Hydrodynamics and Salinity Response to Levee Breaches in the Suisun Marsh

Mechanisms,
Restoration Design, and
CALFED Science Review

Chris Enright

Callie Harrison

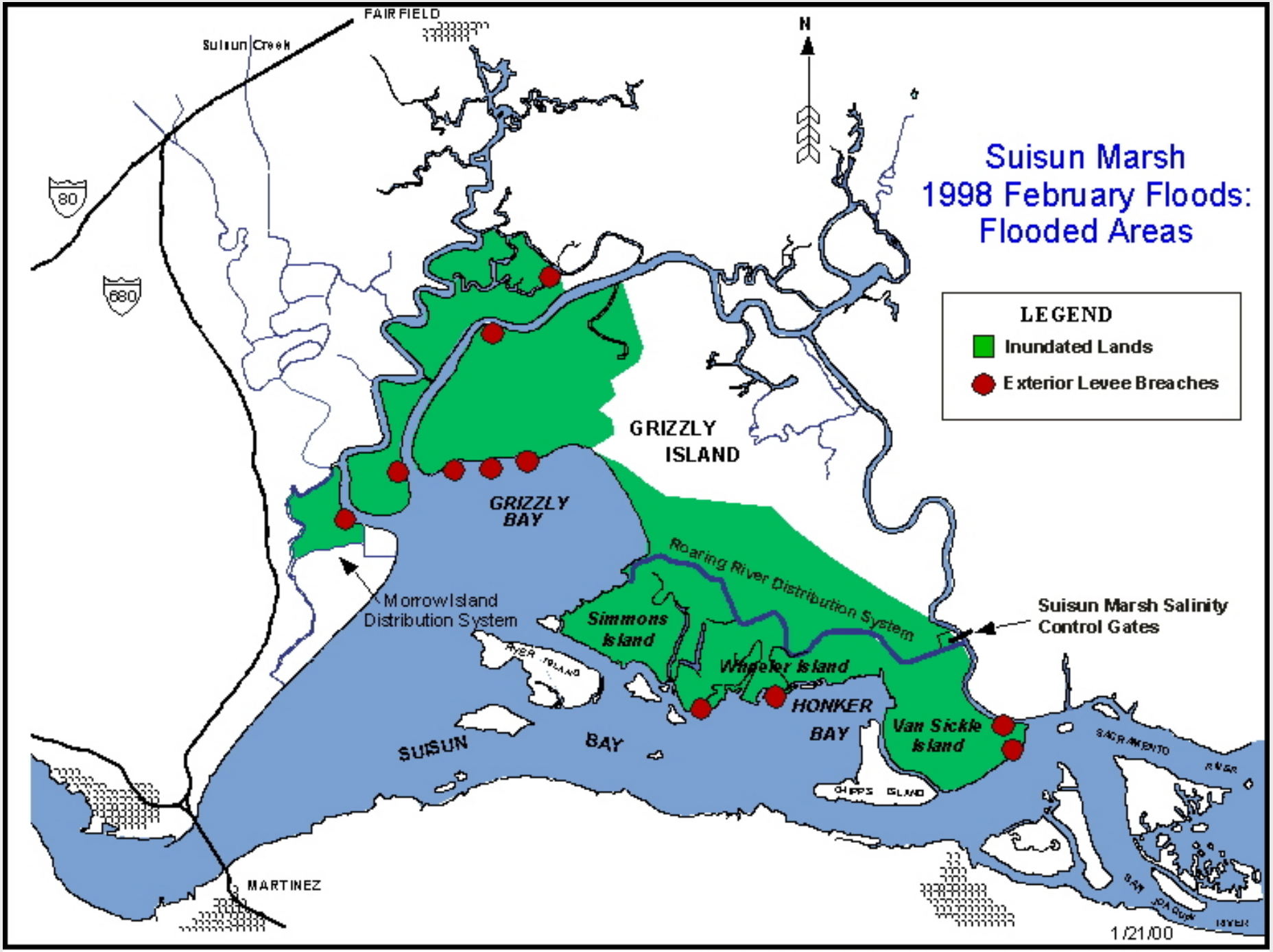
DWR

Topics

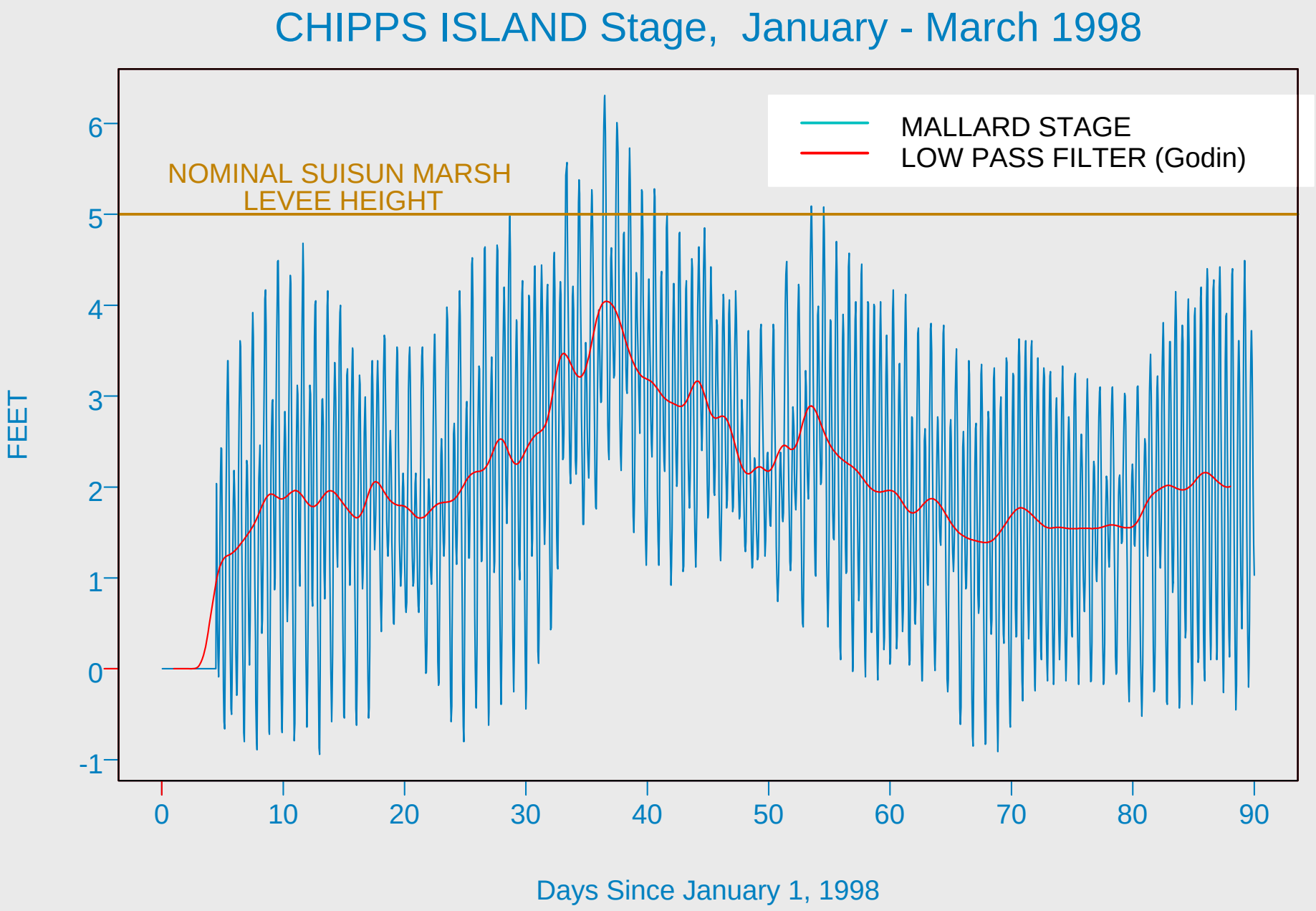
1. Review what we've learned.
2. Recent sensitivity analysis modeling for CALFED Science Panel review
3. Why do the "Tidal Marsh Options" work? (Tidal Restoration Design Implications)
4. Modeling verification: Sunrise Club

Themes

- Competing/interacting physical mechanisms
- Complex, non-linear response
- The modeling analysis has been broadly reviewed and corroborated. Review, collaboration, and research continues. Yahoo!
- Address some of Cecilia’s comments

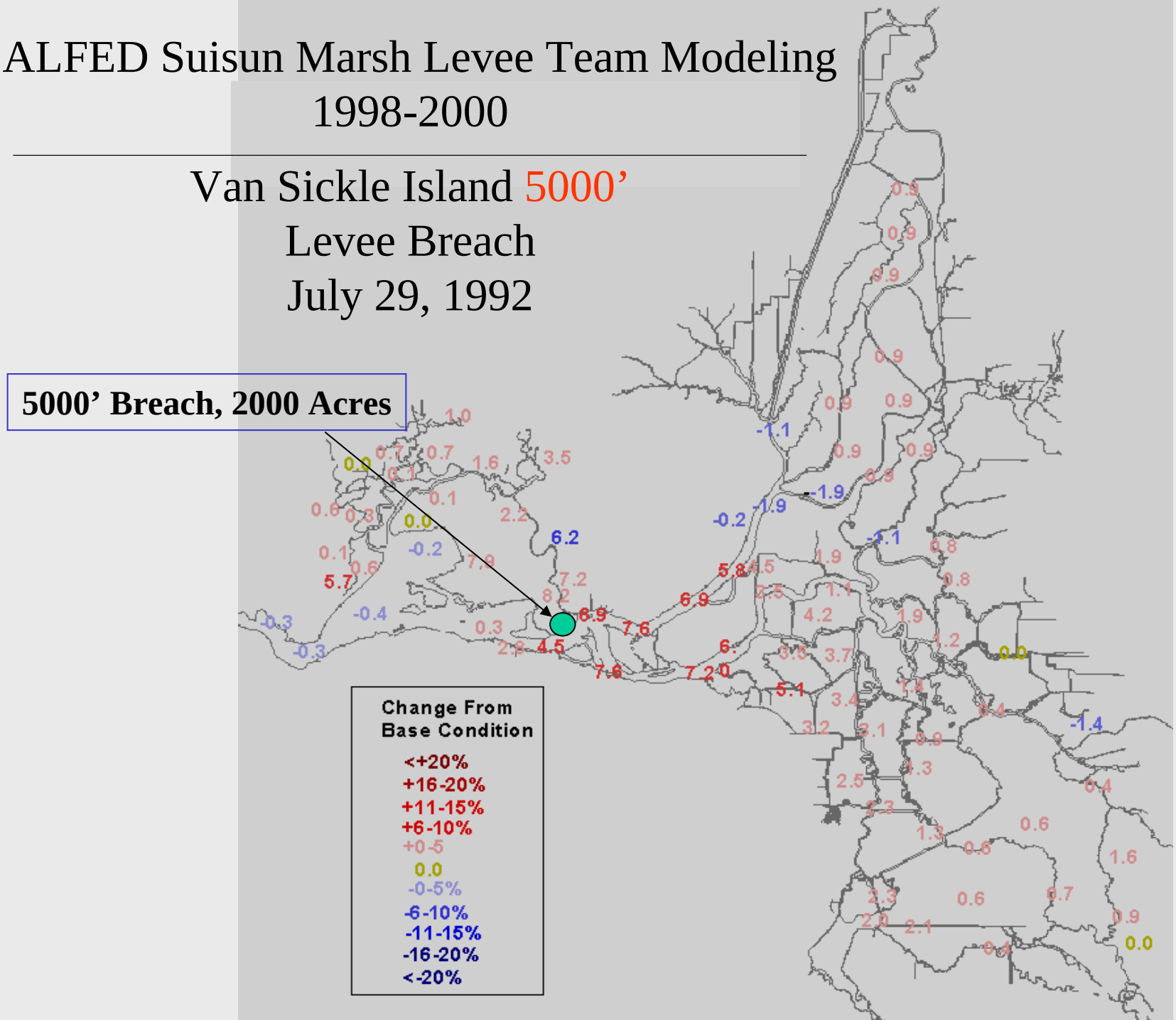


Department of Water Resources - Suisun Marsh Planning


CHIPPS ISLAND Stage, January - March 1998
MALLARD STAGE
LOW PASS FILTER (Godin)
NOMINAL SUISUN MARSH
LEVEE HEIGHT
FEET
6
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70
80
90
Days Since January 1, 1998

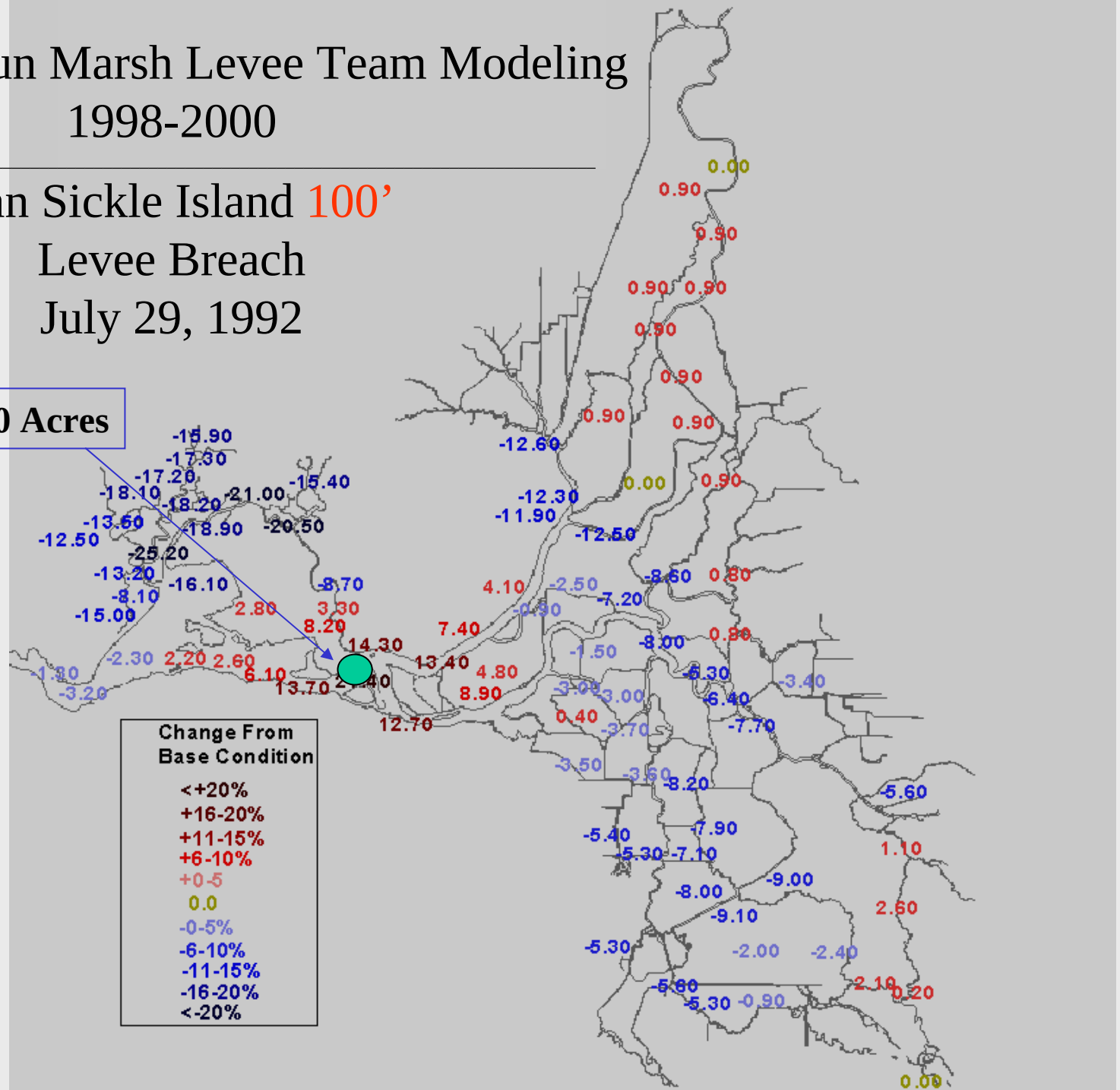
CALFED Suisun Marsh Levee Team Modeling 1998-2000

Van Sickle Island 5000’ Levee Breach July 29, 1992



CALFED Suisun Marsh Levee Team Modeling 1998-2000

Van Sickle Island 100’ Levee Breach July 29, 1992



Two *"competing"* mechanisms are at work:

1) Breached areas dissipate tidal energy and reduce tidal range. This reduces tidal excursion which is proportional to dispersion of salt.

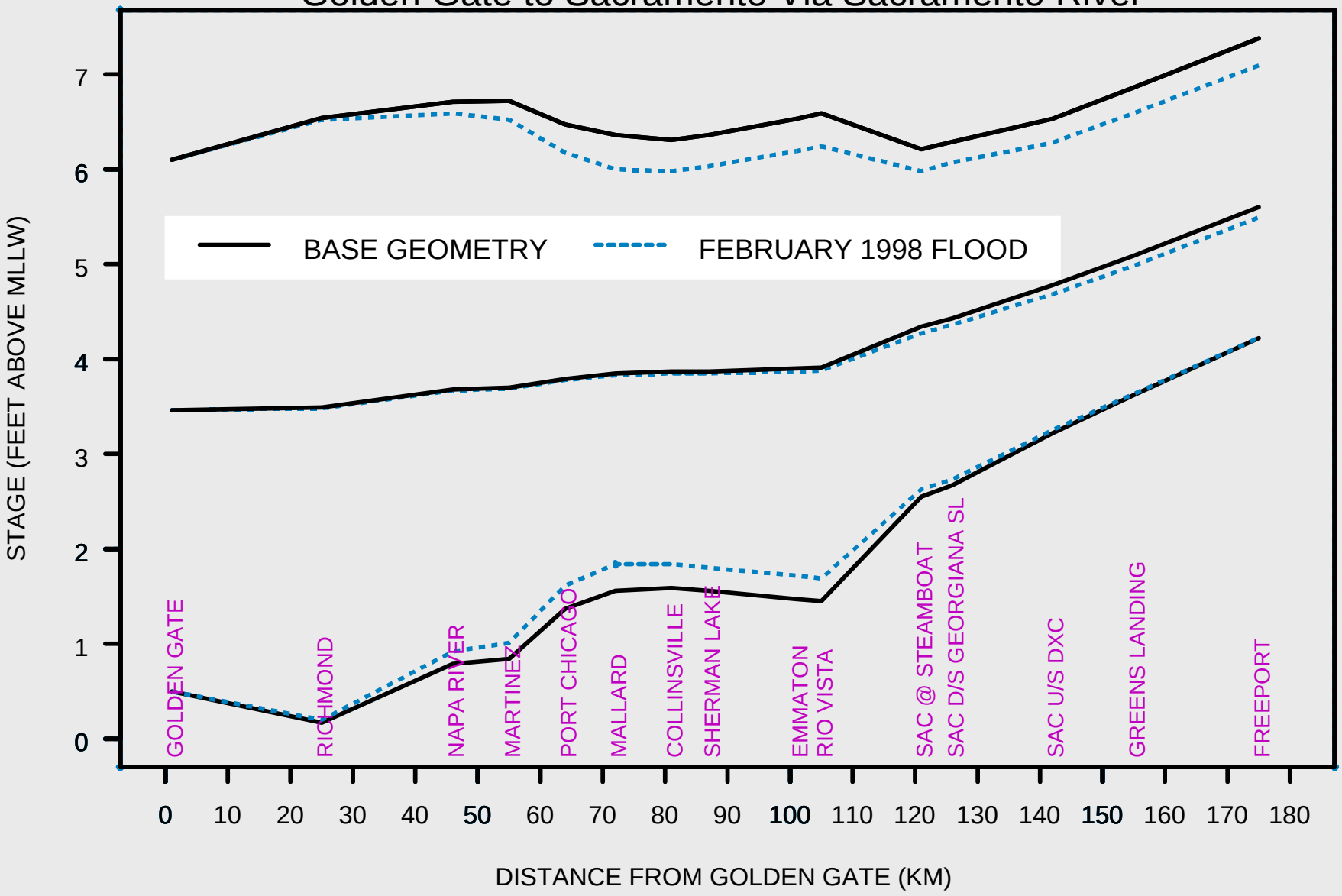
   ➔***Salinity tends to be reduced.***

2) Asymmetry between tidal flows inside and outside levee breaches can “trap” salinity upstream.

   ➔***Salinity tends to be increased.***

28 Day Average Tidal Range

Golden Gate to Sacramento Via Sacramento River



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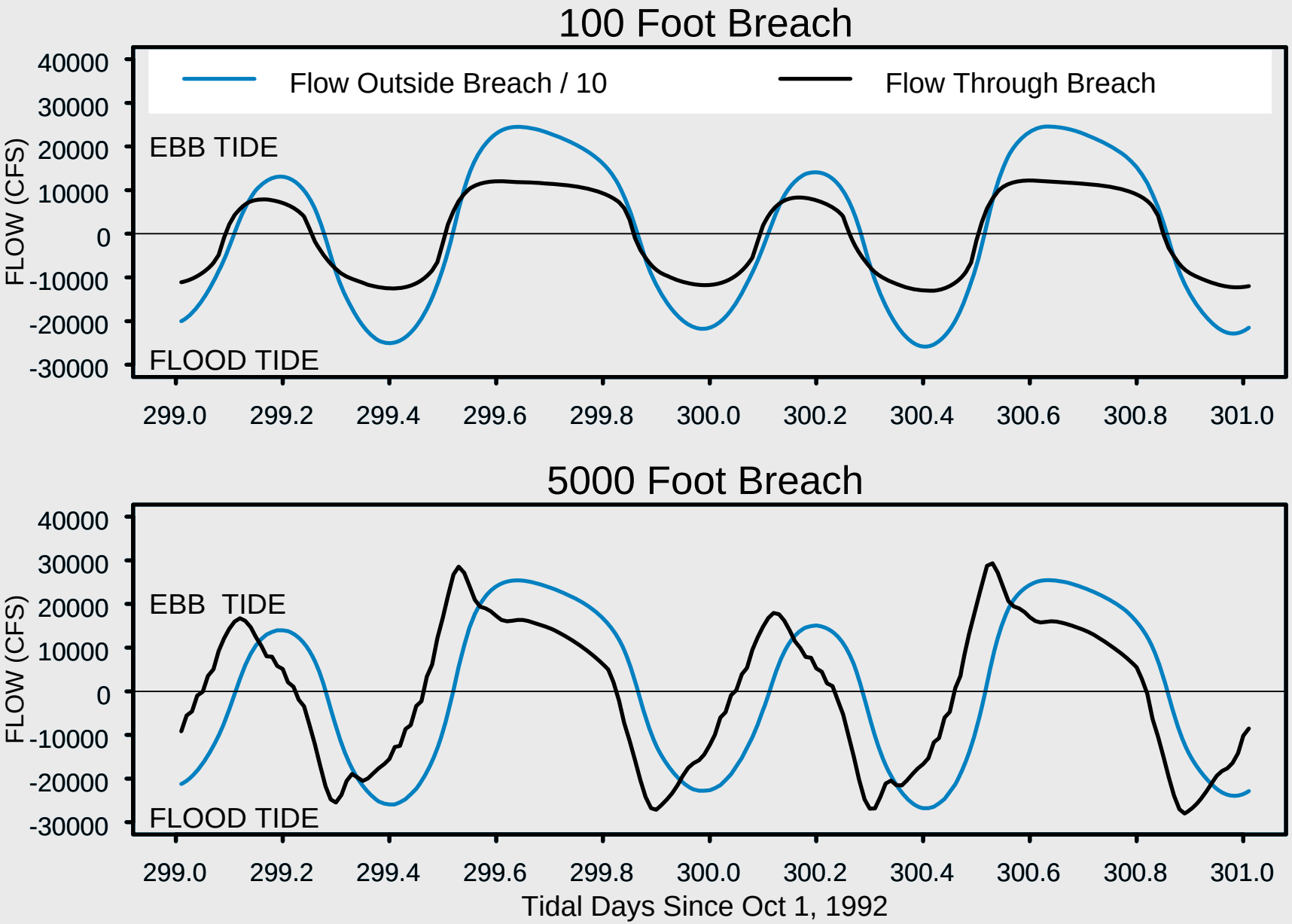
Van Sickle Island

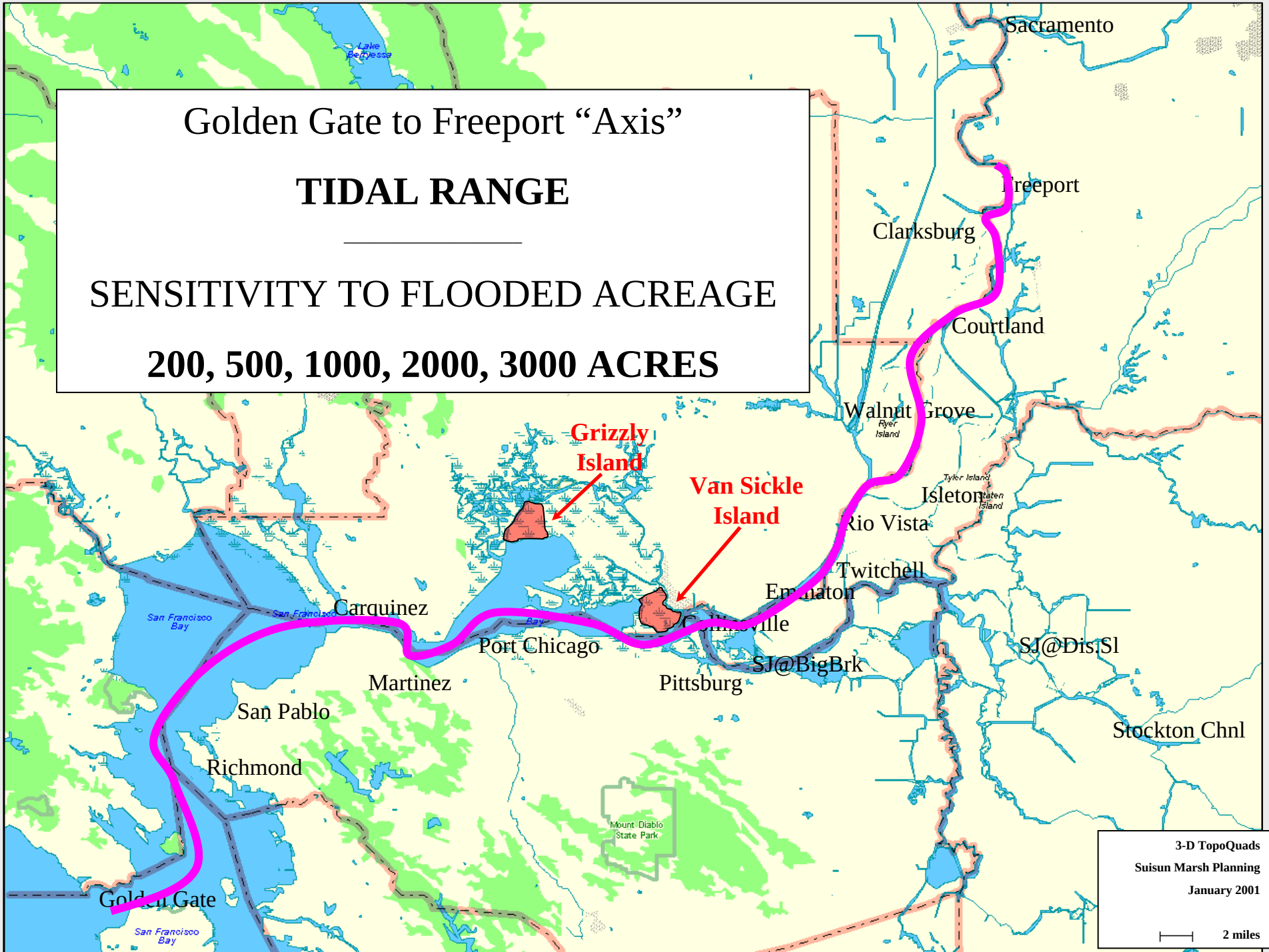
BREACH versus CHANNEL FLOW ASYMMETRY



Sensitivity Analysis

We looked at sensitivity of hydrodynamics and salinity response to:

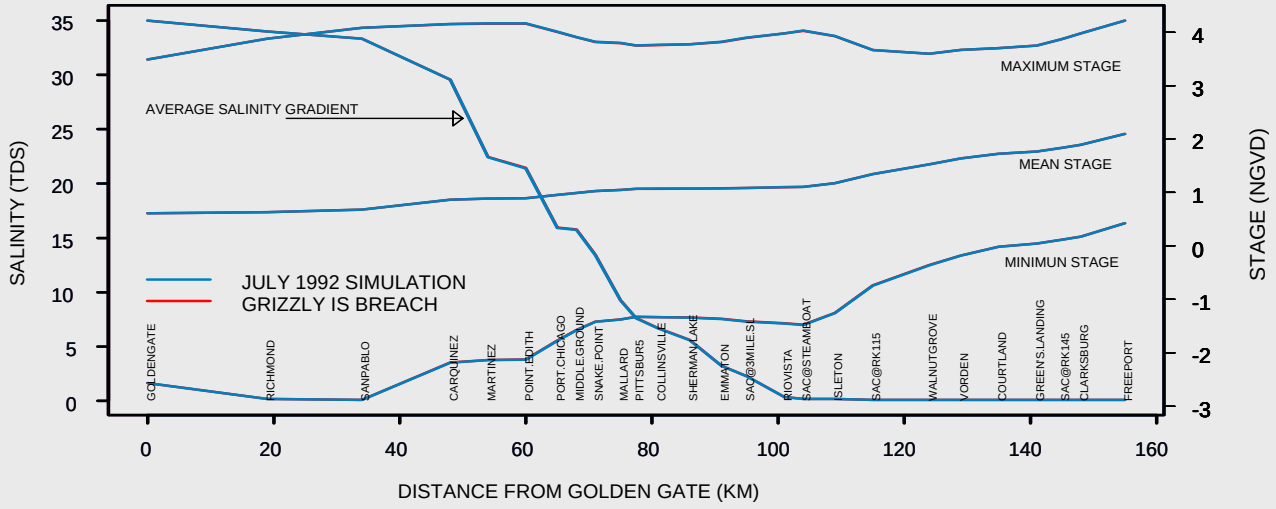
- Breach size
- Breach depth
- Flooded area roughness
- ***Flooded area acreage***
    1. ***System-wide Tidal Range***
    2. ***Local Levee Breach Hydrodynamics***
    3. ***System-wide Salinity***
    4. ***Tidal Flux***


Golden Gate to Freeport "Axis"
TIDAL RANGE
SENSITIVITY TO FLOODED ACREAGE
200, 500, 1000, 2000, 3000 ACRES
Sacramento
Freeport
Clarksburg
Courtland
Walnut Grove
Grizzly Island
Van Sickle Island
Isleton
Rio Vista
Twitchell
Carquinez
Port Chicago
Martinez
Pittsburg
SJ@BigBrk
SJ@DisSl
San Pablo
Richmond
Stockton Chnl
Golden Gate
San Francisco Bay
Mount Diablo State Park
3-D TopoQuads
Suisun Marsh Planning
January 2001
2 miles

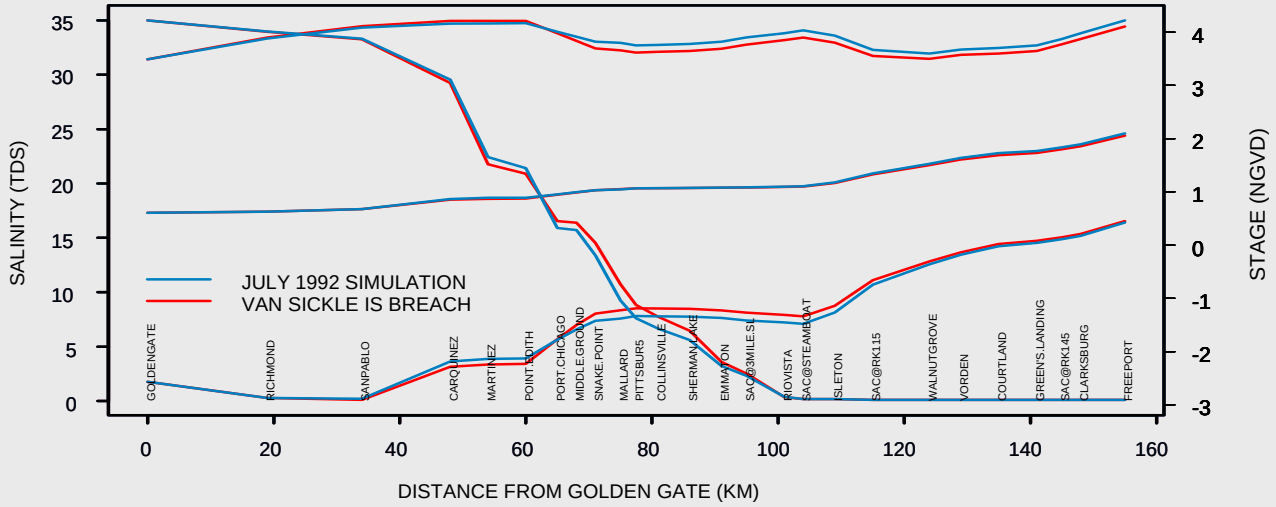
200 ACRES

AVERAGE TIDAL RANGE and SALINITY GRADIENT 1/

GRIZZLY IS 100' BREACH: 200 ACRE FLOODED AREA



VAN SICKLE IS 100' BREACH: 200 ACRE FLOODED AREA

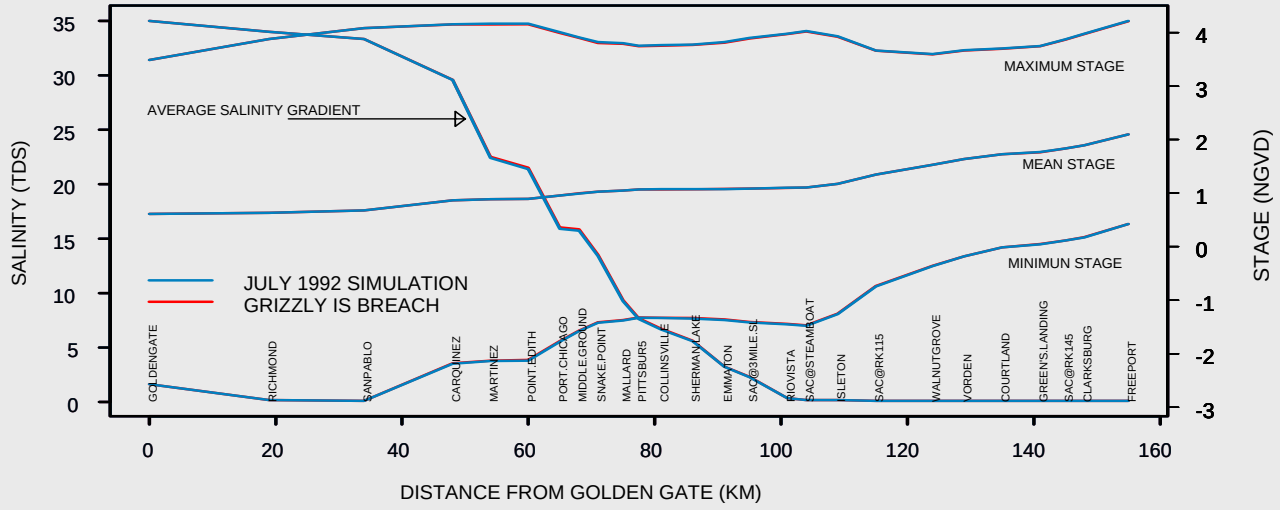


1/ July 1-29, 1992 Historical Simulation
Breaches are 100 ft wide, with 20 ft invert
Stage values are 29-day average of tidal day max, mean, and min.
Gradient values are 29-day average of daily means.
DSM1 Suisun Marsh Version

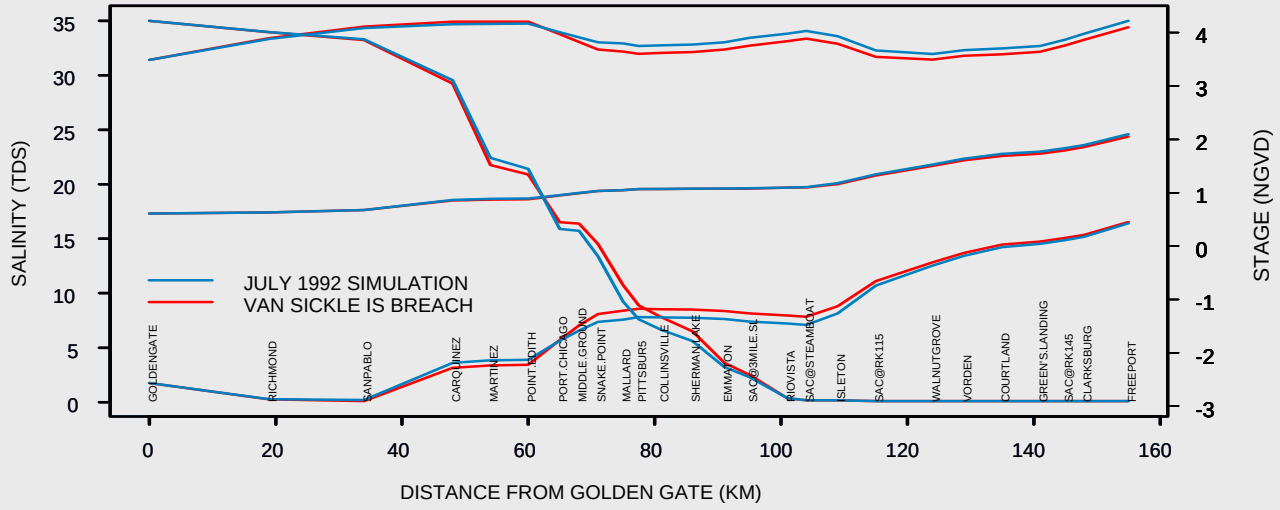
500 ACRES

AVERAGE TIDAL RANGE and SALINITY GRADIENT 1/

GRIZZLY IS 100' BREACH: 500 ACRE FLOODED AREA



VAN SICKLE IS 100' BREACH: 500 ACRE FLOODED AREA



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1000 ACRES

AVERAGE TIDAL RANGE and SALINITY GRADIENT 1/

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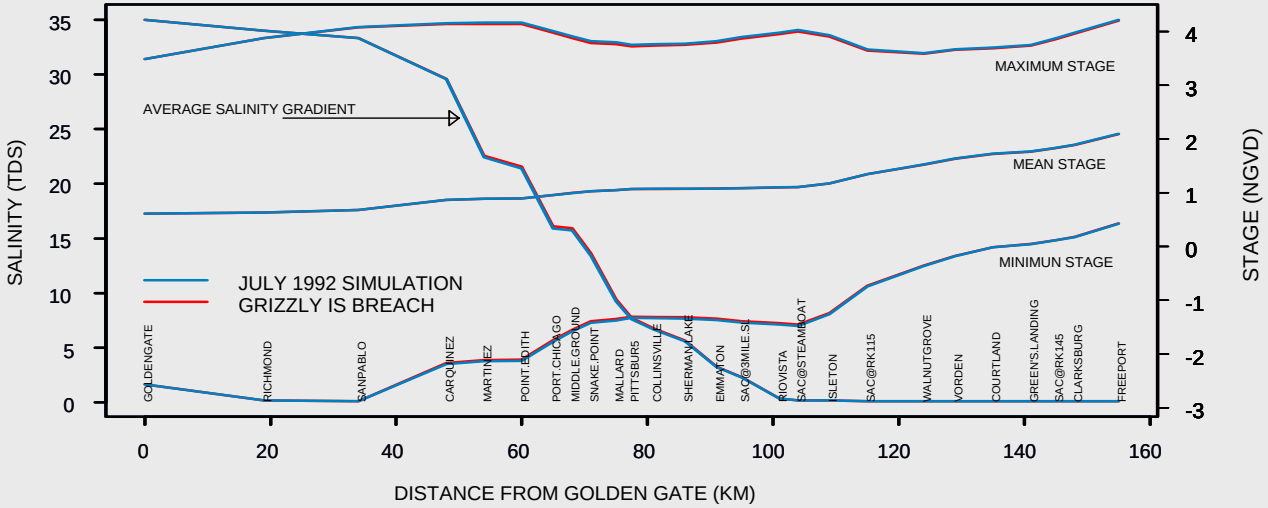
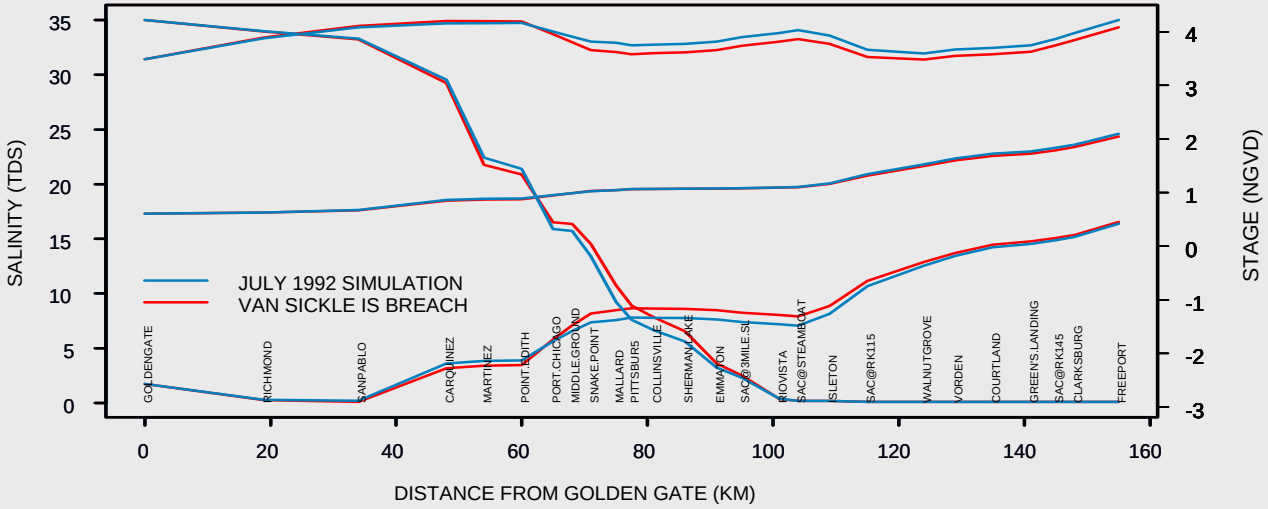


VAN SICKLE IS 100' BREACH: 1000 ACRE FLOODED AREA



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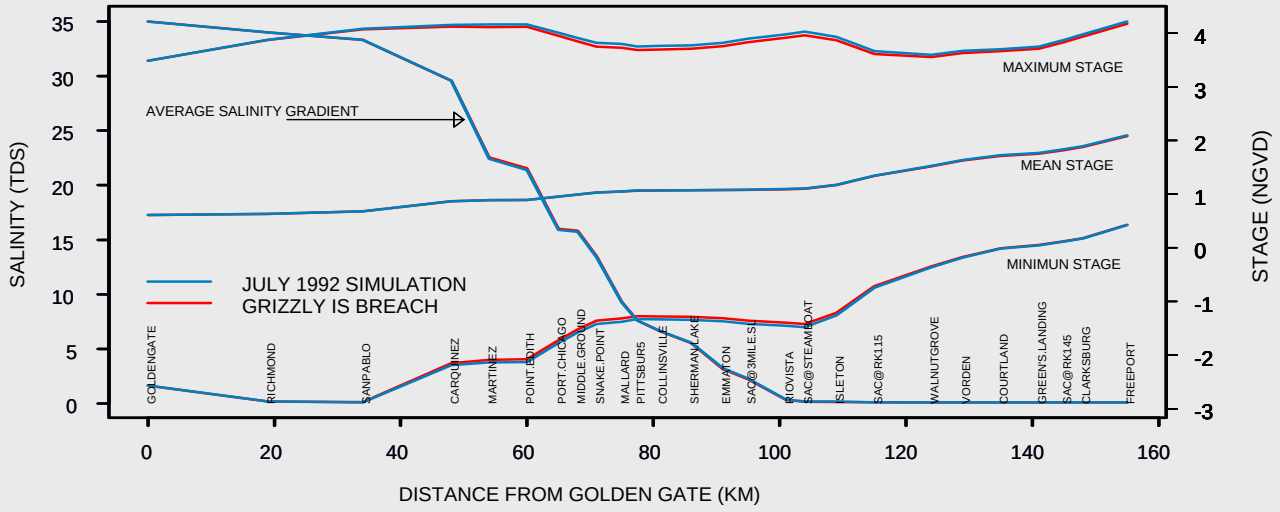
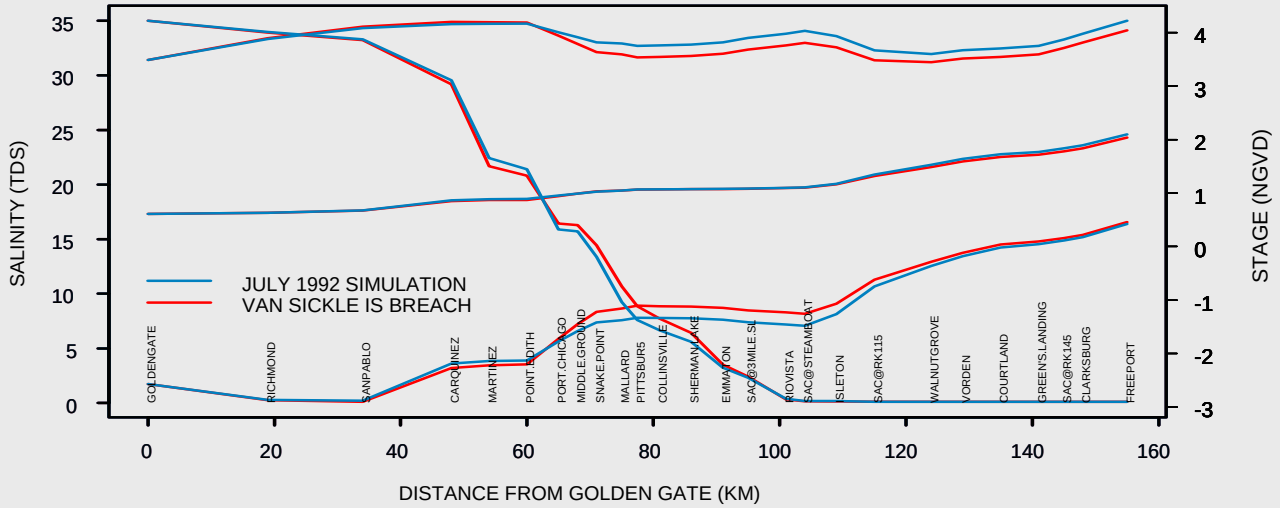
2000 ACRES

AVERAGE TIDAL RANGE and SALINITY GRADIENT 1/

GRIZZLY IS 100' BREACH: 2000 ACRE FLOODED AREA



VAN SICKLE IS 100' BREACH: 2000 ACRE FLOODED AREA



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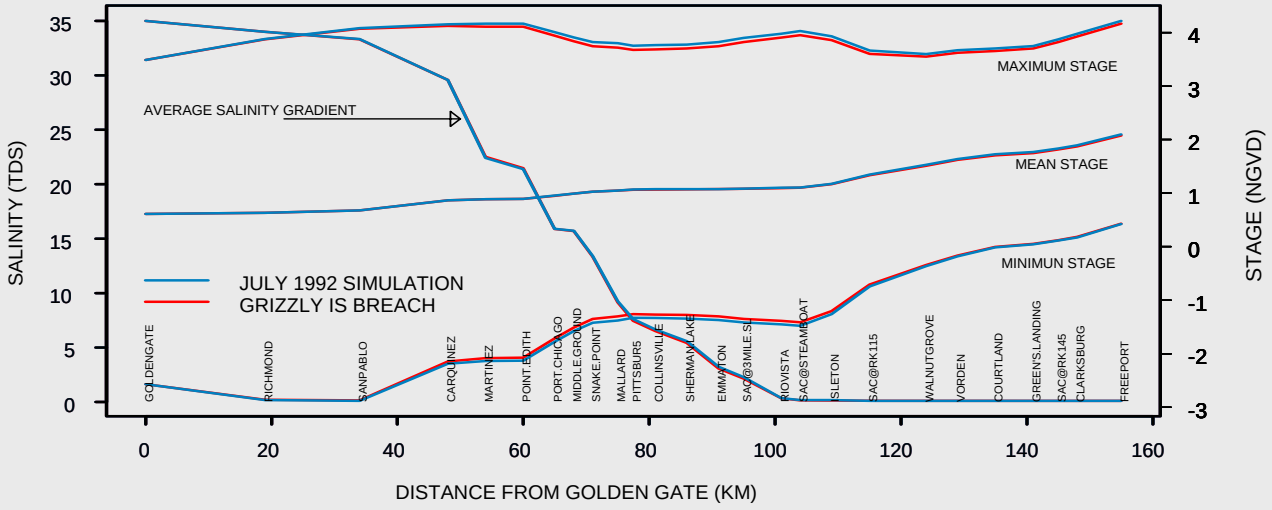
DSM1 Suisun Marsh Version

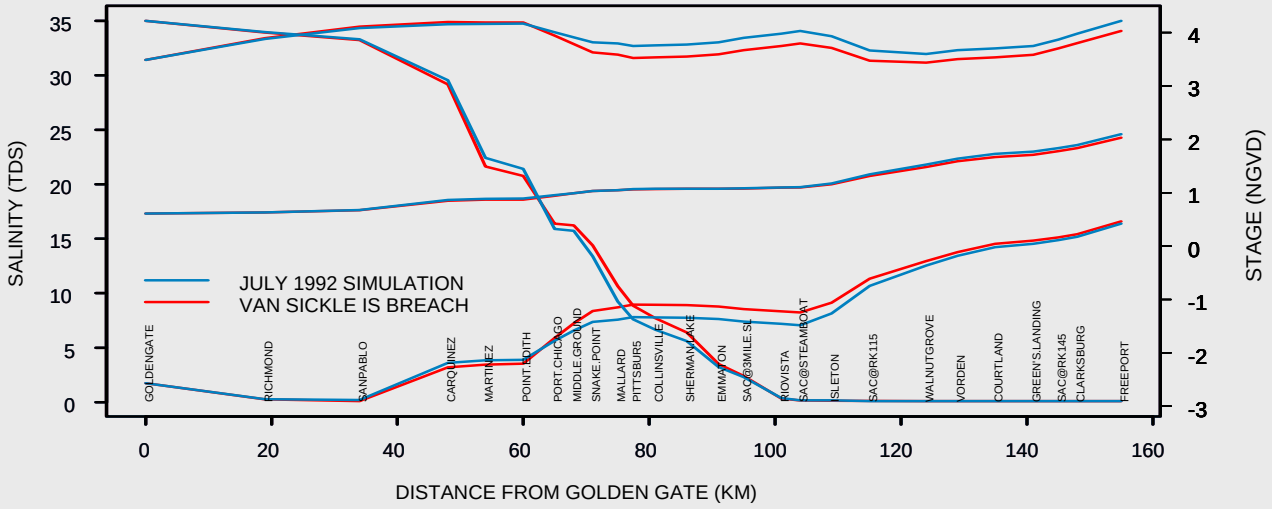
3000 ACRES

AVERAGE TIDAL RANGE and SALINITY GRADIENT 1/

GRIZZLY IS 100' BREACH: 3000 ACRE FLOODED AREA



VAN SICKLE IS 100' BREACH: 3000 ACRE FLOODED AREA



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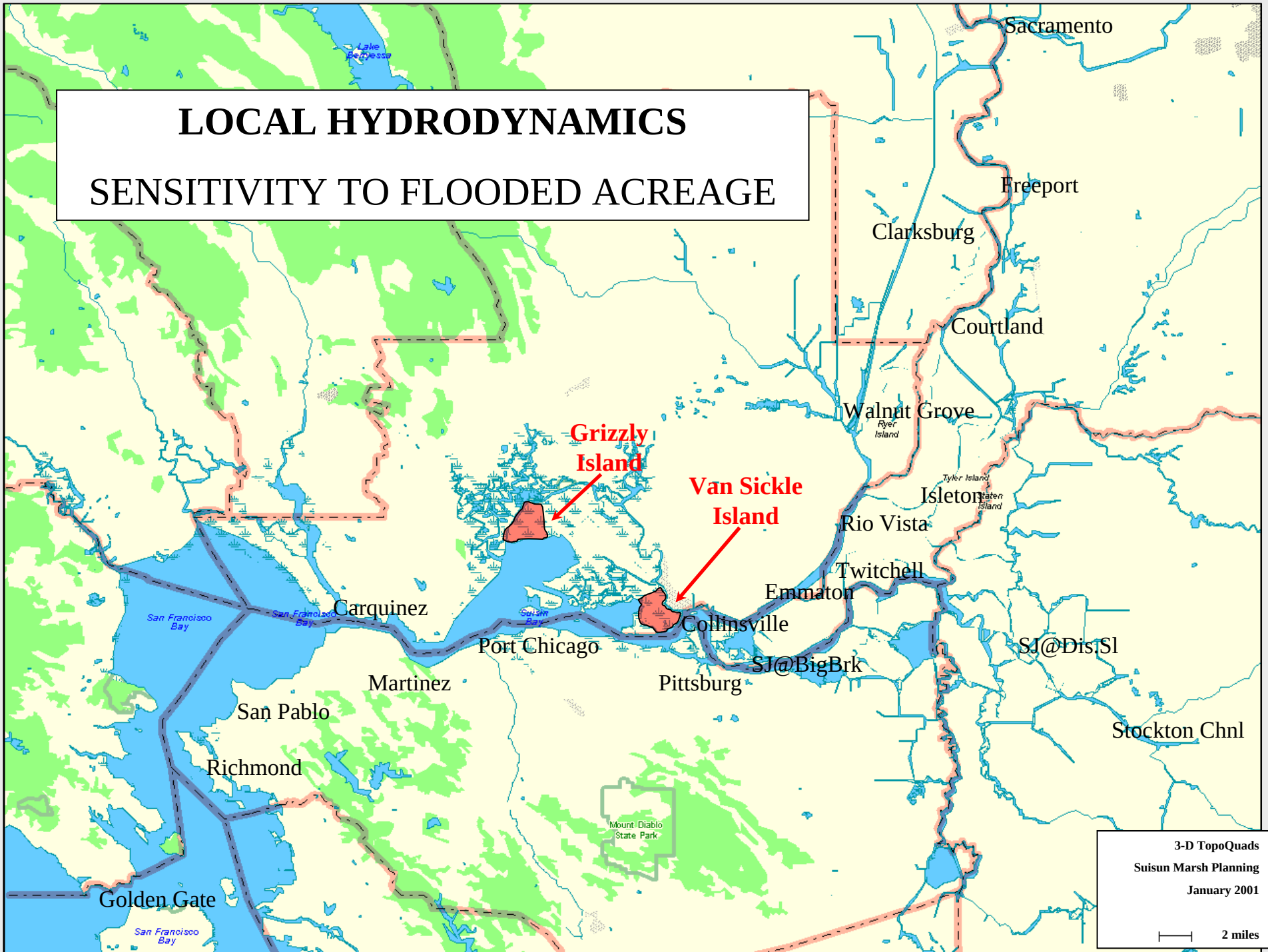
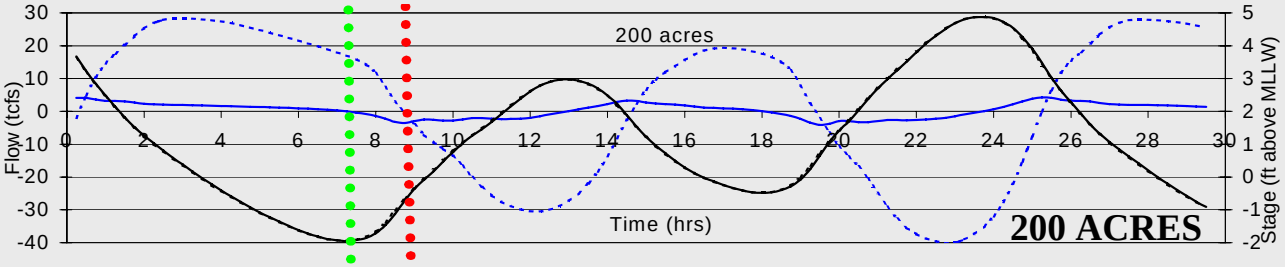
DSM1 Suisun Marsh Version

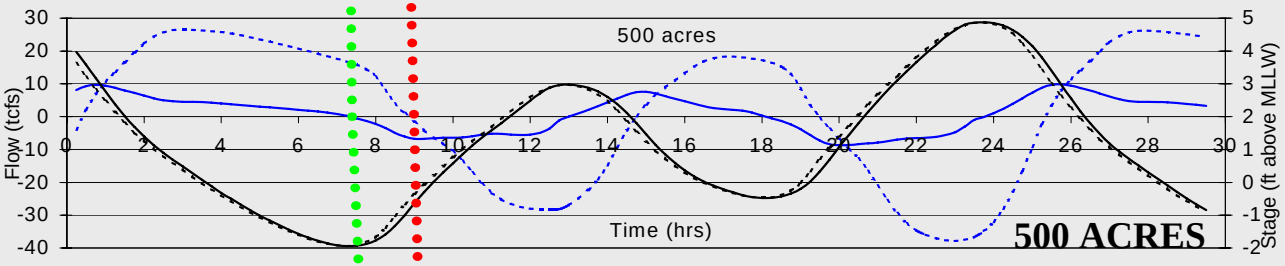
LOCAL HYDRODYNAMICS

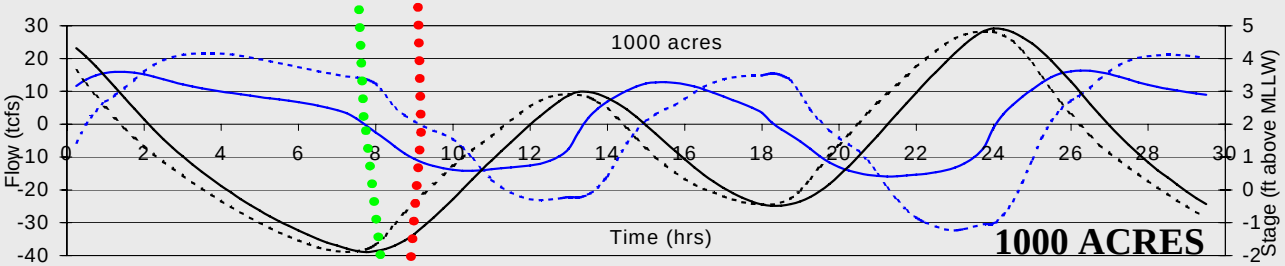
SENSITIVITY TO FLOODED ACREAGE

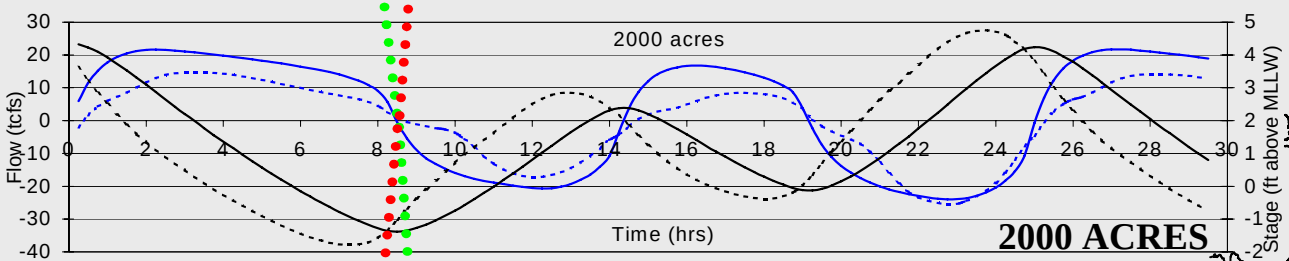


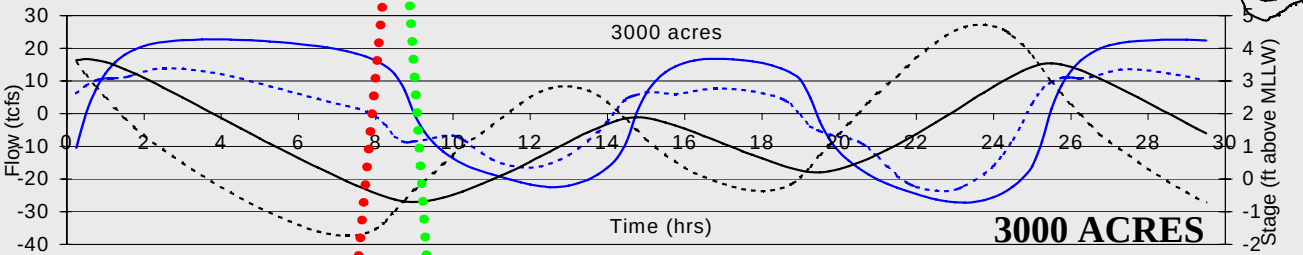
GRIZZLY ISLAND 100 FT BREACH











Inside Breach

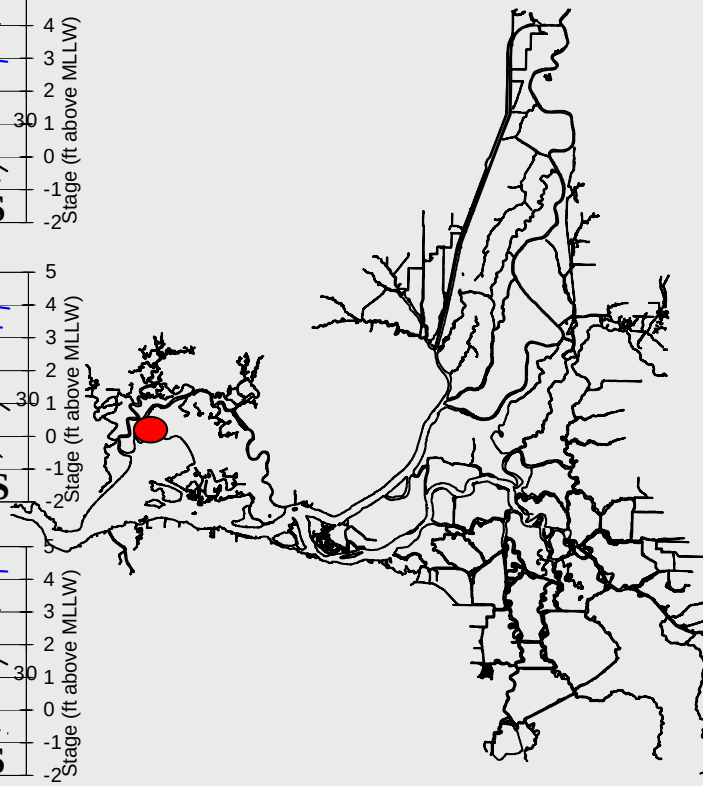
Flow

Stage

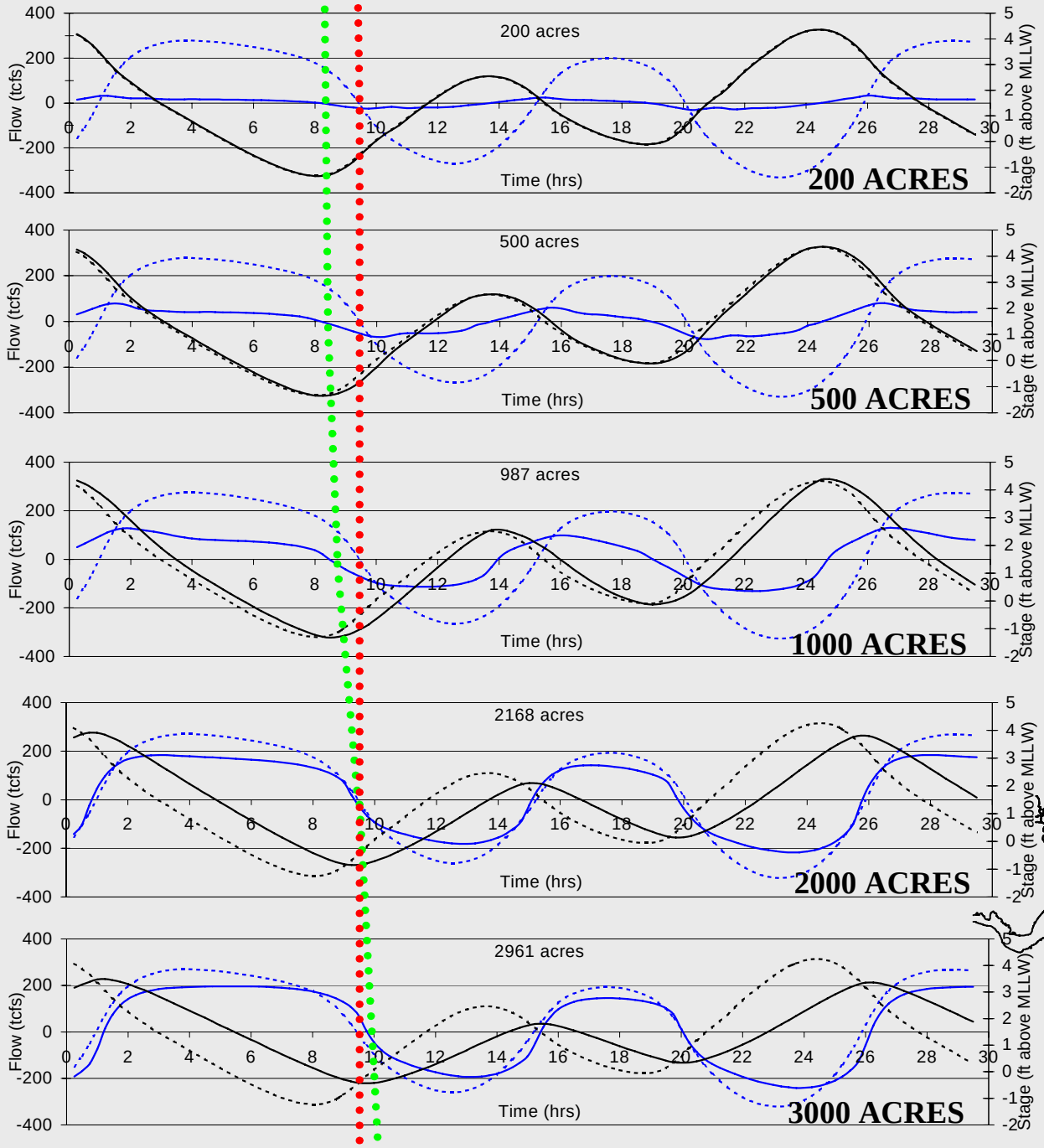
Outside Breach

Flow

Stage



VAN SICKLE ISLAND 100 FT BREACH



Inside Breach

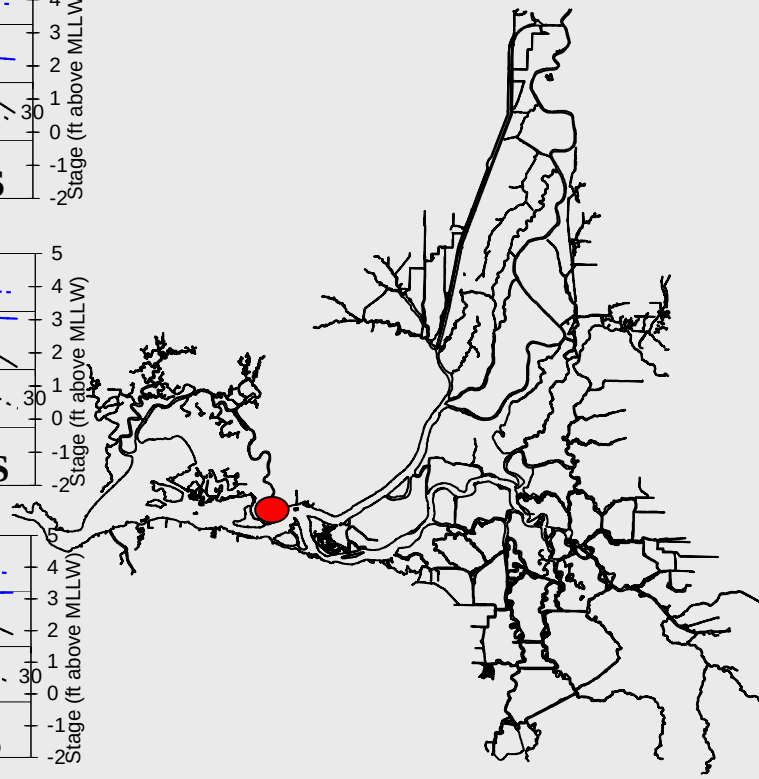
Flow

Stage

Outside Breach

Flow

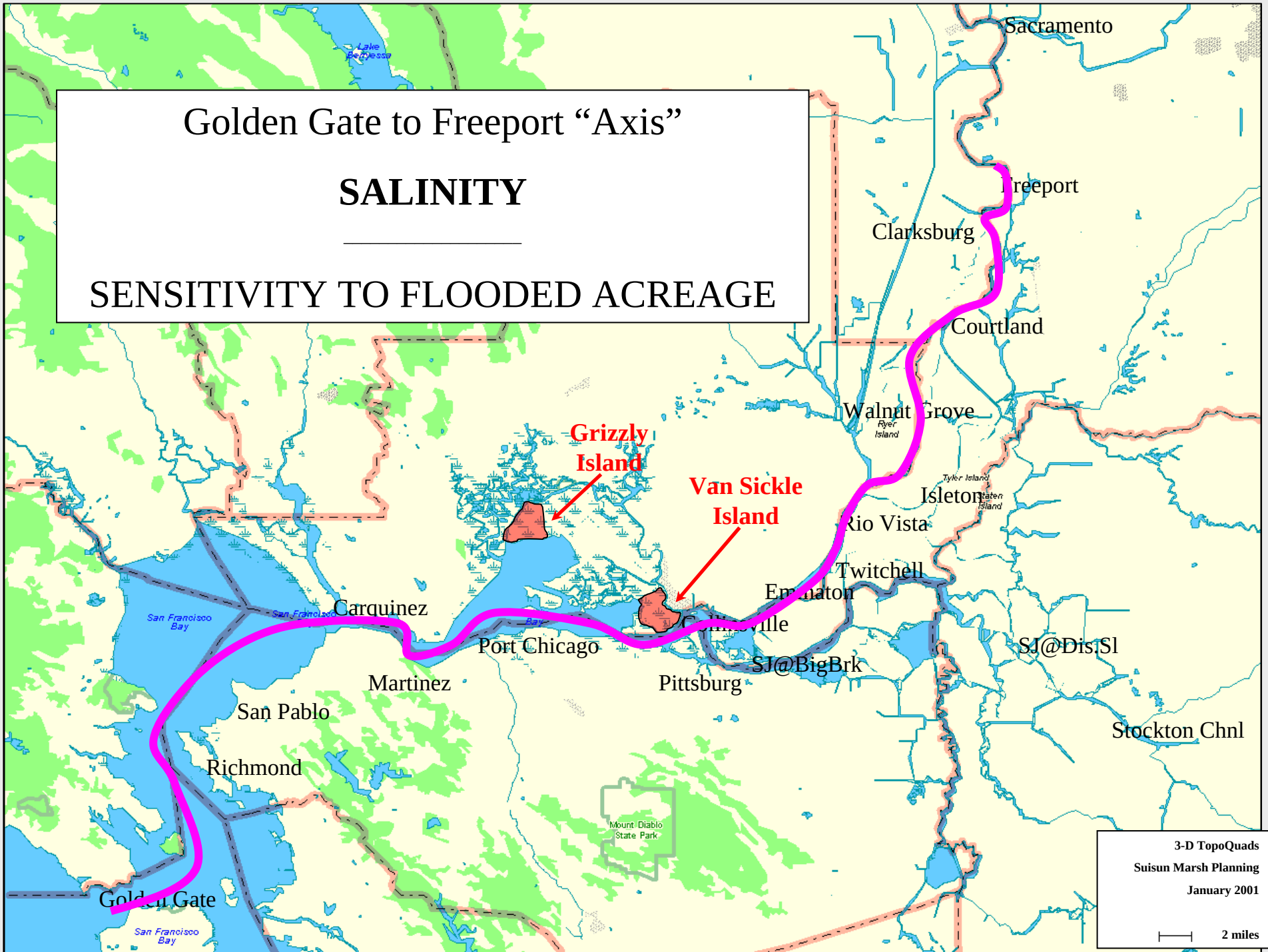
Stage



Golden Gate to Freeport "Axis"

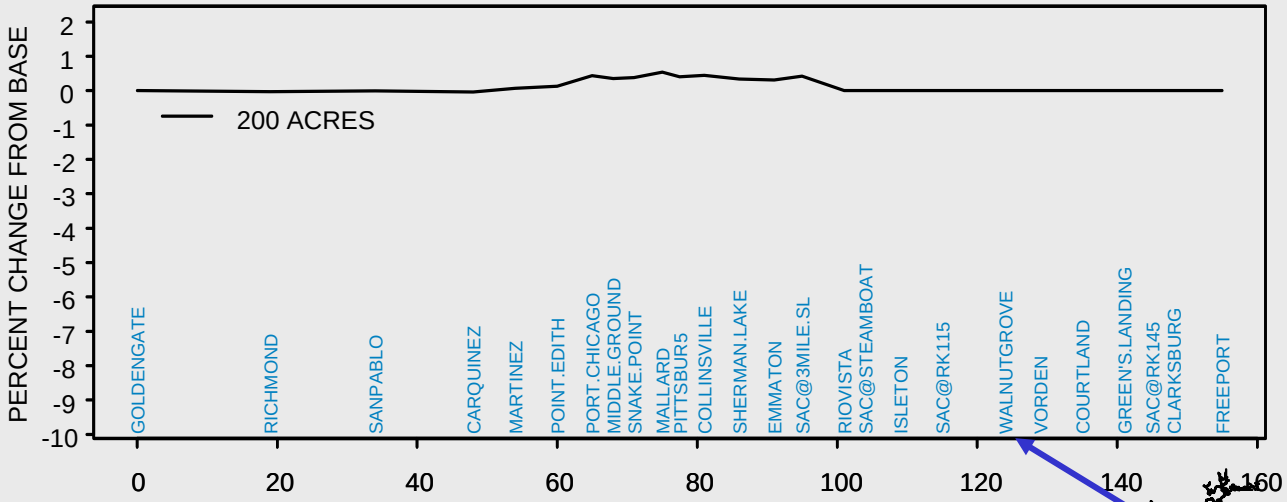
SALINITY

SENSITIVITY TO FLOODED ACREAGE



TIDAL DAY AVERAGE SALINITY ALONG SACRAMENTO RIVER AXIS

GRIZZLY ISLAND 100' LEVEE BREACH



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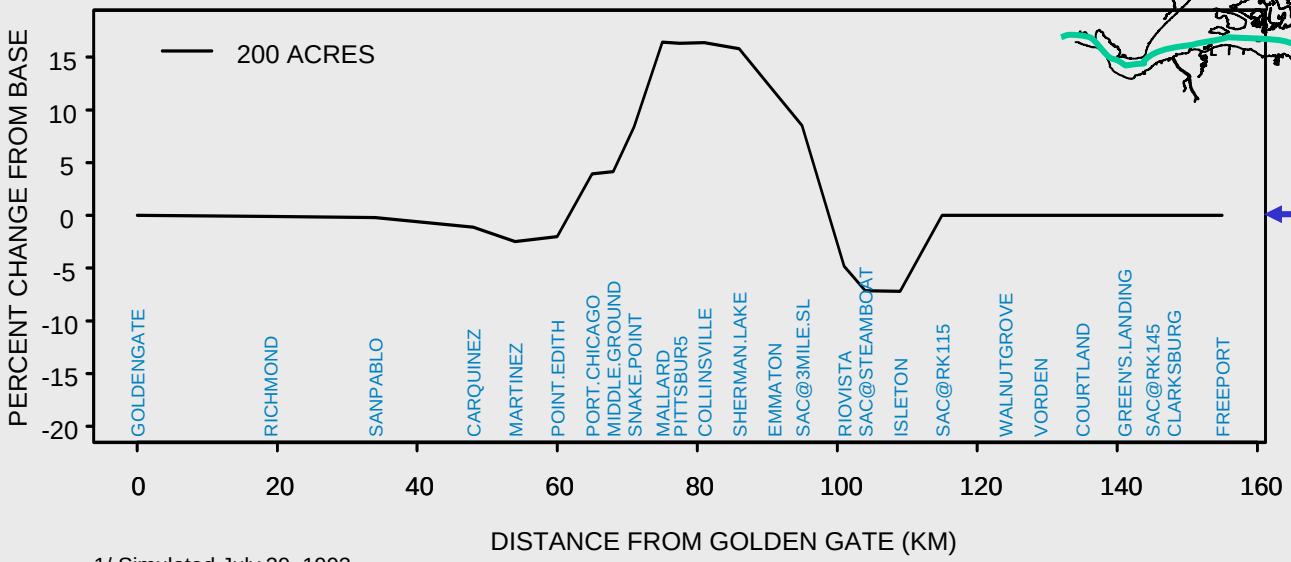

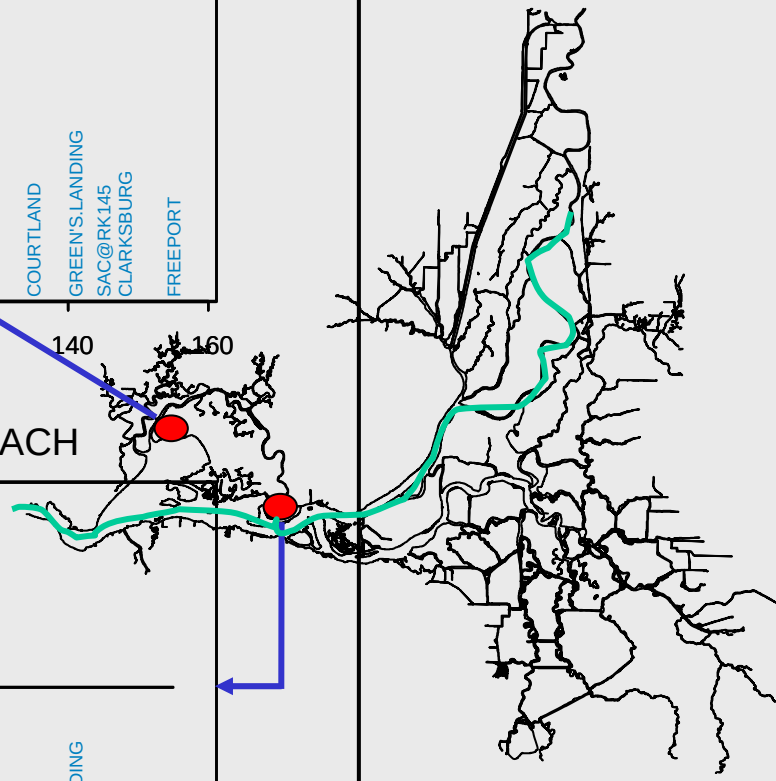

1/ Simulated July 29, 1992
DSM1 Suisun Marsh Version

TIDAL DAY AVERAGE SALINITY ALONG SACRAMENTO RIVER AXIS

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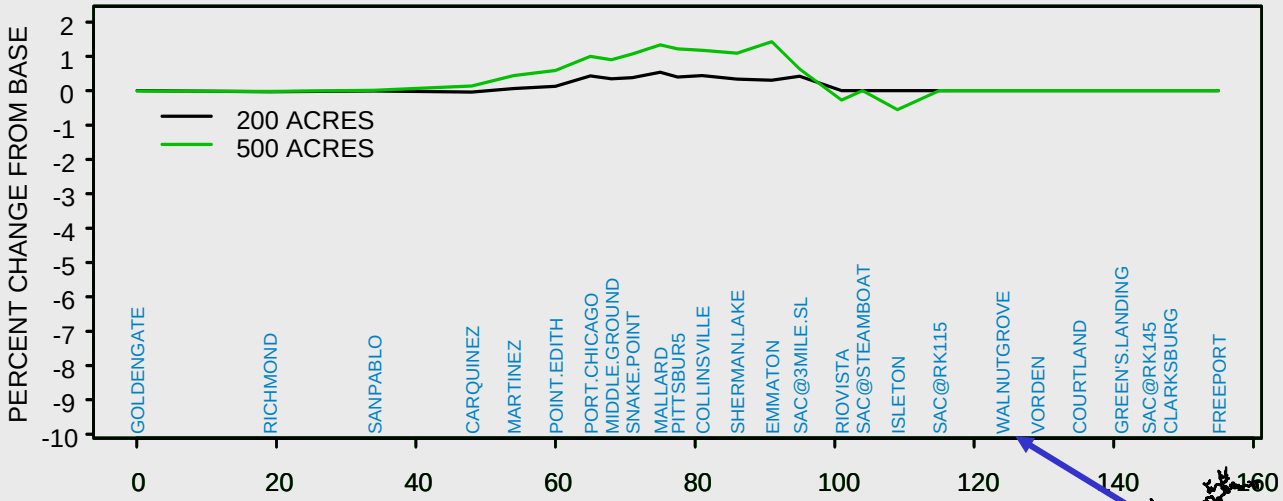

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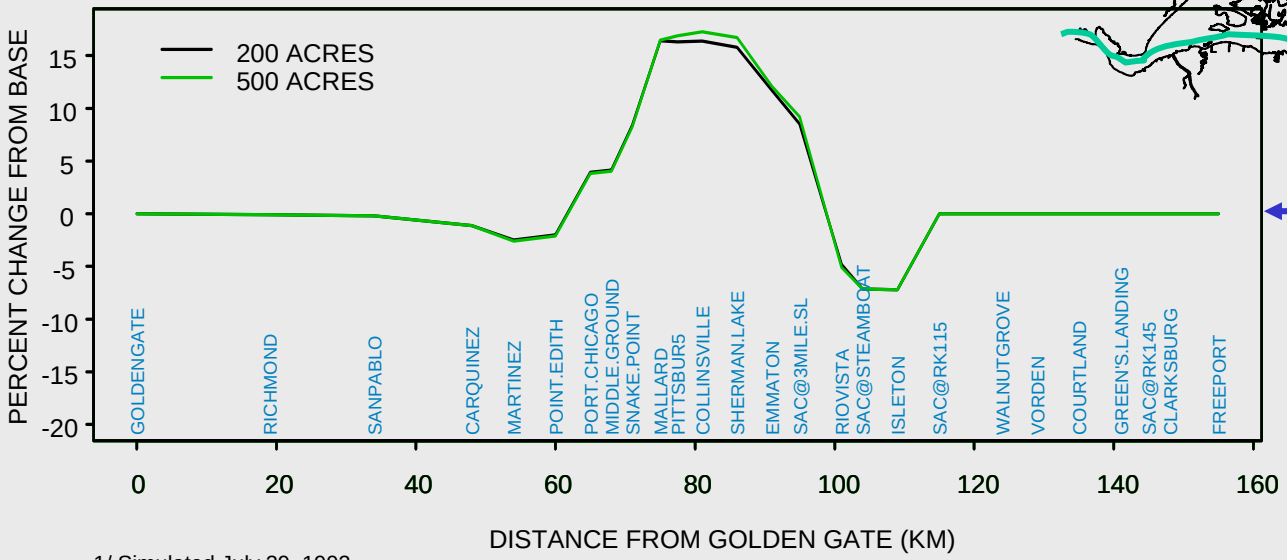

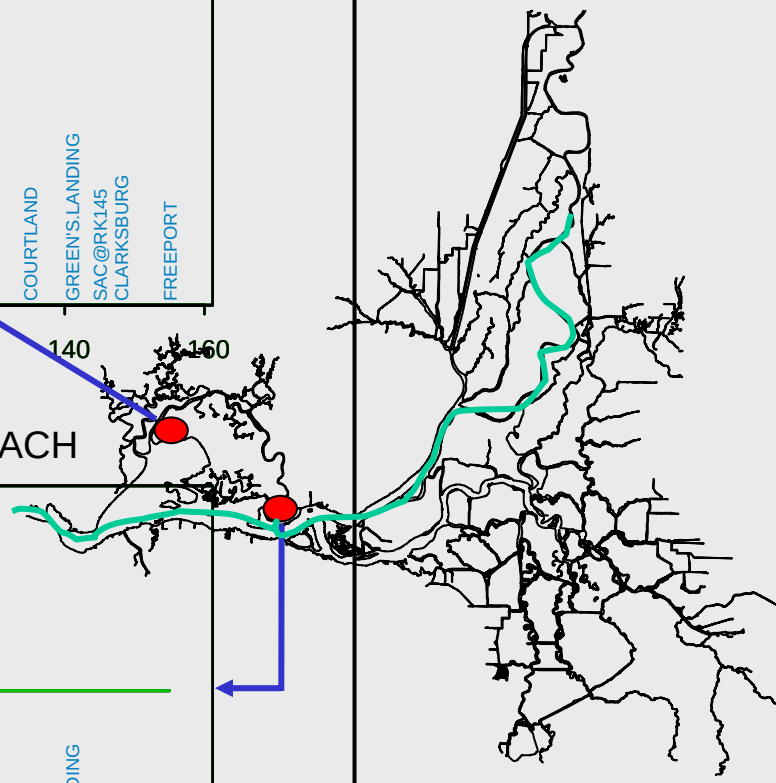

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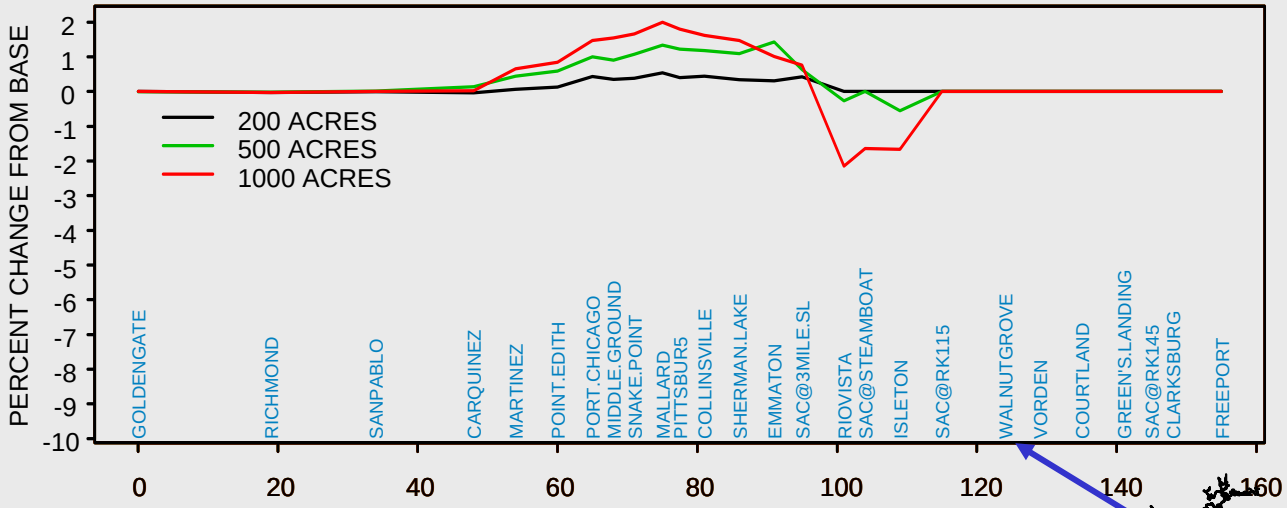
GRIZZLY ISLAND 100' LEVEE BREACH



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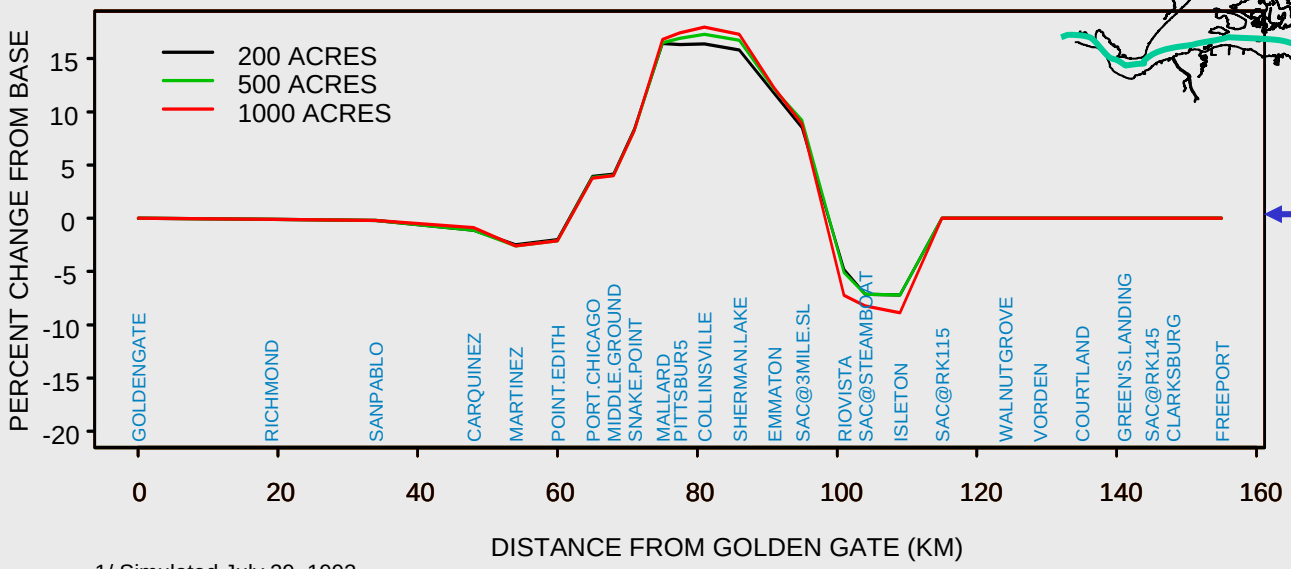

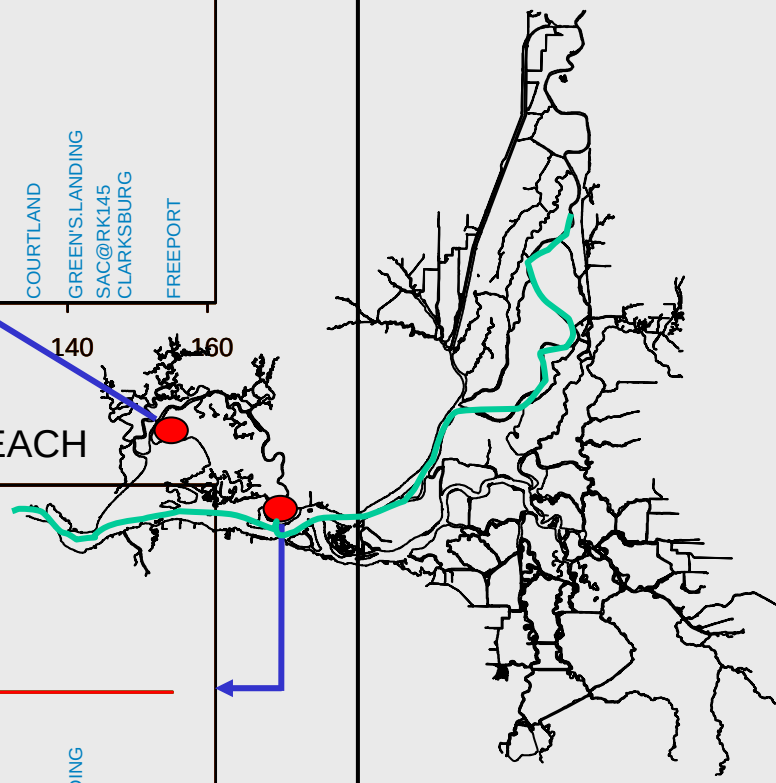

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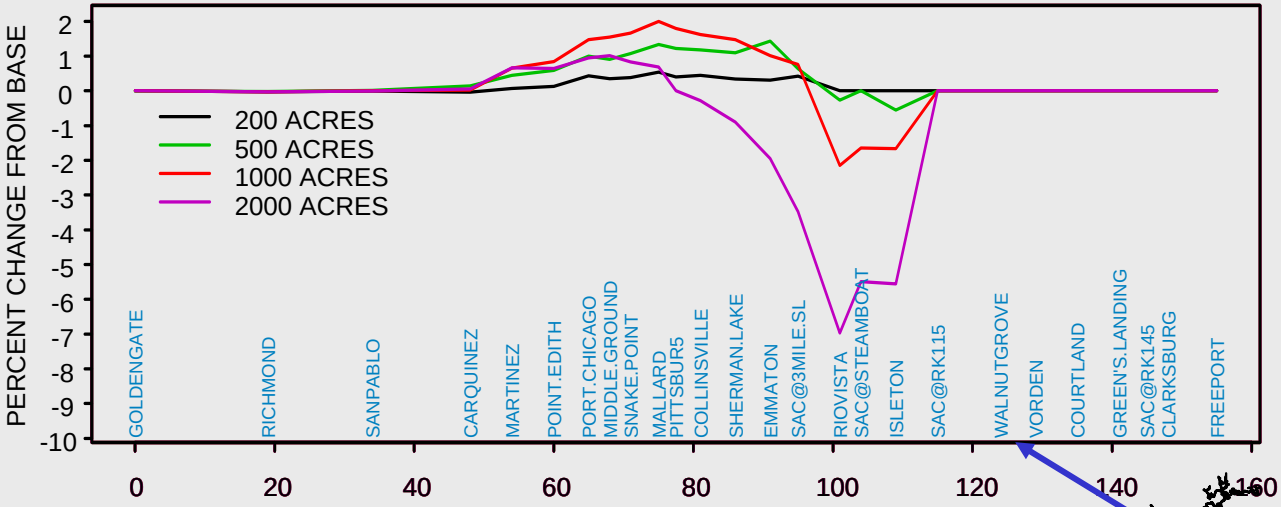
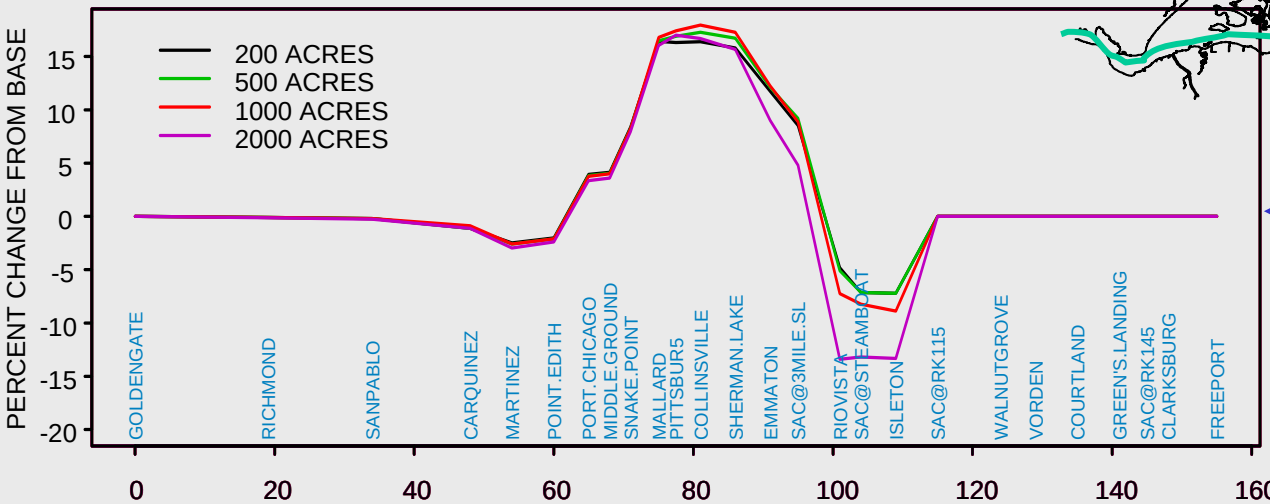
DSM1 Suisun Marsh Version

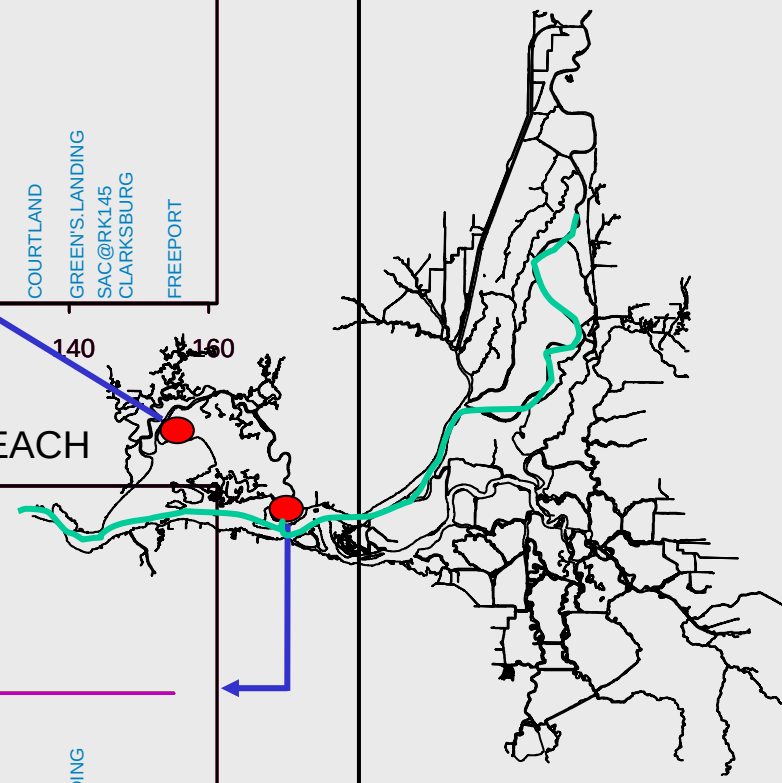
TIDAL DAY AVERAGE SALINITY ALONG SACRAMENTO RIVER AX

GRIZZLY ISLAND 100' LEVEE BREACH



VAN SICKLE ISLAND 100' LEVEE BREACH





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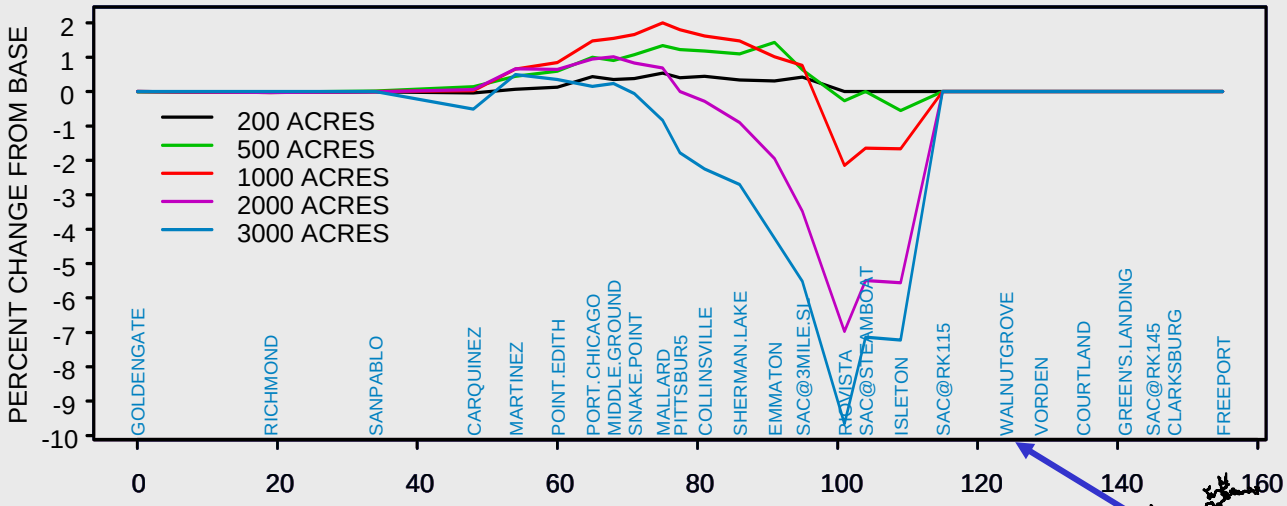
DSM1 Suisun Marsh Version

TIDAL DAY AVERAGE SALINITY ALONG SACRAMENTO RIVER AXIS

GRIZZLY ISLAND 100' LEVEE BREACH



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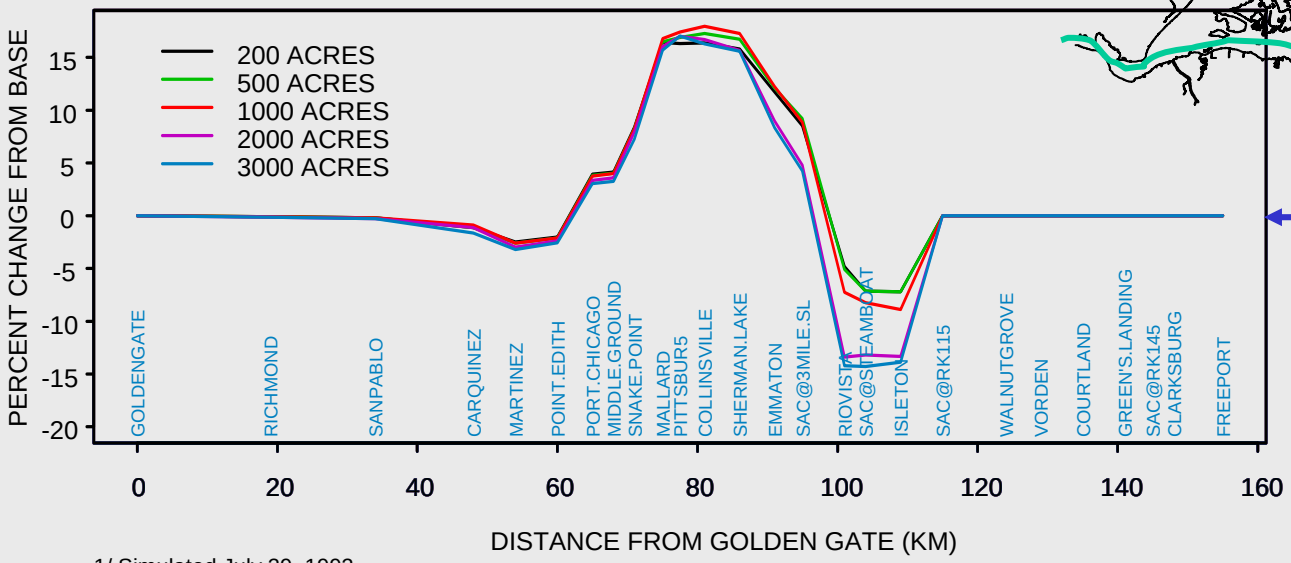
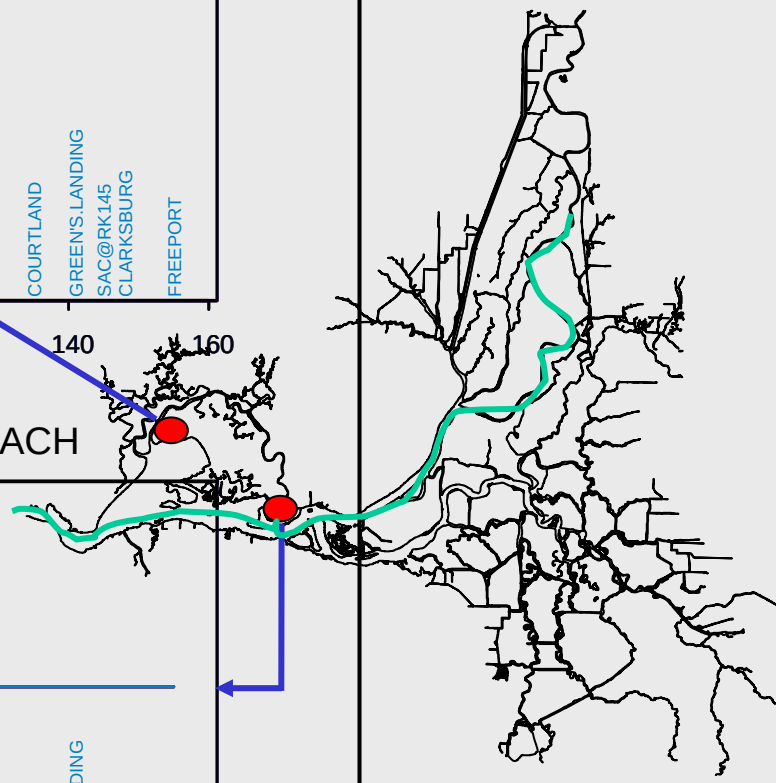


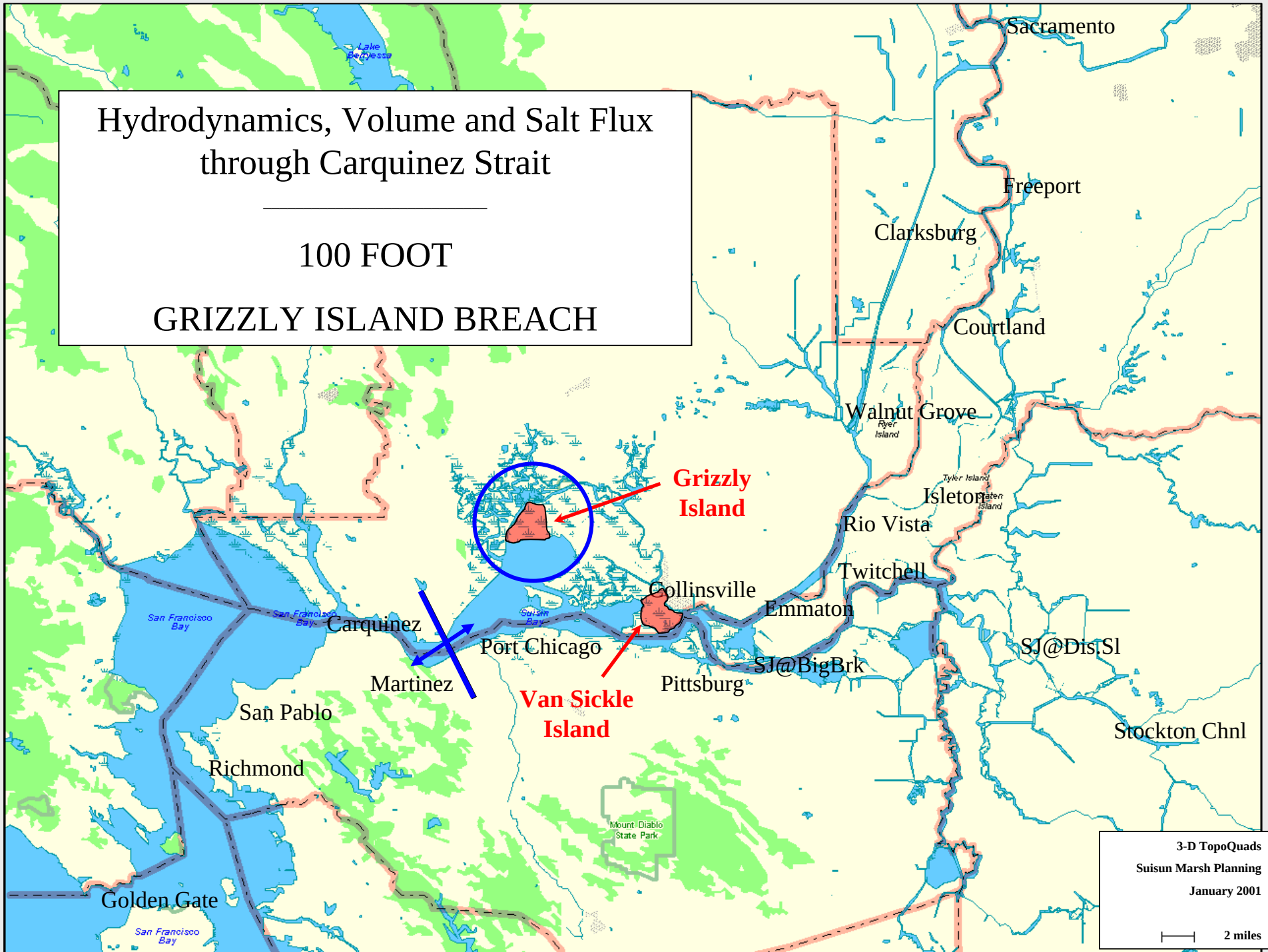


1/ Simulated July 29, 1992
DSM1 Suisun Marsh Version

Hydrodynamics, Volume and Salt Flux through Carquinez Strait

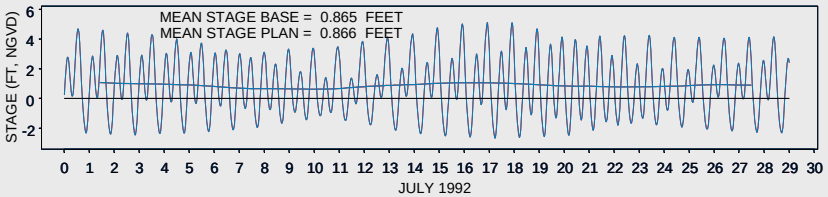
100 FOOT

GRIZZLY ISLAND BREACH

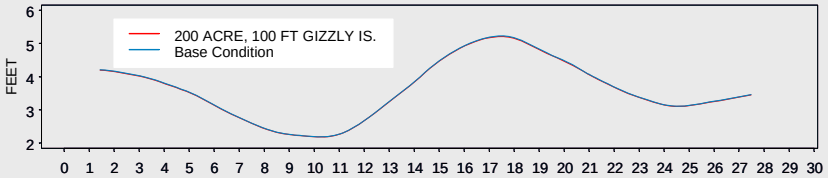


Carquinez Strait Hydrodynamics (July 1992) 1/
200 ACRE, 100 FT GIZZLY IS. Breach vs Base Condition

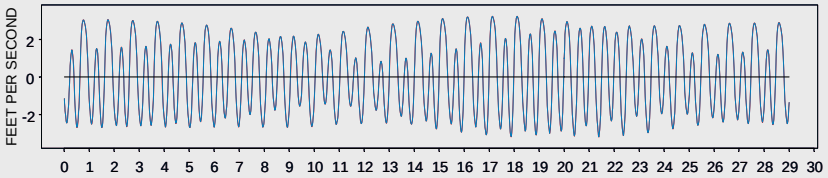
STAGE AND LOW PASS FILTER



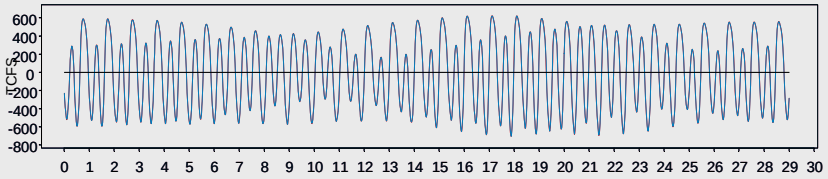
RMS TIDE HEIGHT



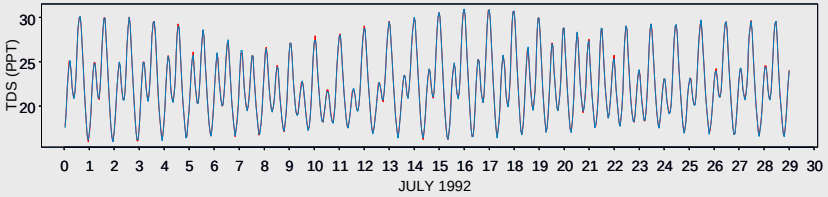
TIDAL CURRENT VELOCITY



TIDAL FLOW



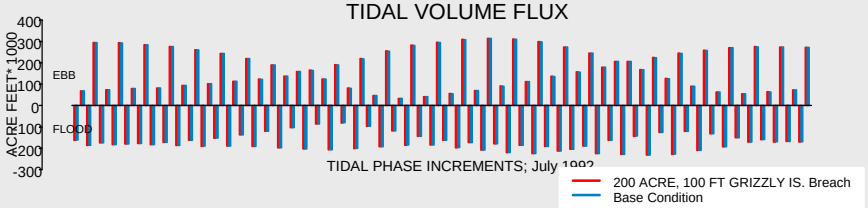
TIDAL SALINITY



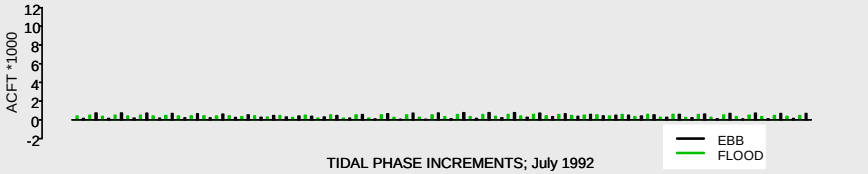
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Tidal Volume and Salt Flux (July 1992) 1/
200 ACRE, 100 FT GRIZZLY IS. Breach vs Base Condition

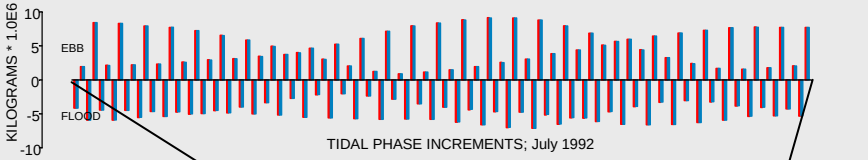
TIDAL VOLUME FLUX



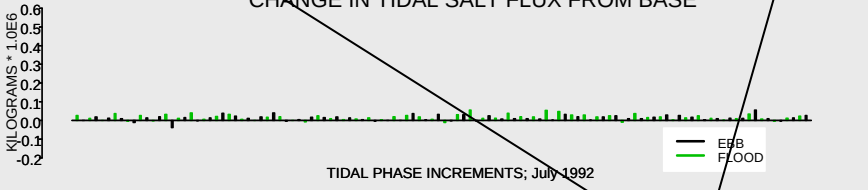
CHANGE IN TIDAL VOLUME FLUX FROM BASE



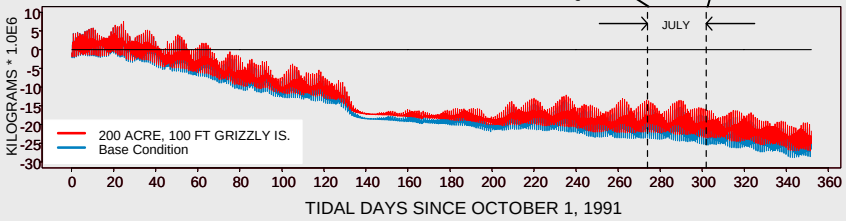
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



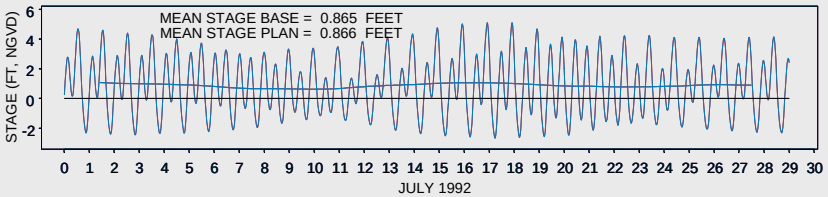
CUMULATIVE SALT LOAD THROUGH CARQUINEZ STRAIT; WY 1992



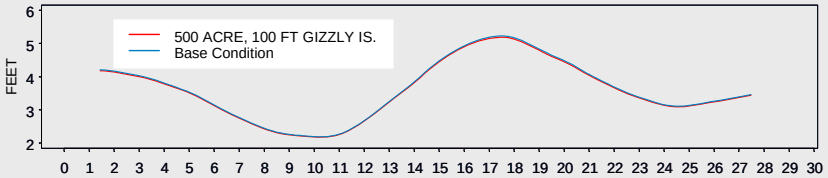
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Hydrodynamics (July 1992) 1/
500 ACRE, 100 FT GIZZLY IS. Breach vs Base Condition

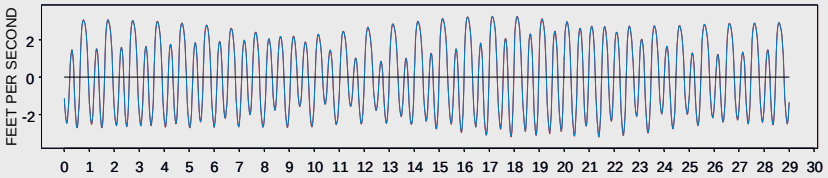
STAGE AND LOW PASS FILTER



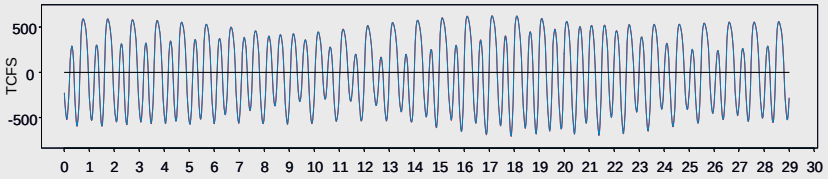
RMS TIDE HEIGHT



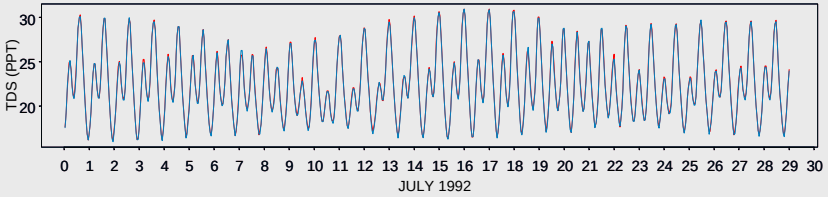
TIDAL CURRENT VELOCITY



TIDAL FLOW



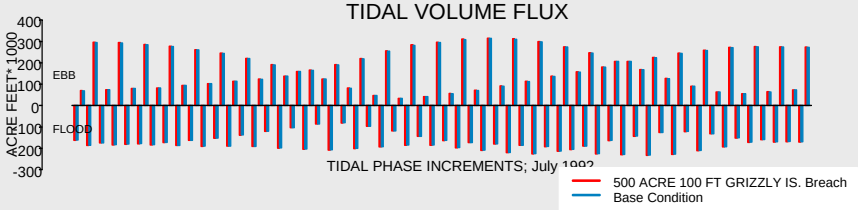
TIDAL SALINITY



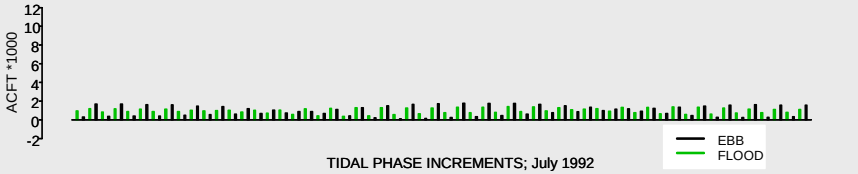
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Tidal Volume and Salt Flux (July 1992) 1/
500 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

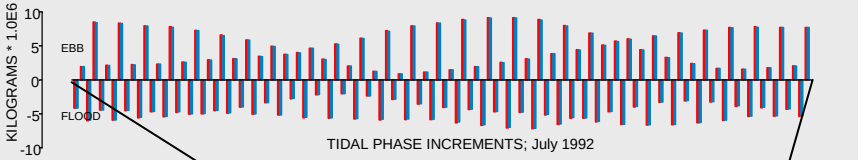
TIDAL VOLUME FLUX



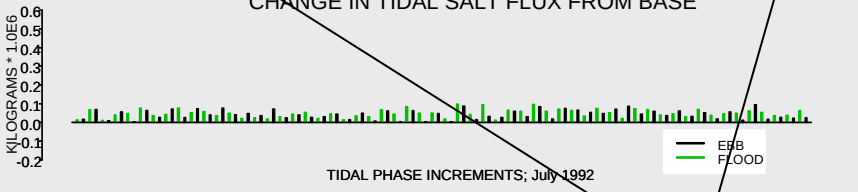
CHANGE IN TIDAL VOLUME FLUX FROM BASE



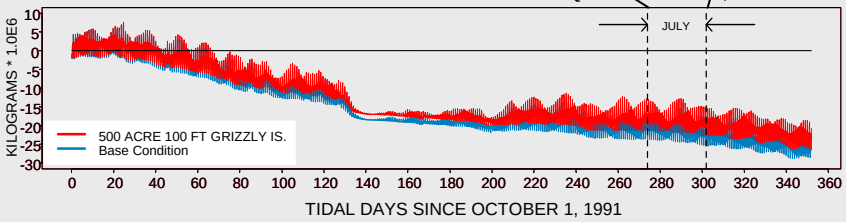
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



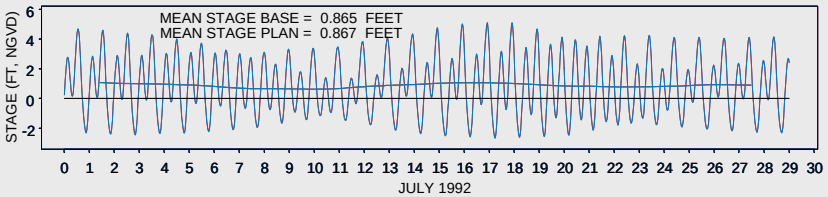
CUMULATIVE SALT LOAD THROUGH CARQUINEZ STRAIT; WY 1992



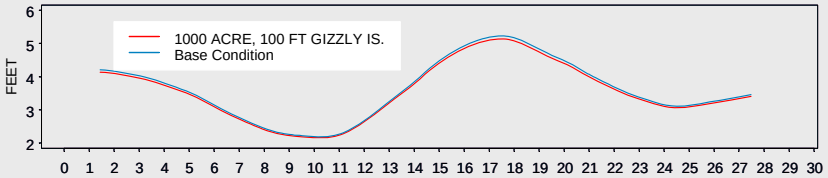
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Hydrodynamics (July 1992) 1/
1000 ACRE, 100 FT GIZZLY IS. Breach vs Base Condition

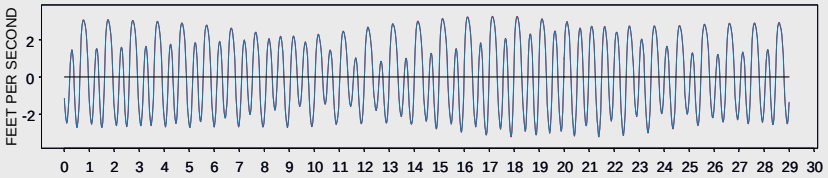
STAGE AND LOW PASS FILTER



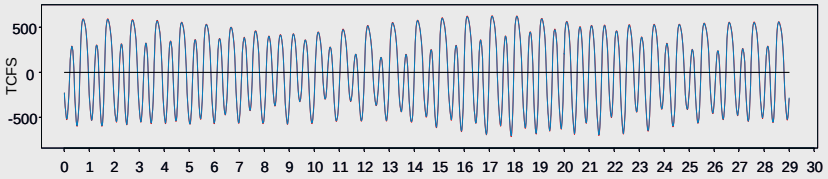
RMS TIDE HEIGHT



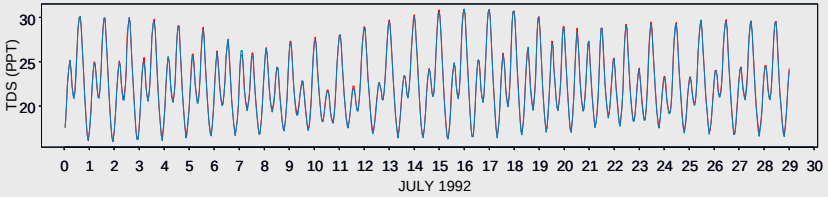
TIDAL CURRENT VELOCITY



TIDAL FLOW



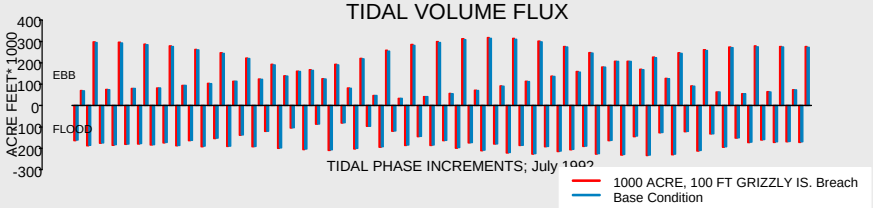
TIDAL SALINITY



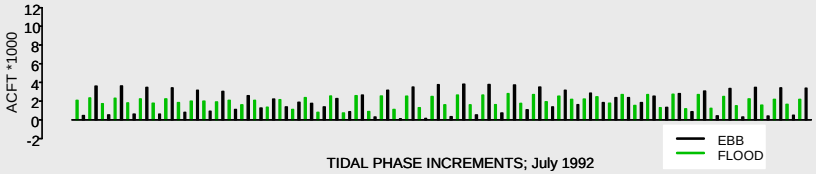
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Tidal Volume and Salt Flux (July 1992) 1/
1000 ACRE, 100 FT GRIZZLY IS. Breach vs Base Condition

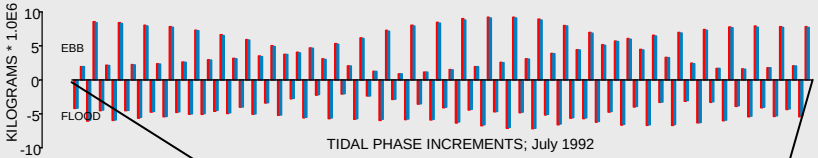
TIDAL VOLUME FLUX



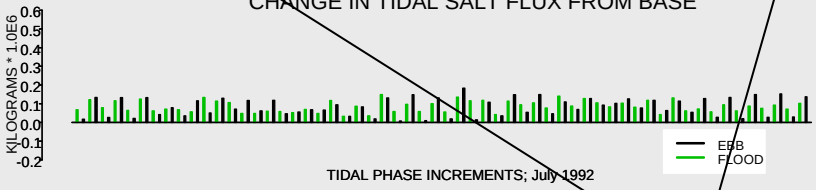
CHANGE IN TIDAL VOLUME FLUX FROM BASE



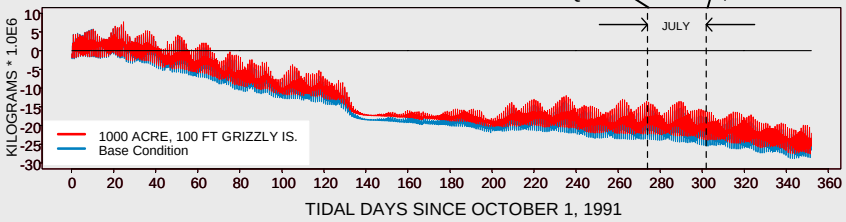
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



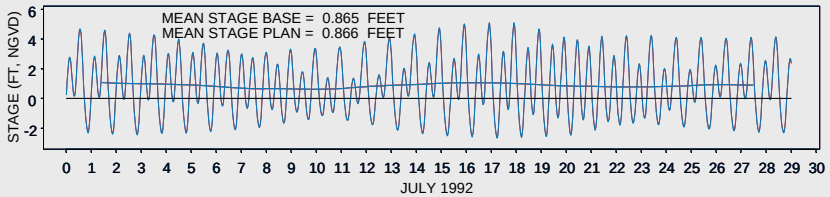
CUMULATIVE SALT LOAD THROUGH CARQUINEZ STRAIT; WY 1992



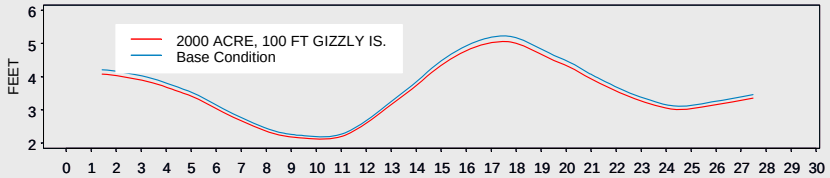
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Hydrodynamics (July 1992) 1/
2000 ACRE, 100 FT GIZZLY IS. Breach vs Base Condition

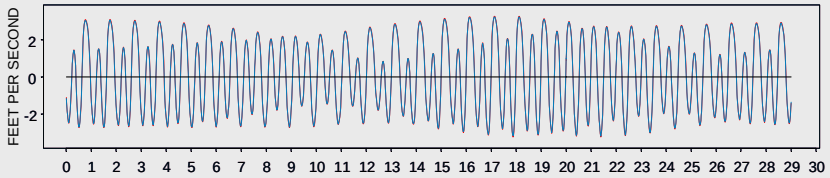
STAGE AND LOW PASS FILTER



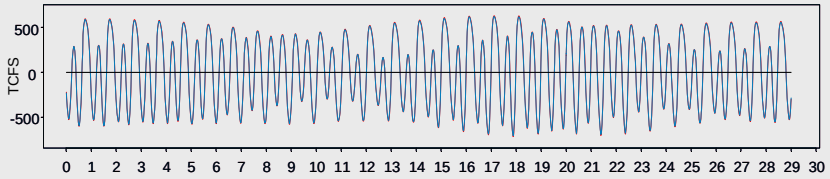
RMS TIDE HEIGHT



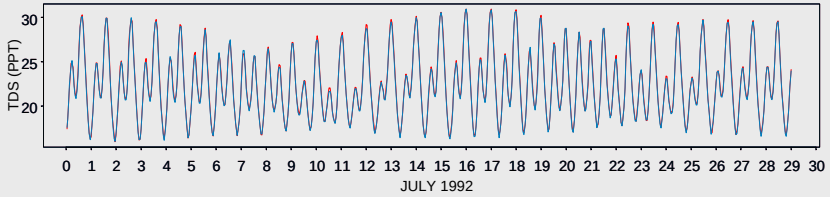
TIDAL CURRENT VELOCITY



TIDAL FLOW



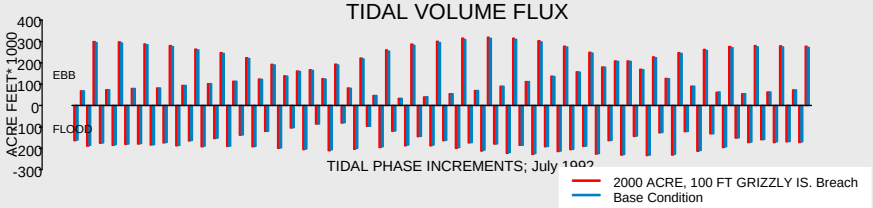
TIDAL SALINITY



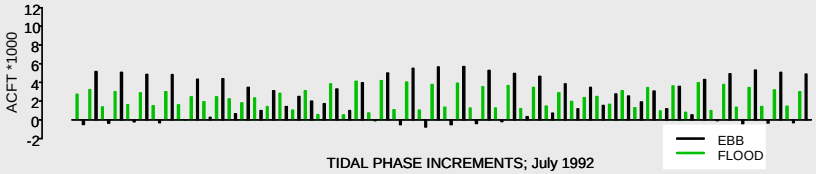
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Tidal Volume and Salt Flux (July 1992) 1/
2000 ACRE, 100 FT GRIZZLY IS. Breach vs Base Condition

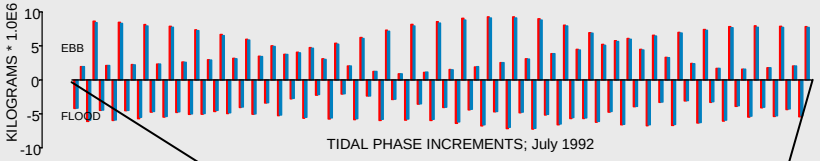
TIDAL VOLUME FLUX



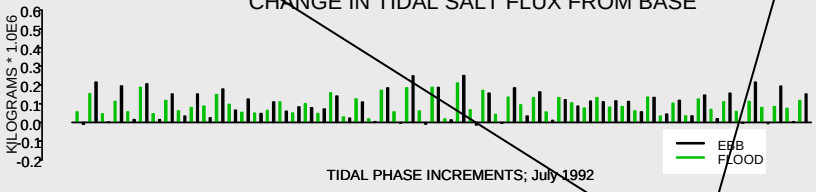
CHANGE IN TIDAL VOLUME FLUX FROM BASE



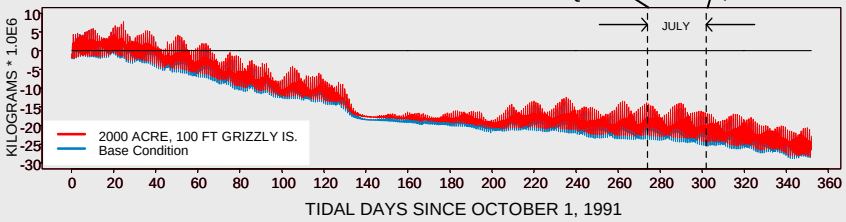
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



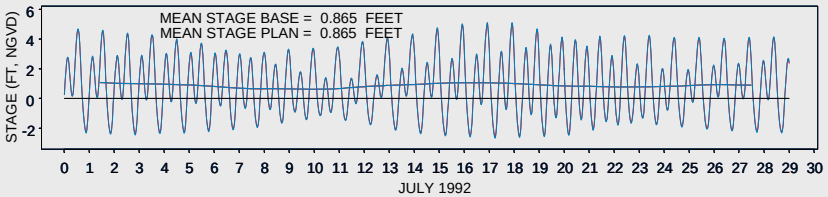
CUMULATIVE SALT LOAD THROUGH CARQUINEZ STRAIT; WY 1992



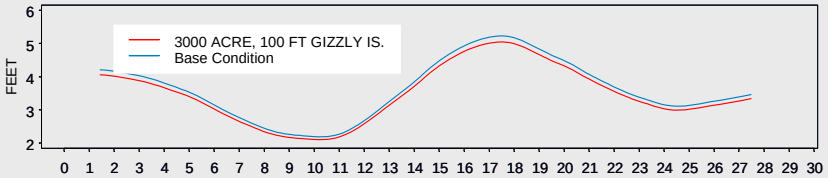
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Hydrodynamics (July 1992) 1/
3000 ACRE, 100 FT GIZZLY IS. Breach vs Base Condition

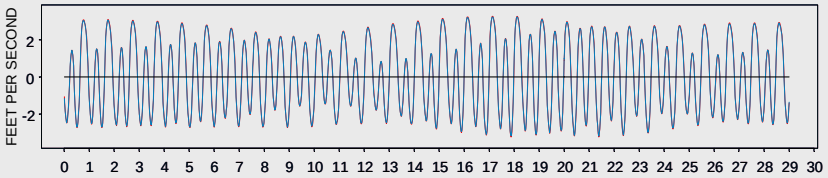
STAGE AND LOW PASS FILTER



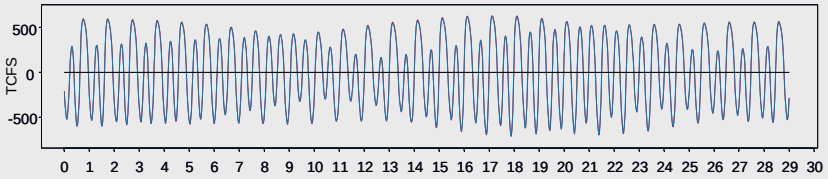
RMS TIDE HEIGHT



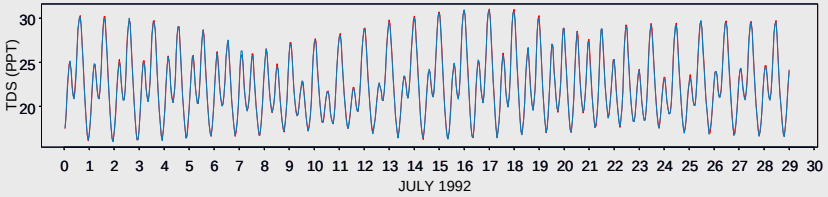
TIDAL CURRENT VELOCITY



TIDAL FLOW



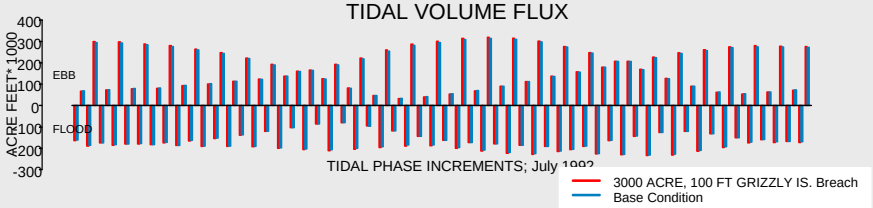
TIDAL SALINITY



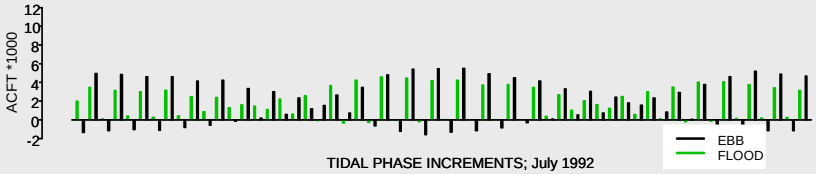
1/ - DSM1 Suisun Marsh Version Simulation.

Carquinez Strait Tidal Volume and Salt Flux (July 1992) 1/
3000 ACRE, 100 FT GRIZZLY IS. Breach vs Base Condition

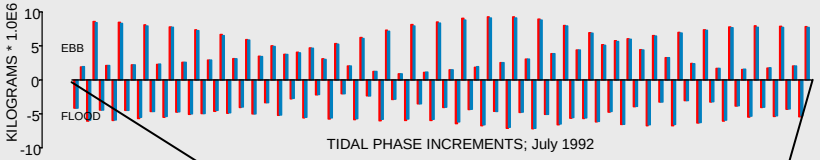
TIDAL VOLUME FLUX



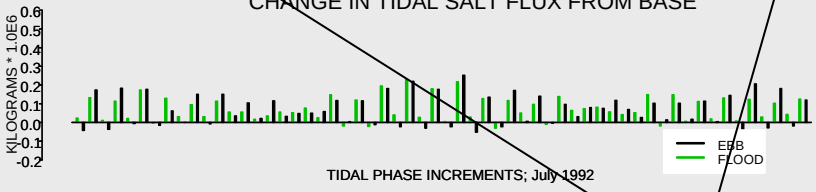
CHANGE IN TIDAL VOLUME FLUX FROM BASE



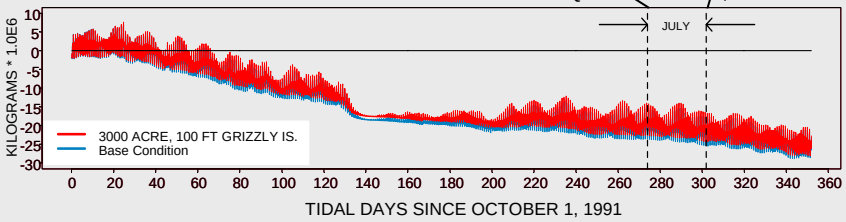
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



CUMULATIVE SALT LOAD THROUGH CARQUINEZ STRAIT; WY 1992



1/ - DSM1 Suisun Marsh Version Simulation.

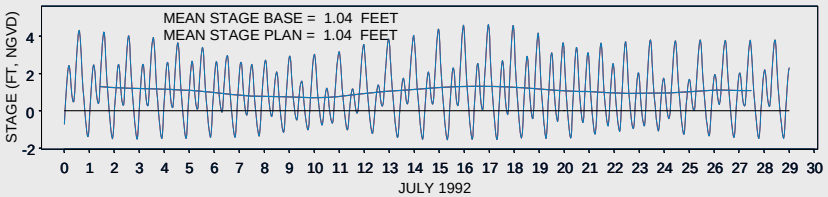
Hydrodynamics, Volume and Salt Flux at CHIPPS ISLAND

100 FOOT BREACH at

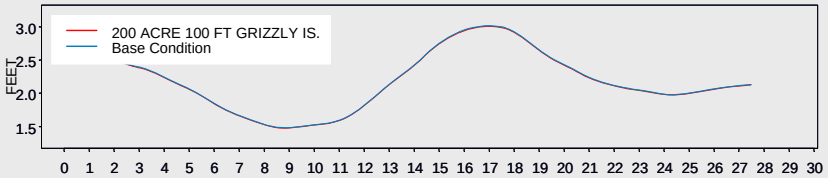
GRIZZLY ISLAND

Chipps Island Hydrodynamics (July 1992) 1/
200 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

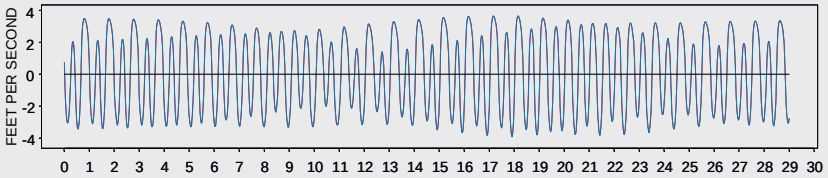
STAGE AND LOW PASS FILTER



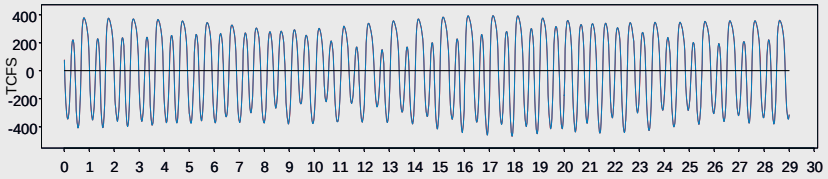
RMS TIDE HEIGHT



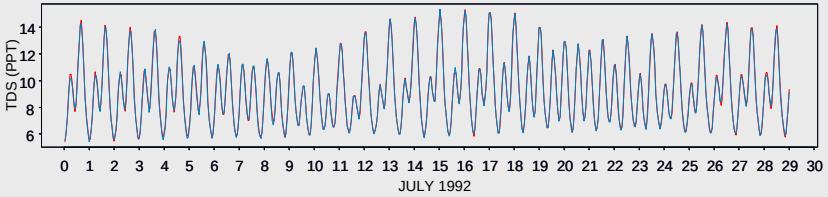
TIDAL CURRENT VELOCITY



TIDAL FLOW



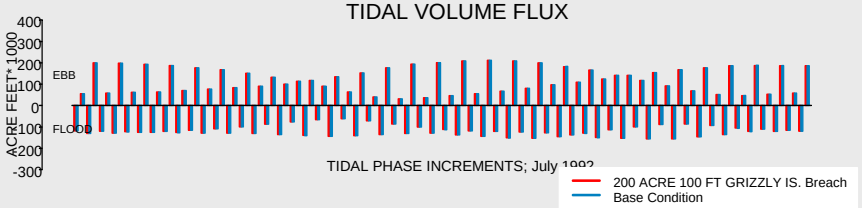
TIDAL SALINITY



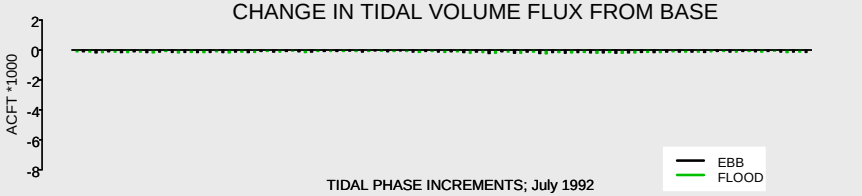
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Tidal Volume and Salt Flux (July 1992) 1/
200 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

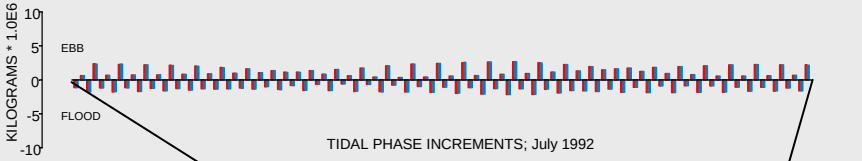
TIDAL VOLUME FLUX



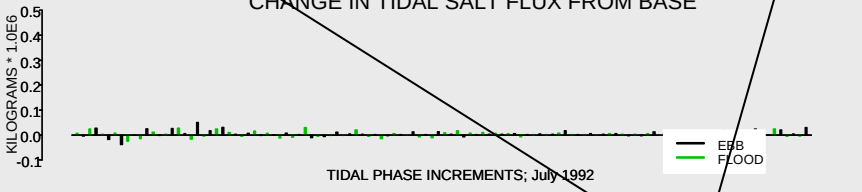
CHANGE IN TIDAL VOLUME FLUX FROM BASE



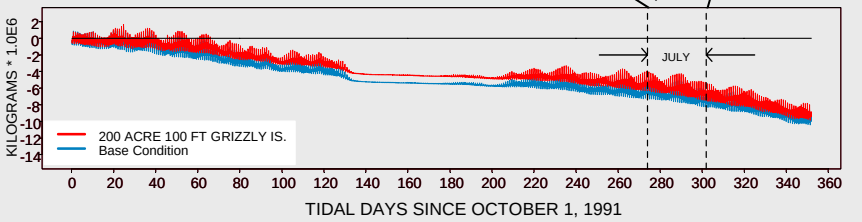
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



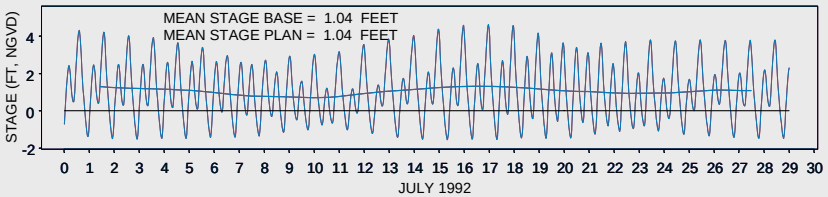
CUMULATIVE SALT LOAD AT CHIPPS ISLAND; WY 1992



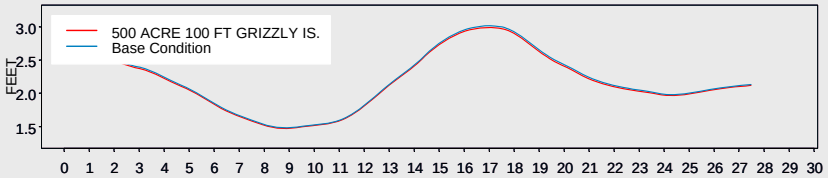
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Hydrodynamics (July 1992) 1/
500 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

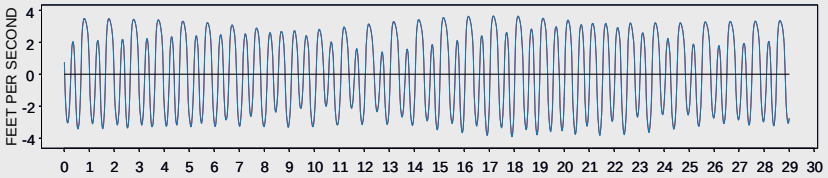
STAGE AND LOW PASS FILTER



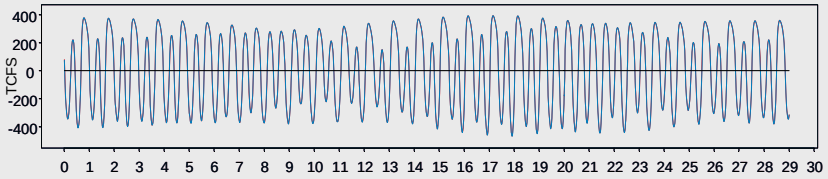
RMS TIDE HEIGHT



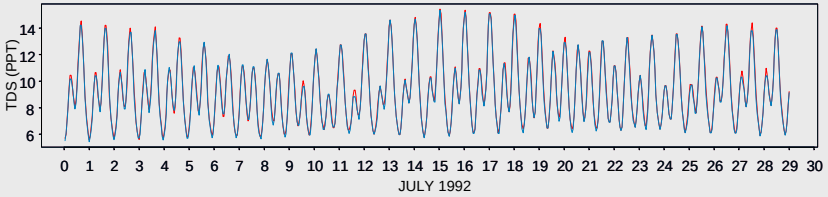
TIDAL CURRENT VELOCITY



TIDAL FLOW



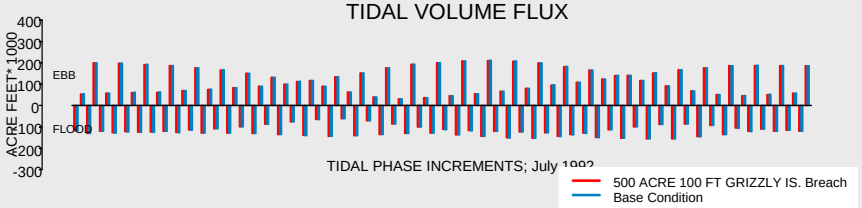
TIDAL SALINITY



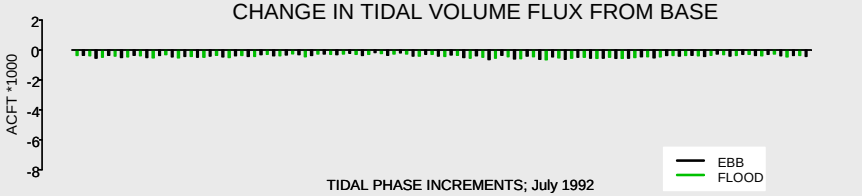
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Tidal Volume and Salt Flux (July 1992) 1/
500 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

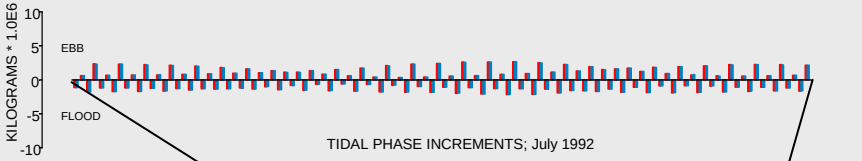
TIDAL VOLUME FLUX



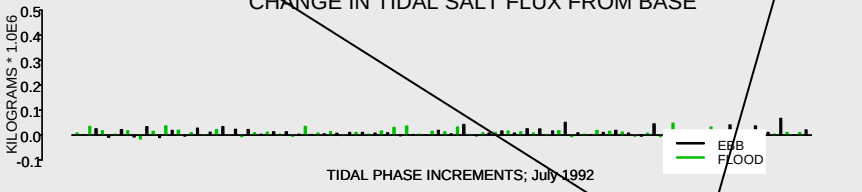
CHANGE IN TIDAL VOLUME FLUX FROM BASE



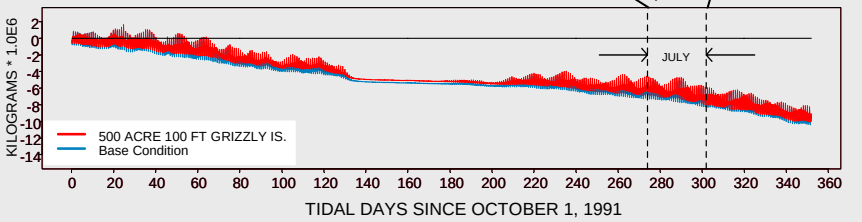
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



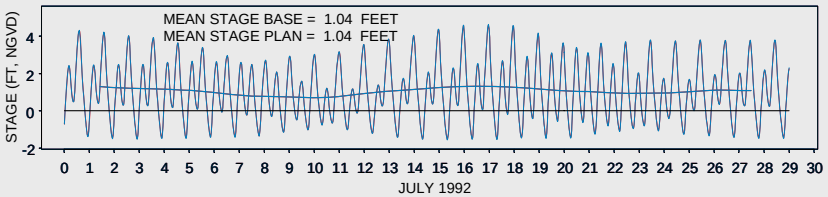
CUMULATIVE SALT LOAD AT CHIPPS ISLAND; WY 1992



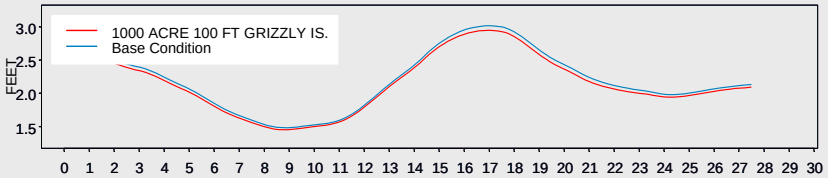
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Hydrodynamics (July 1992) 1/
1000 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

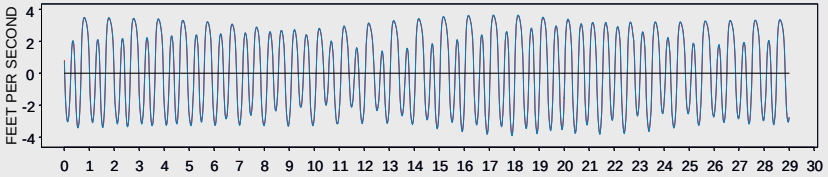
STAGE AND LOW PASS FILTER



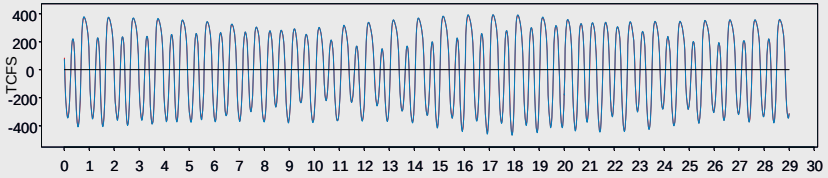
RMS TIDE HEIGHT



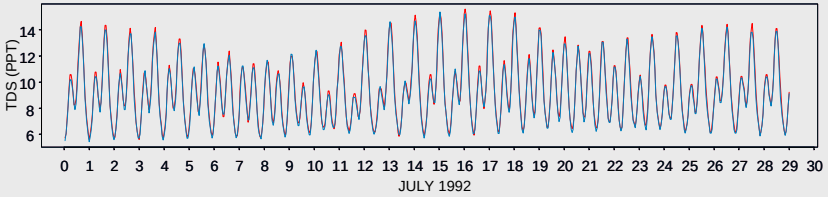
TIDAL CURRENT VELOCITY



TIDAL FLOW



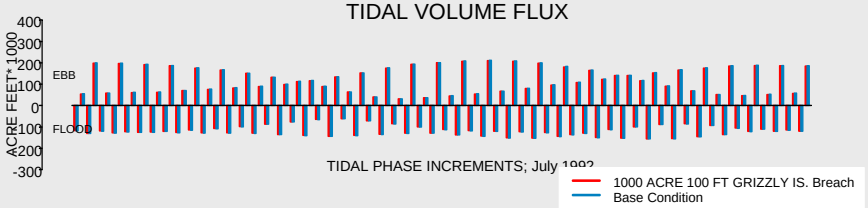
TIDAL SALINITY



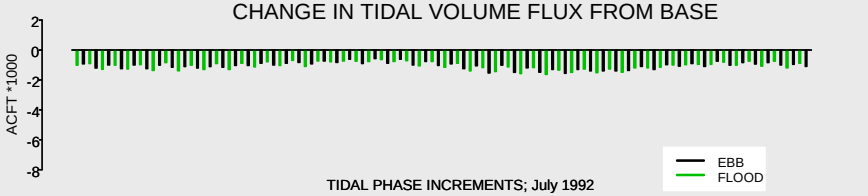
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Tidal Volume and Salt Flux (July 1992) 1/
1000 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

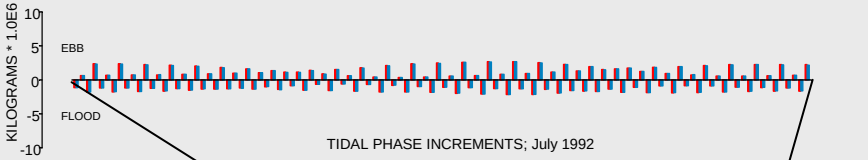
TIDAL VOLUME FLUX



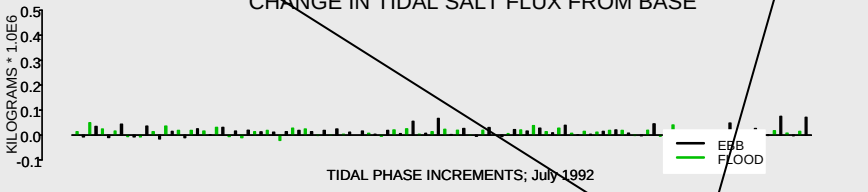
CHANGE IN TIDAL VOLUME FLUX FROM BASE



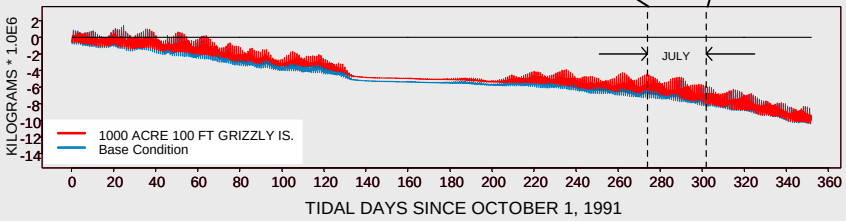
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



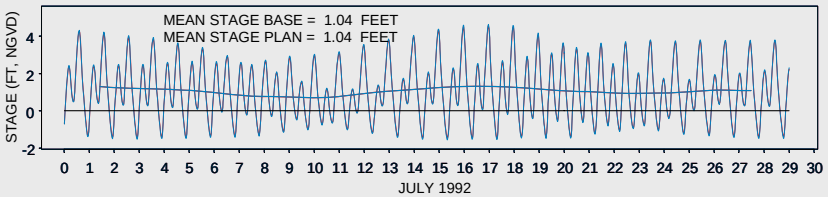
CUMULATIVE SALT LOAD AT CHIPPS ISLAND; WY 1992



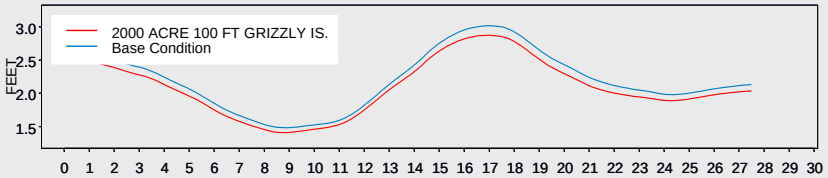
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Hydrodynamics (July 1992) 1/
2000 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

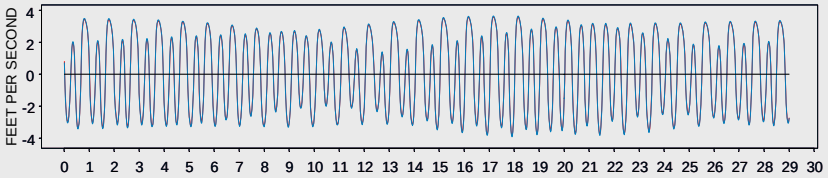
STAGE AND LOW PASS FILTER



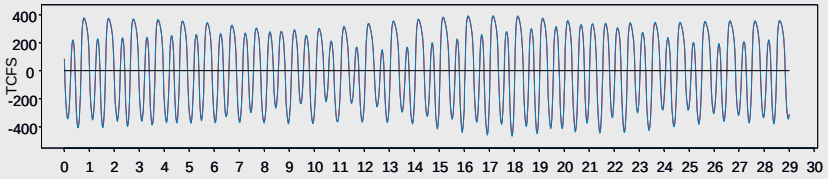
RMS TIDE HEIGHT



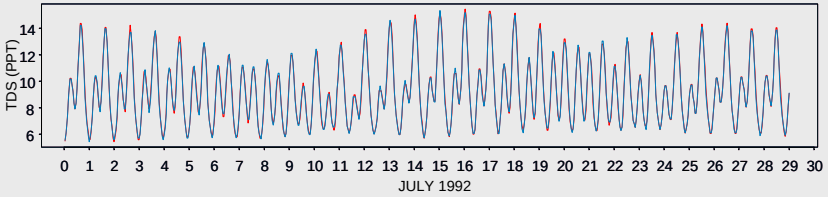
TIDAL CURRENT VELOCITY



TIDAL FLOW



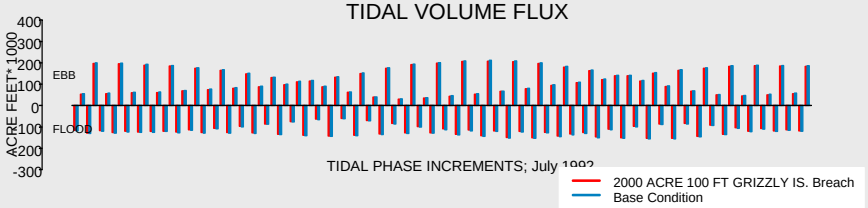
TIDAL SALINITY



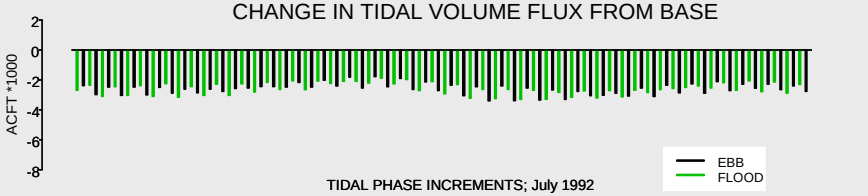
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Tidal Volume and Salt Flux (July 1992) 1/
2000 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

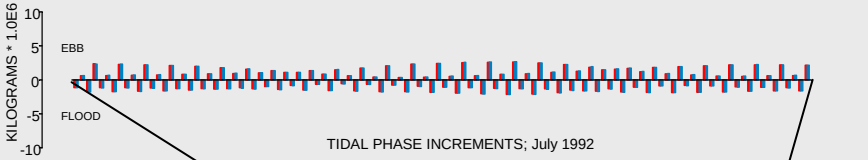
TIDAL VOLUME FLUX



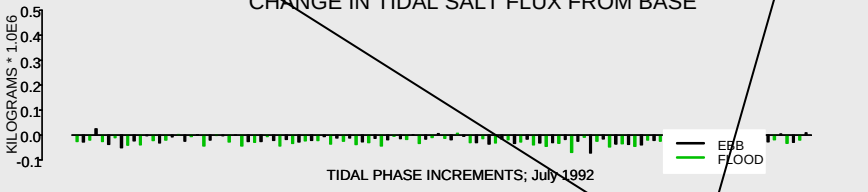
CHANGE IN TIDAL VOLUME FLUX FROM BASE



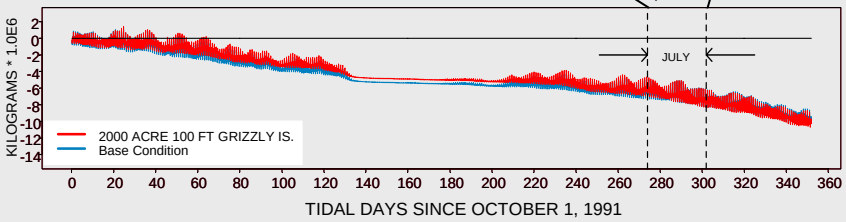
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



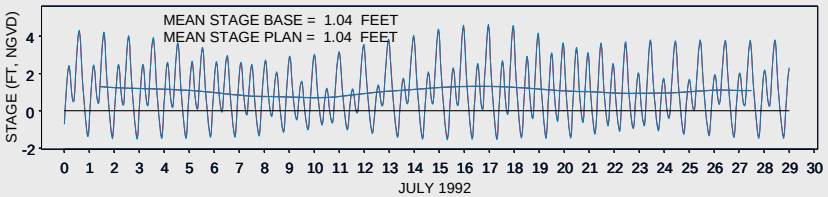
CUMULATIVE SALT LOAD AT CHIPPS ISLAND; WY 1992



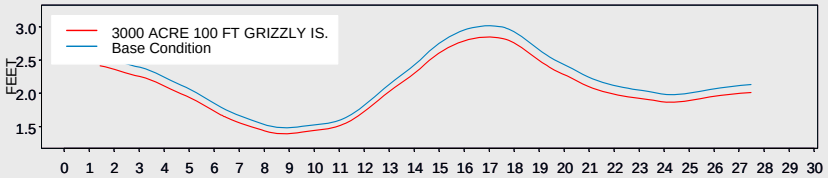
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Hydrodynamics (July 1992) 1/
3000 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

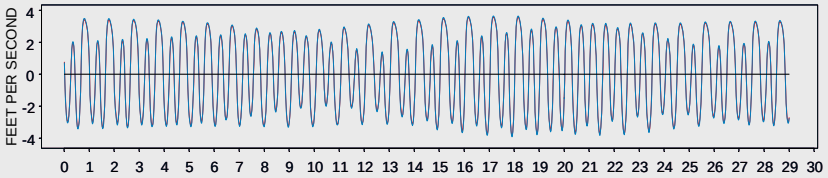
STAGE AND LOW PASS FILTER



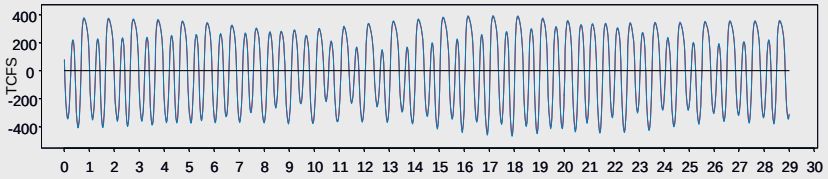
RMS TIDE HEIGHT



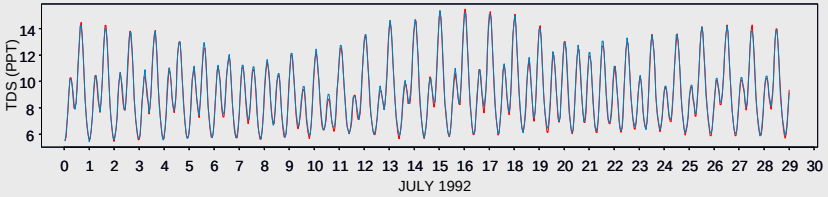
TIDAL CURRENT VELOCITY



TIDAL FLOW



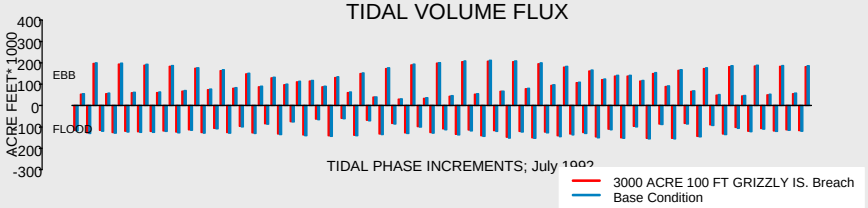
TIDAL SALINITY



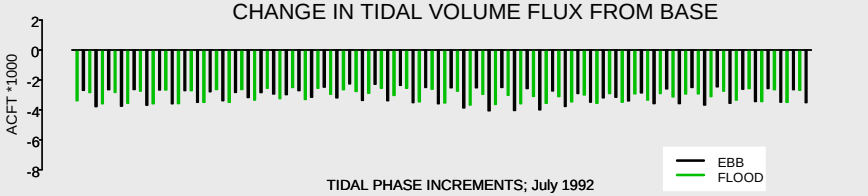
1/ - DSM1 Suisun Marsh Version Simulation.

Chipps Island Tidal Volume and Salt Flux (July 1992) 1/
3000 ACRE 100 FT GRIZZLY IS. Breach vs Base Condition

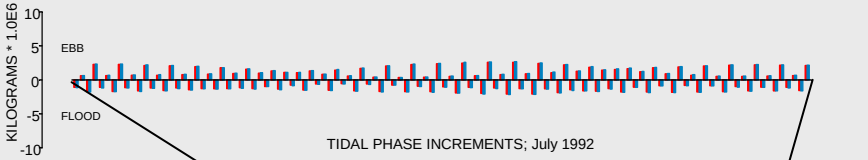
TIDAL VOLUME FLUX



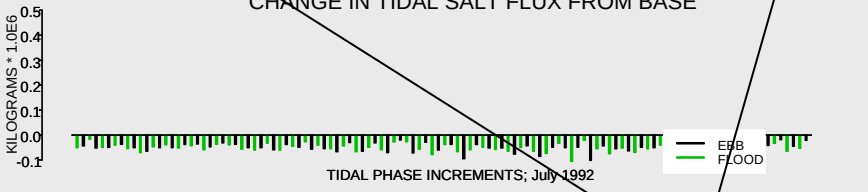
CHANGE IN TIDAL VOLUME FLUX FROM BASE



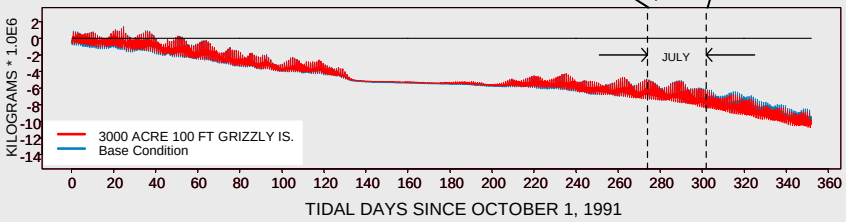
TIDAL SALT FLUX



CHANGE IN TIDAL SALT FLUX FROM BASE



CUMULATIVE SALT LOAD AT CHIPPS ISLAND; WY 1992

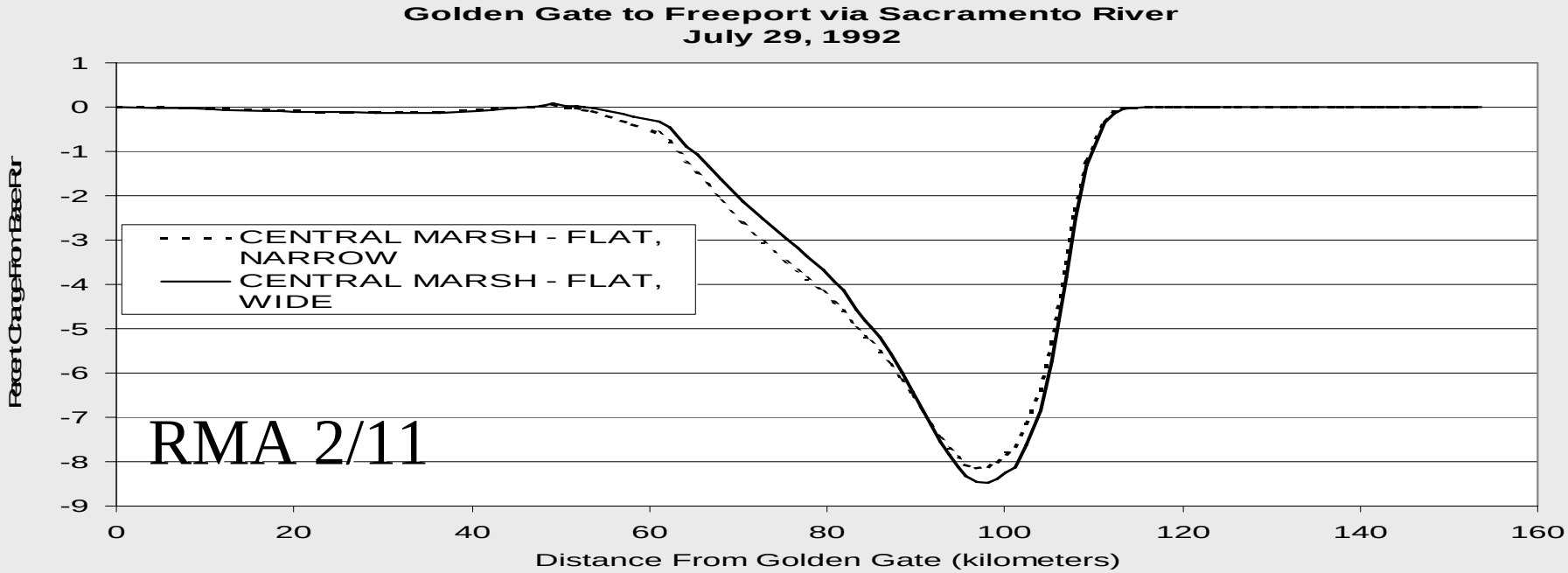


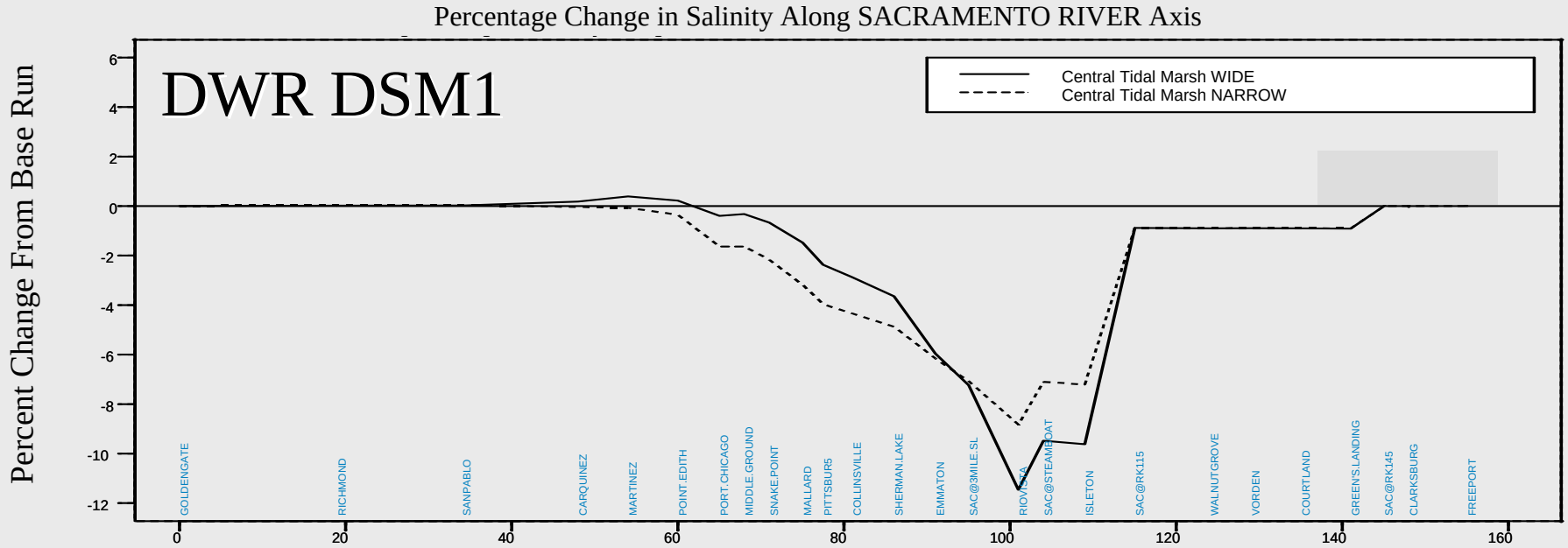
1/ - DSM1 Suisun Marsh Version Simulation.

Why did the “Tidal Marsh Options” work so well?

-Restoration Design Implications-

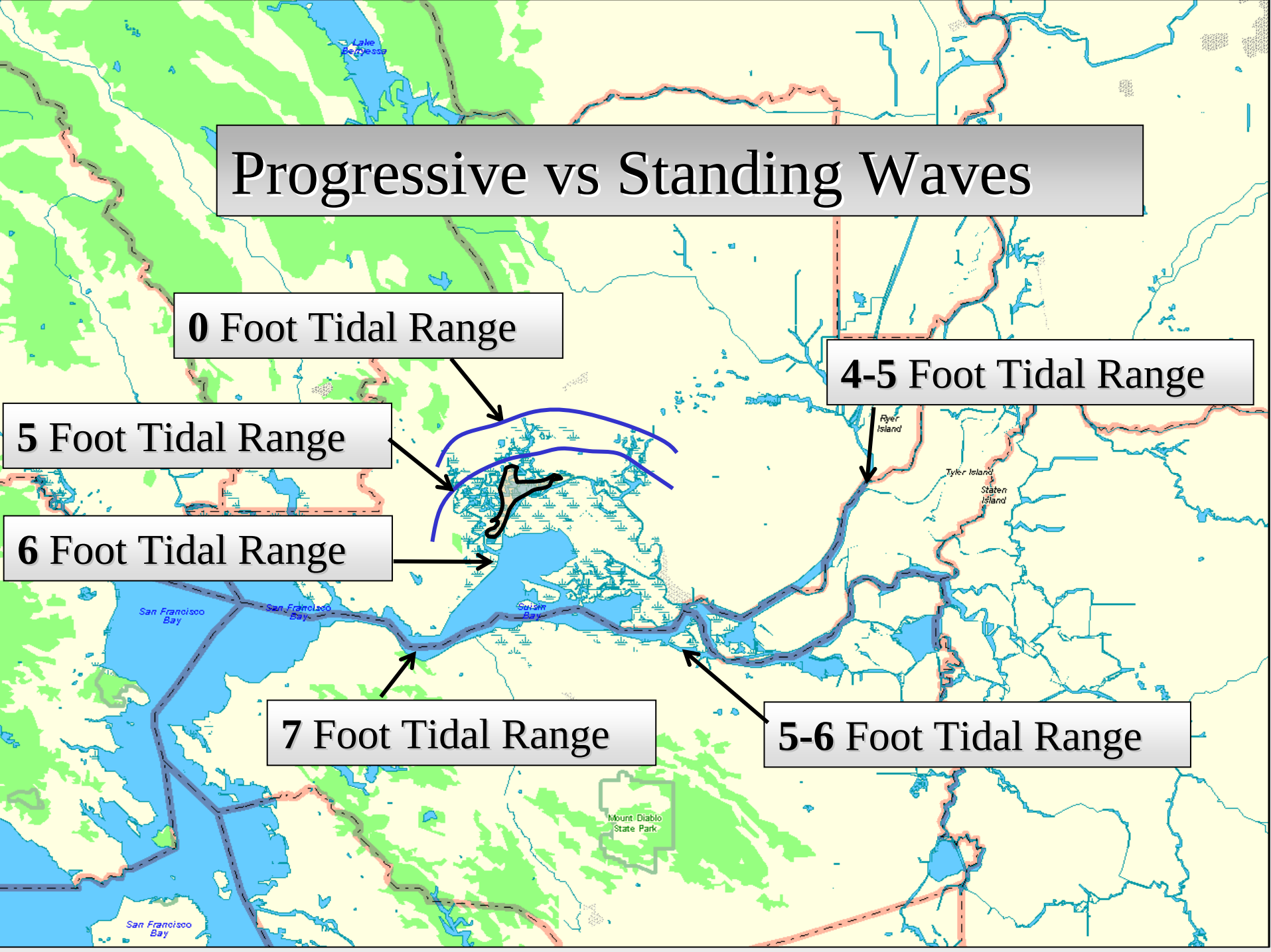
Central Tidal Marsh Option





1/ DSM1 Suisun Marsh Version: Historical Simulation

Progressive vs Standing Waves



“Standing Waves” in breach areas and sloughs

“Progressive Waves” in main channels

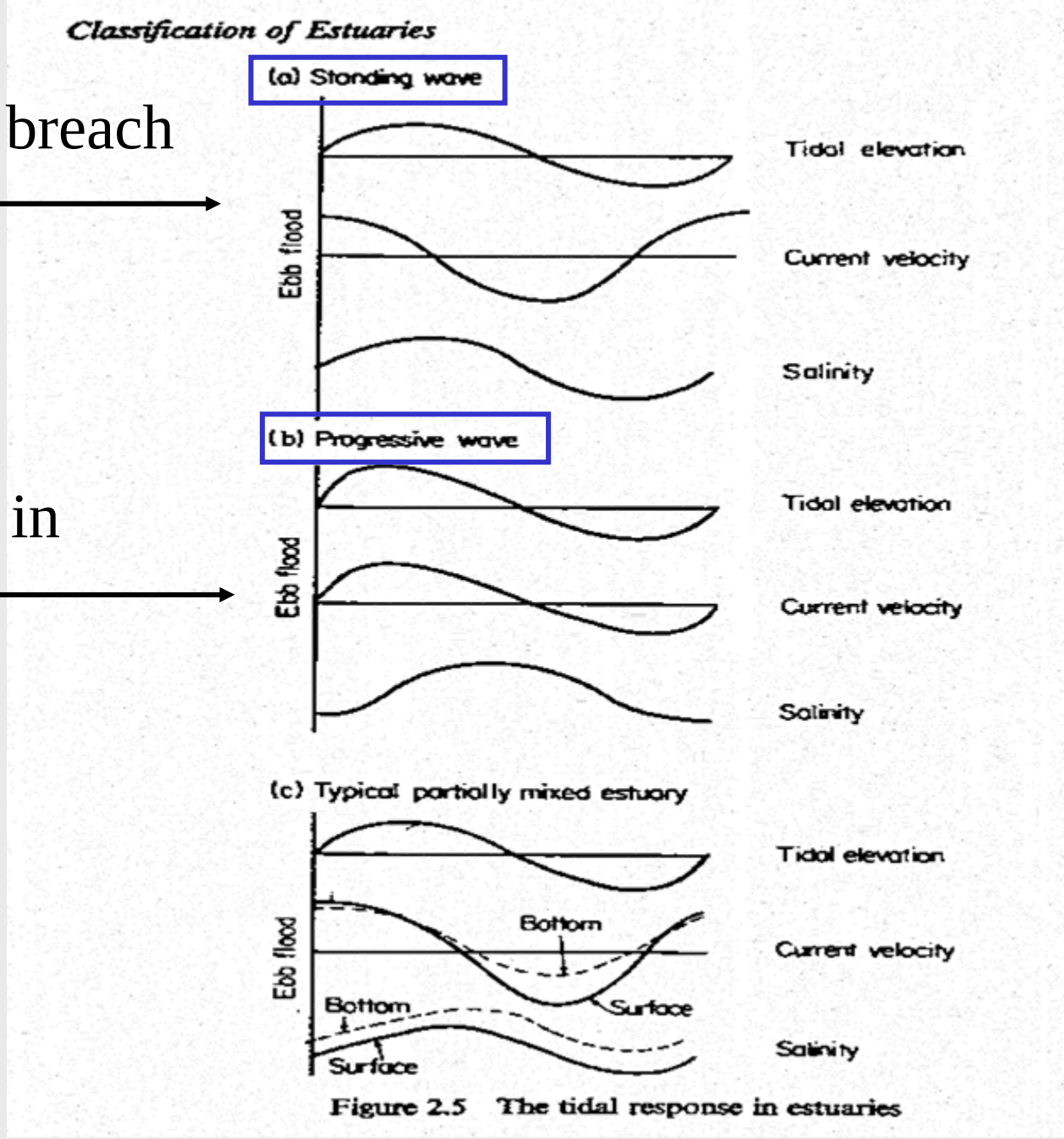
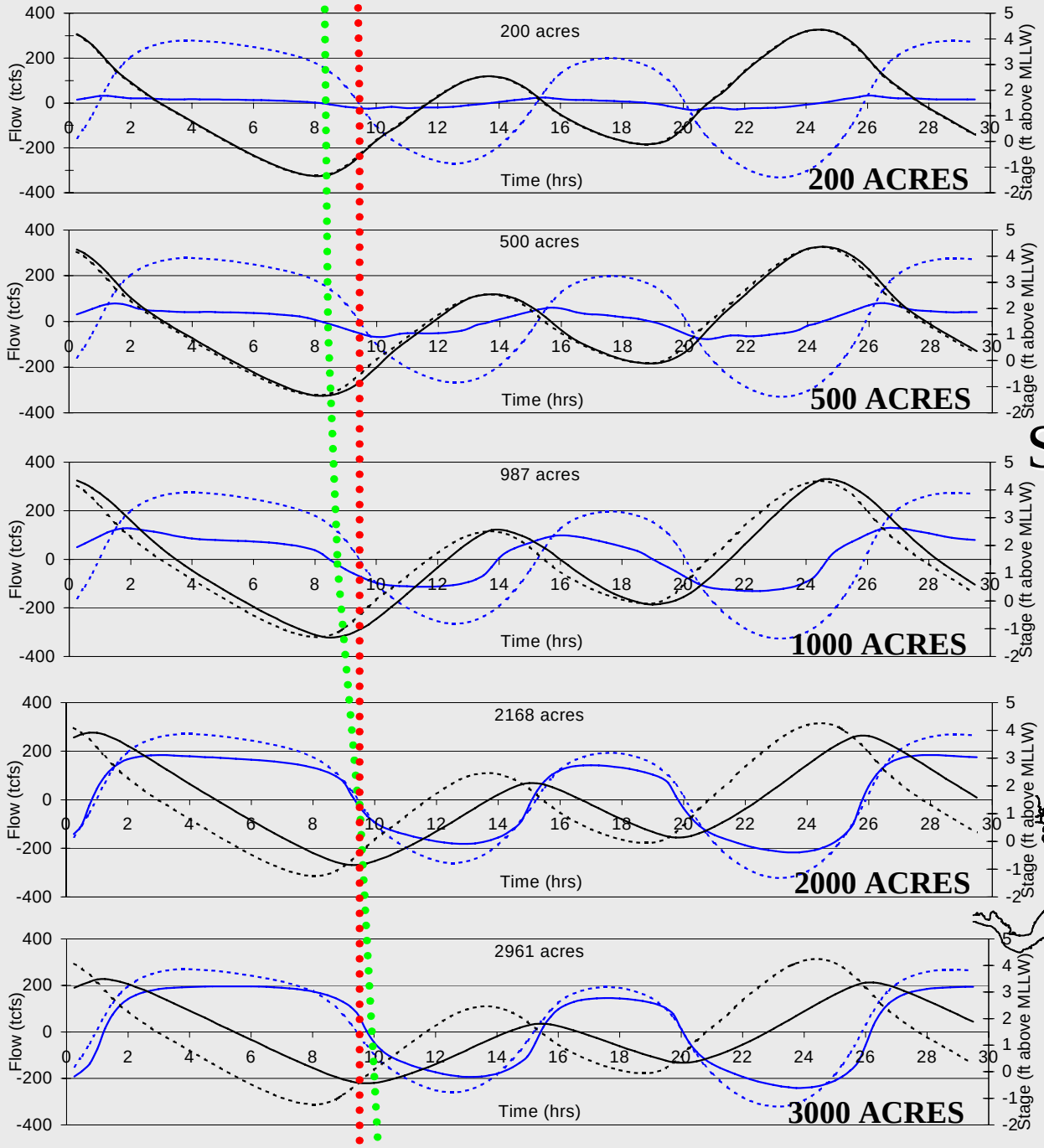


Figure 2.5 The tidal response in estuaries

From Dyer, 1973

VAN SICKLE ISLAND 100 FT BREACH



Inside Breach

Flow

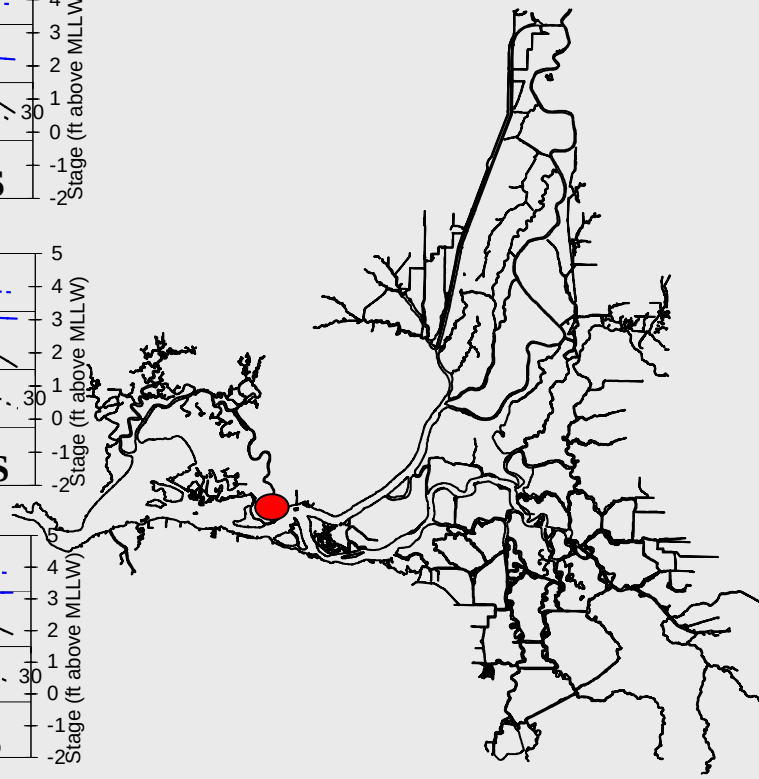
Stage

Outside Breach

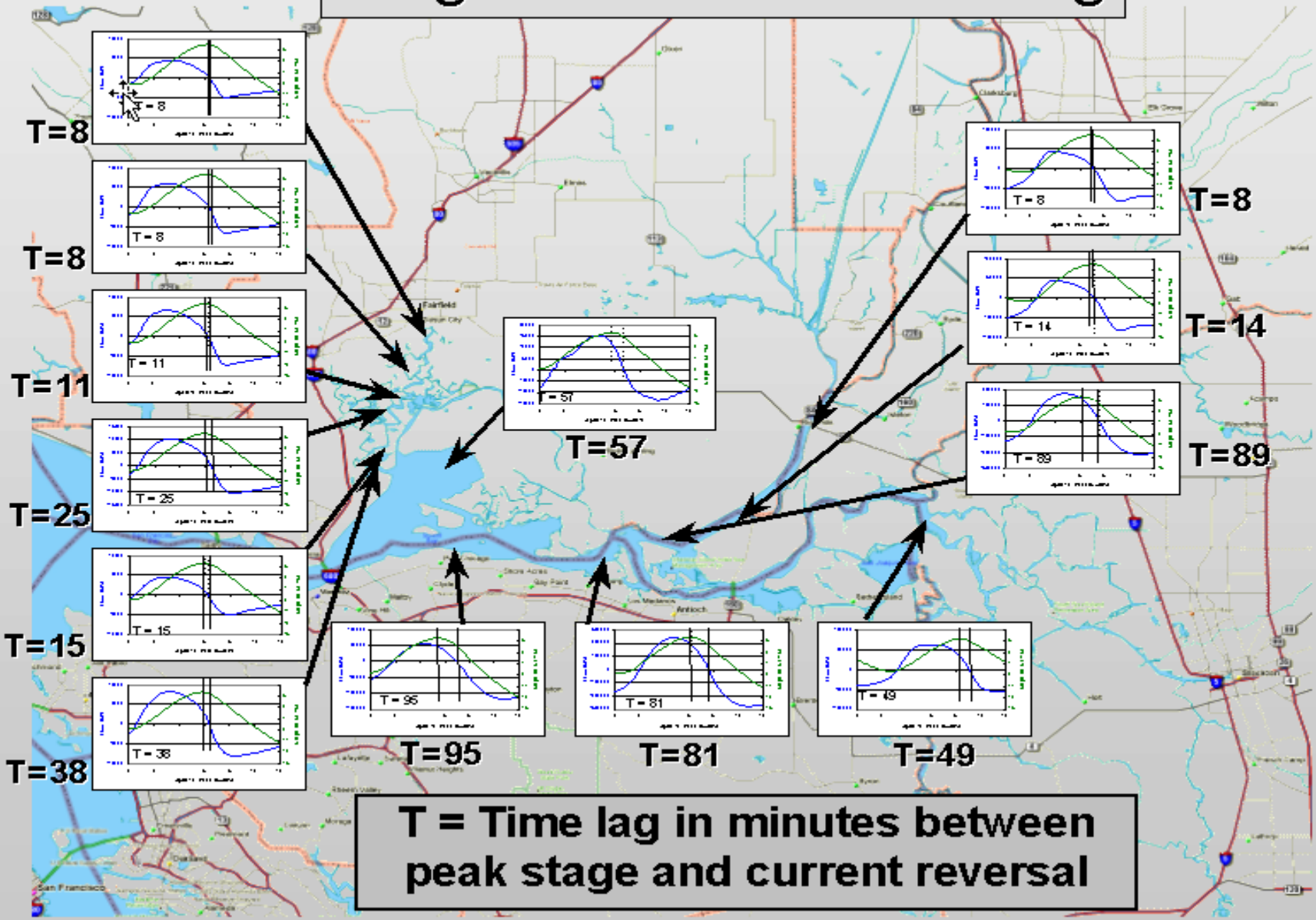
Flow

Stage

STANDING WAVES

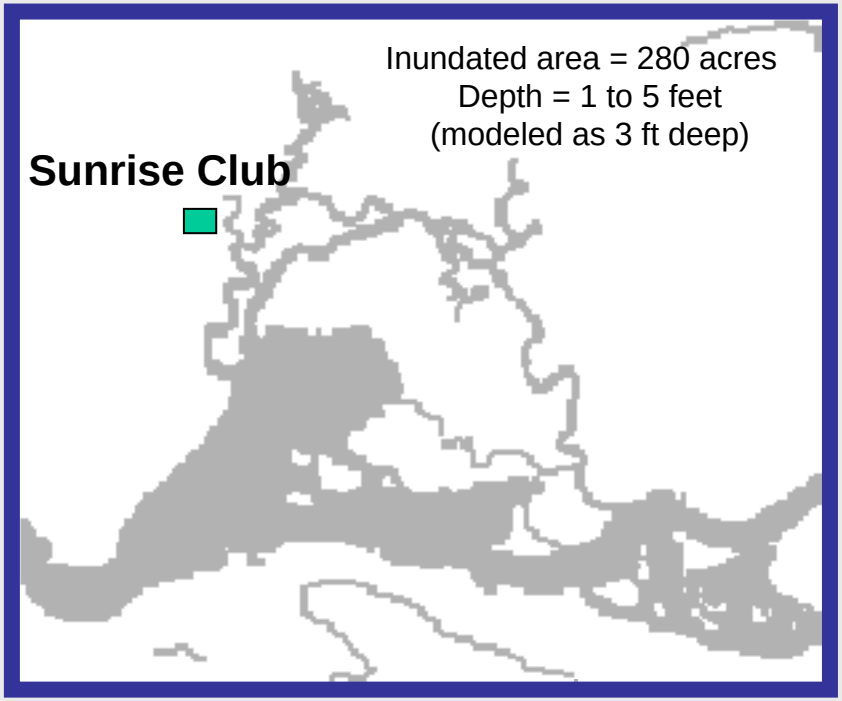


Stage and Current Phasing



Preliminary Sunrise Club Breach Simulation

- Sunrise Club breached in July 1999 due to high tides
- Breach repaired in July 2000

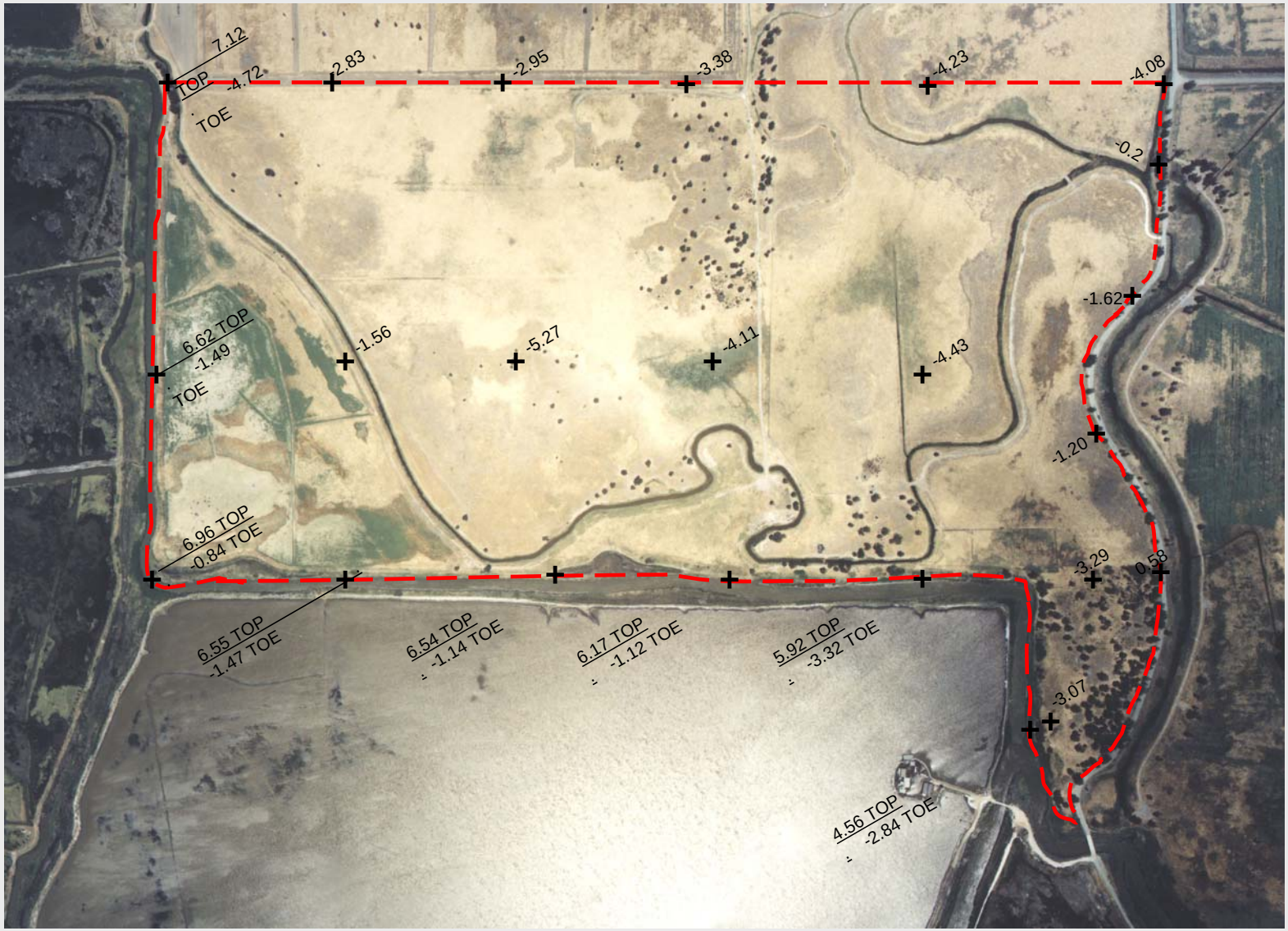


Sunrise Breach Site

Suisun Marsh Property Acquisition

Property 1:

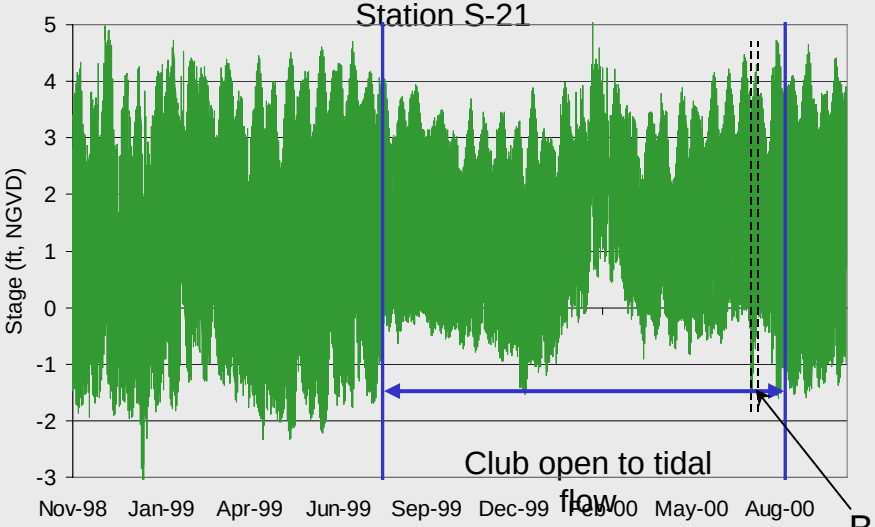
Suisun Marsh Hunting Preserve (west of Chadborne Road)



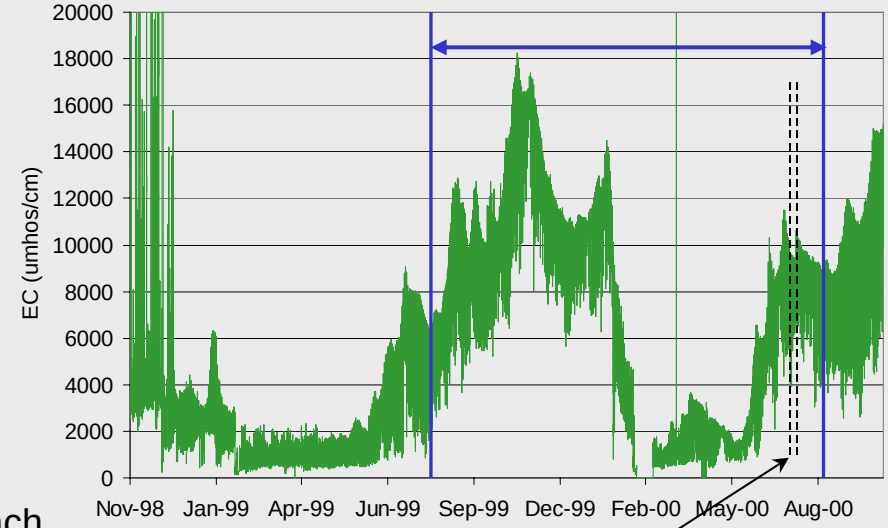
Note: Elevations based upon Bench Mark "S 21 Reset." NGVD 1929 Elevation 4.33 ft. per August 1996 GPS Survey of Suisun Marsh Area. (SR 96-29)

Field Data and DSM2 Modeling

Water Surface Elevation at Sunrise Club Monitoring Station S-21

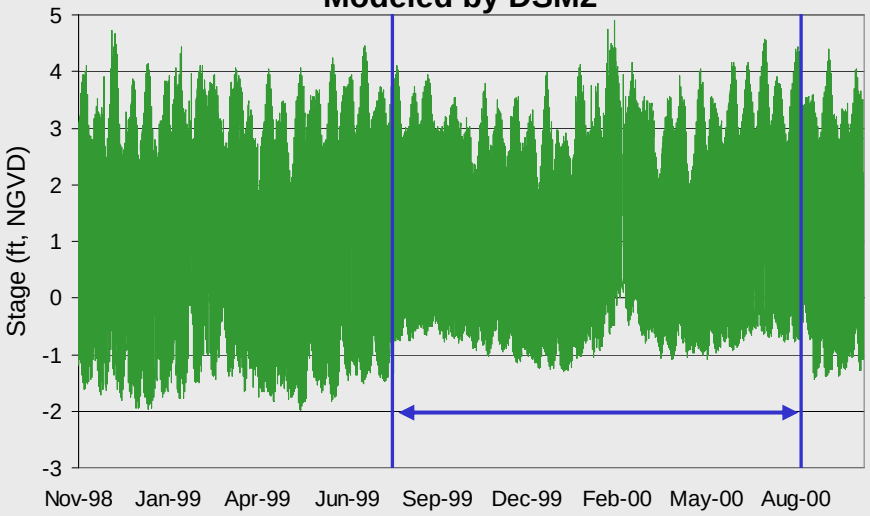


EC at Sunrise Club Monitoring Station S-21

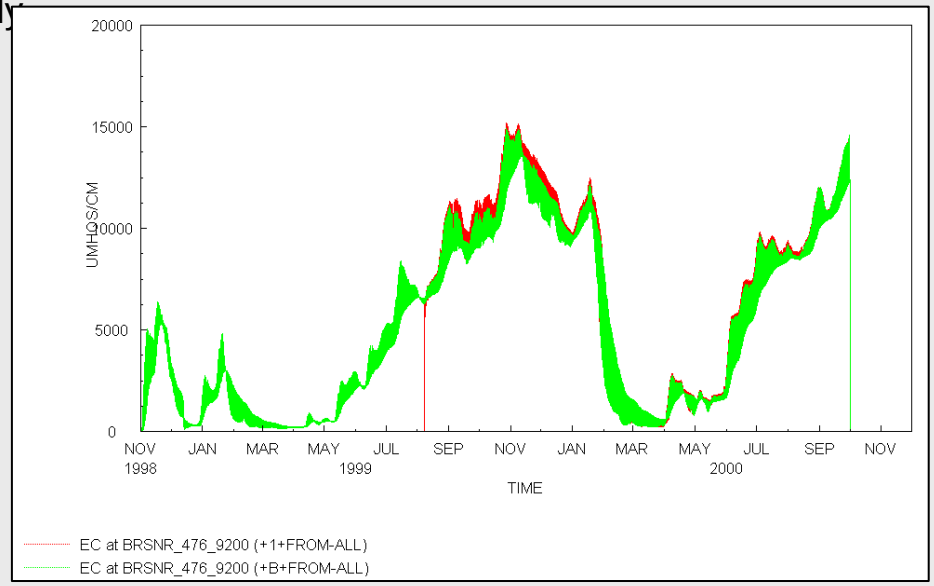


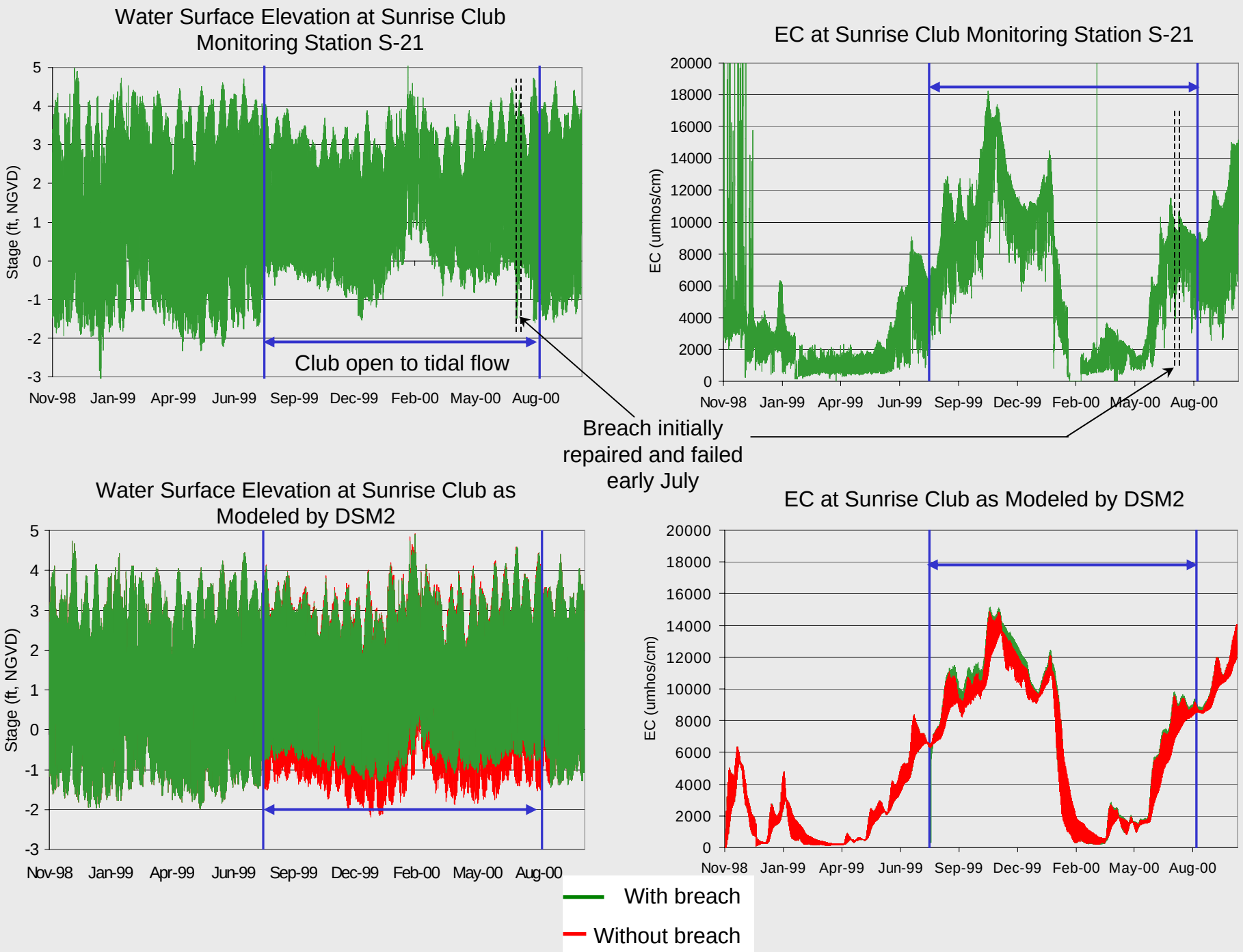
Breach initially repaired and failed early July

Water Surface Elevation at Sunrise Club as **Modeled by DSM2**



EC at Sunrise Club as **Modeled by DSM2**




Water Surface Elevation at Sunrise Club Monitoring Station S-21
Stage (ft, NGVD)
5
4
3
2
1
0
-1
-2
-3
Nov-98
Jan-99
Apr-99
Jun-99
Sep-99
Dec-99
Feb-00
May-00
Aug-00
Club open to tidal flow
EC at Sunrise Club Monitoring Station S-21
EC (umhos/cm)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Breach initially repaired and failed early July
Water Surface Elevation at Sunrise Club as Modeled by DSM2
EC at Sunrise Club as Modeled by DSM2
With breach
Without breach

Percent Change in Salinity due to breach at

Sunrise Club

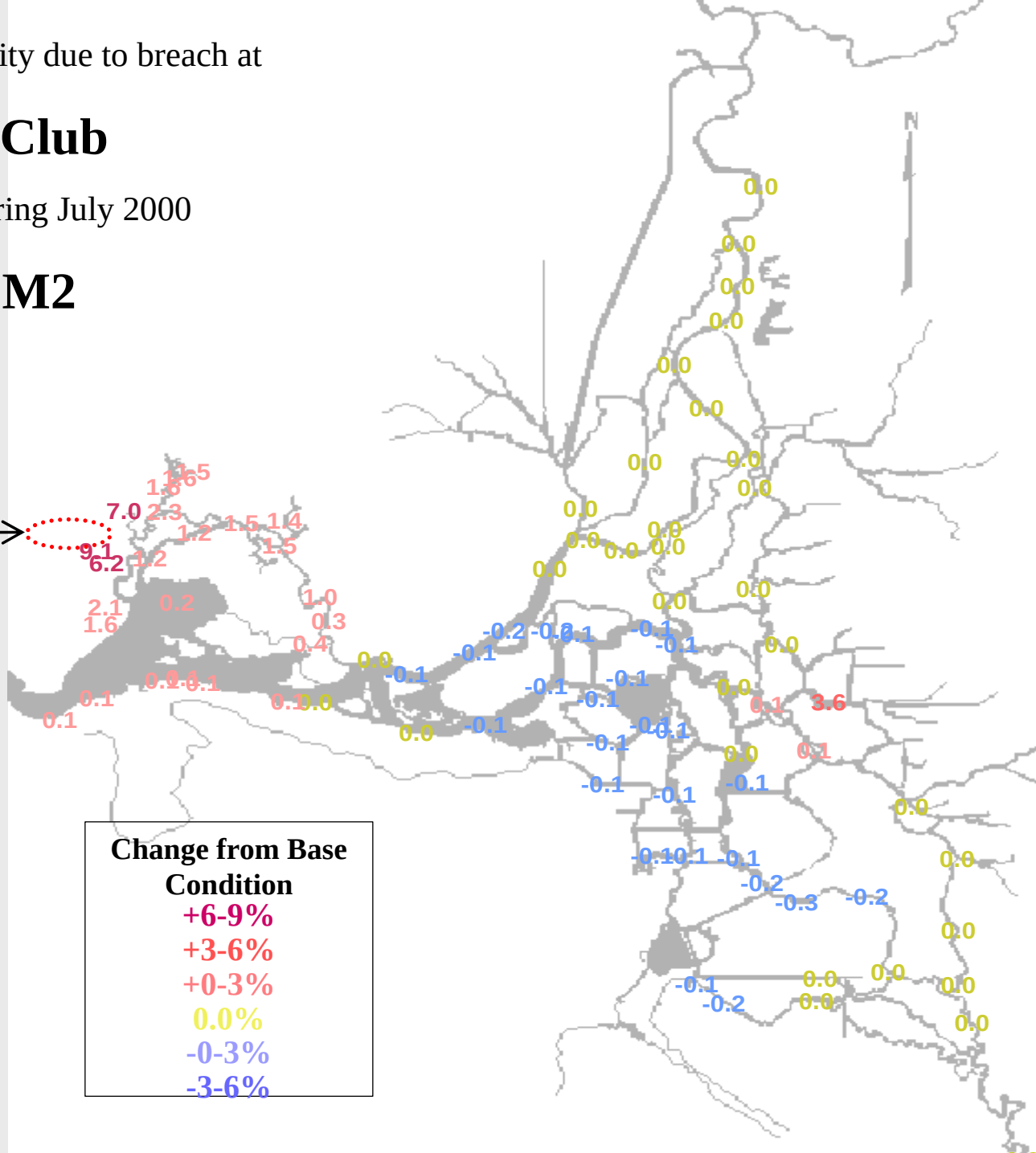
average change during July 2000

using **DSM2**

Approximate location of Sunrise Club

Inundated area of 280 acres

depth of 3 feet



Percent Change in Salinity due to breach at

Sunrise Club

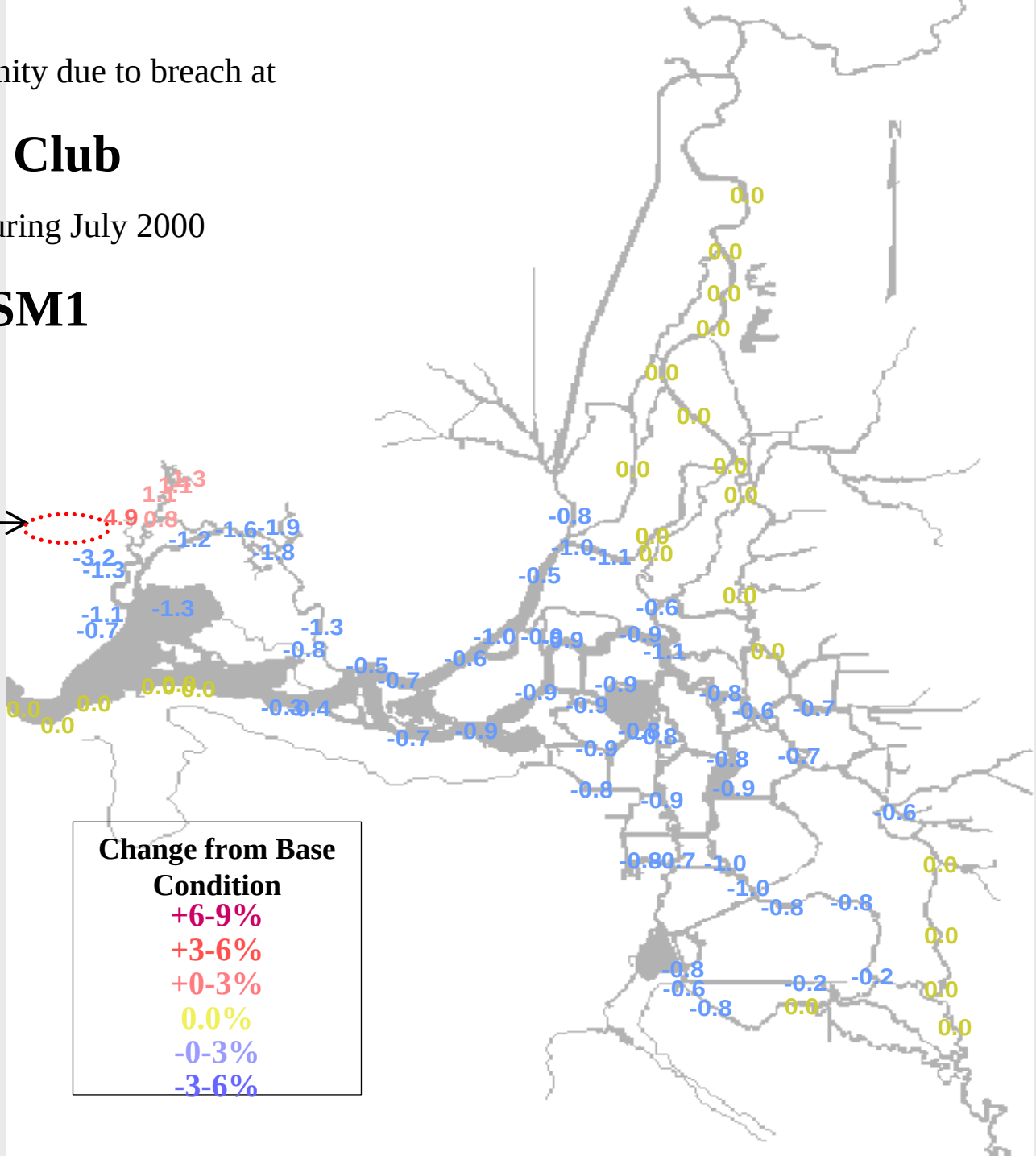
average change during July 2000

using **DSM1**

Approximate location of Sunrise Club

Inundated area of 280 acres

depth of 3 feet



Future Work

- Support CALFED Science Panel
- How is energy dissipated by levee breaches?
- Higher dimensional modeling of muted tidal marsh geometry
- Sediment transport: field measurement and modeling

Thank You