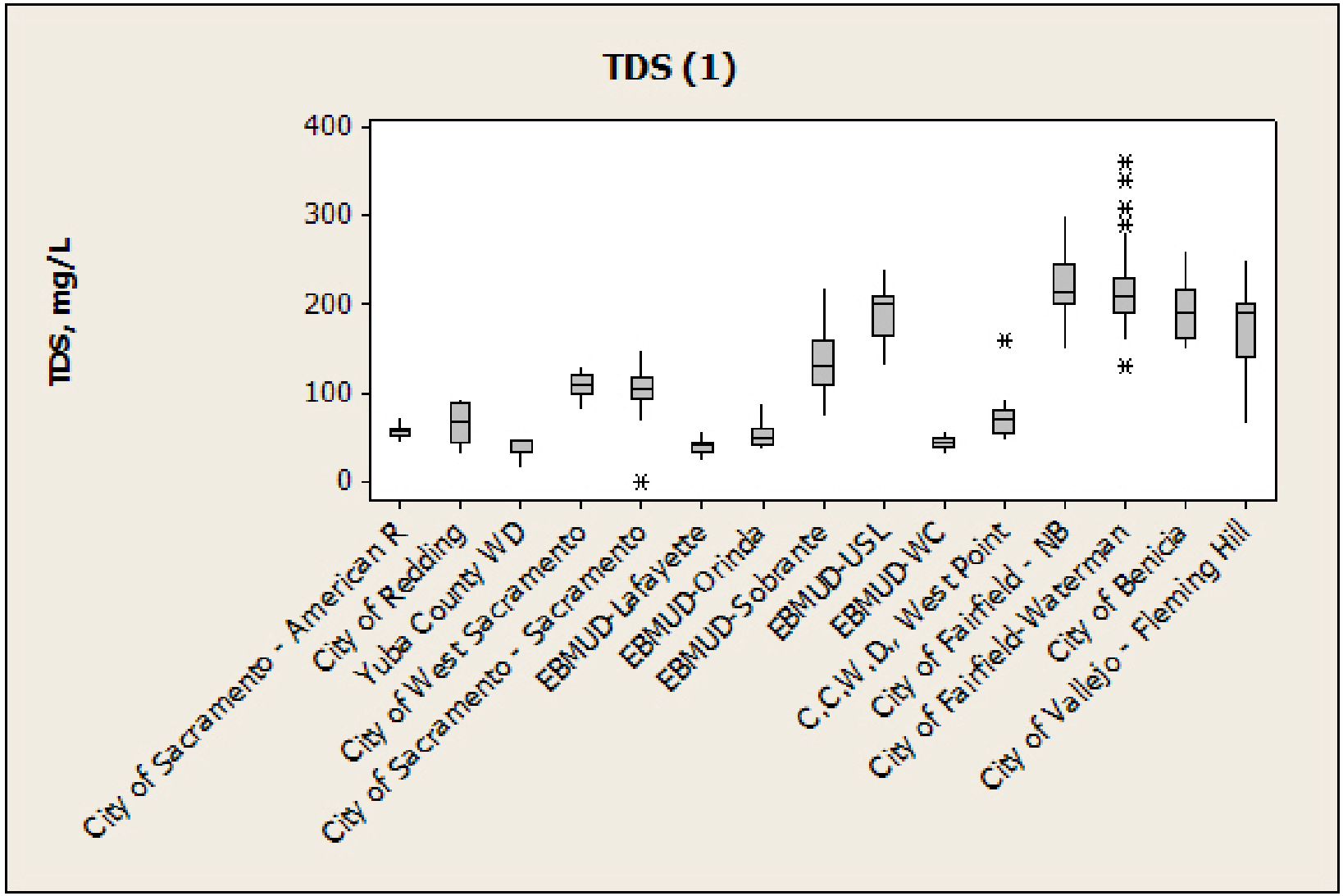
- Identified 62 treatment plants that treat some portion of Delta water, with DHS assistance:
  - 48 conventional treatment
  - 4 direct filtration
  - 1 alternative technology
  - 3 membrane/ultrafiltration
  - 7 not yet categorized
- Disinfection use:
  - 16 employ ozone
  - 21 employ hypochlorination
  - 34 employ chlorination
  - 28 employ chloramines
  - 1 employs MIOX
  - 21 of these are in combination

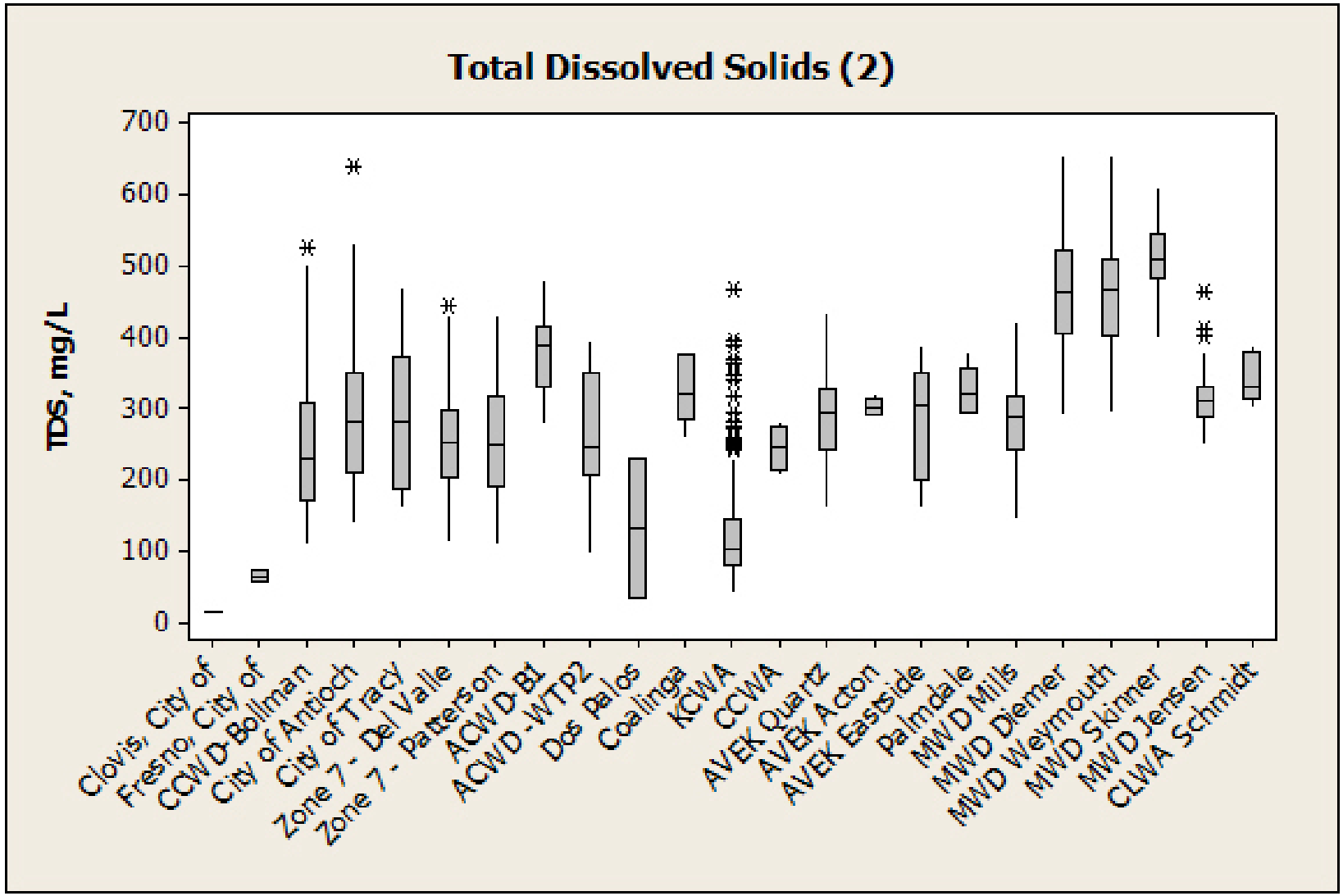

HAA5s
HAA5s, ug/L
70
60
50
40
30
20
10
0
Carmichael WD
Yuba County WD
SEWD
C.C.W.D. West Point
City of Benicia
CCWD-Bollman
Randall-Bold
ACWD-BI
ACWD-WTP2
Coalinga
Huron
CCWA


Total Trihalomethanes (1)
TTHMs, ug/L
0
10
20
30
40
50
60
70
80
90
City of Sacramento-American R
Carmichael WD
City of Redding
Yuba County WD
City of West Sacramento
EBMUD-Lafayette
EBMUD-USL
SEWD
C.C.W.D., West Point
City of Fairfield - NB
City of Fairfield-Waterman
City of Benicia


Total Trihalomethanes (2)
THMs, ug/L
120
100
80
60
40
20
0
CCWD-Bollman
Randall-Bold
Zone 7 - Del Valle
Zone 7 - Patterson
ACWD-B1
ACWD-B3
ACWD-WTP2
Dos Palos
Coalinga
KCWA
CCWA
AVEK Quartz


Bromate
Bromate, ug/L
0.025
0.020
0.015
0.010
0.005
0.000
EBMUD-Lafayette
EBMUD-Orinda
EBMUD-USL
EBMUD-Sobrante
EBMUD-WC
Fresno, City of
City of Fairfield - NB
City of Fairfield-Waterman
City of Vallejo - Fleming Hill
City of Vallejo - Travis
CCWD-Bollman
Randall-Bold
CLWA - Rio Vista


TDS (1)
TDS, mg/L
400
300
200
100
0
City of Sacramento - American R
City of Redding
Yuba County WD
City of West Sacramento
City of Sacramento - Sacramento
EBMUD-Lafayette
EBMUD-Orinda
EBMUD-Sobrante
EBMUD-USL
EBMUD-WC
C.C.W.D. West Point
City of Fairfield - NB
City of Fairfield-Waterman
City of Benicia
City of Vallejo - Fleming Hill


Total Dissolved Solids (2)
TDS, mg/L
700
600
500
400
300
200
100
0
Clovis, City of
Fresno, City of
CCWD-Bollman
City of Antioch
City of Tracy
Zone 7 - Del Valle
Zone 7 - Patterson
ACWD-BI
ACWD-WTP2
Dos Palos
Coalinga
KCWA
CCWA
AVEK Quartz
AVEK Acton
AVEK Eastside
Palmdale
MWD Mills
MWD Diemer
MWD Weymouth
MWD Skinner
MWD Jensen
CLWA Schmidt

Next steps

- Continue work with DHS data base (next steps: plant source water data, analysis of treated water data)
- Survey utilities for factors not included in DHS database
- Use data to select representative treatment plants for further investigation, with CALFED consultant
- Develop treatment conceptual model

Final Assessment Schedule

- Draft chapters by the end of July 2007
- Final draft chapters by the end of September 2007
- Final draft document by the end of October 2007
- Peer review process? (Resources not yet identified)

- Performance measure development in parallel with Final Assessment schedule

Questions/Comments/Advice

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