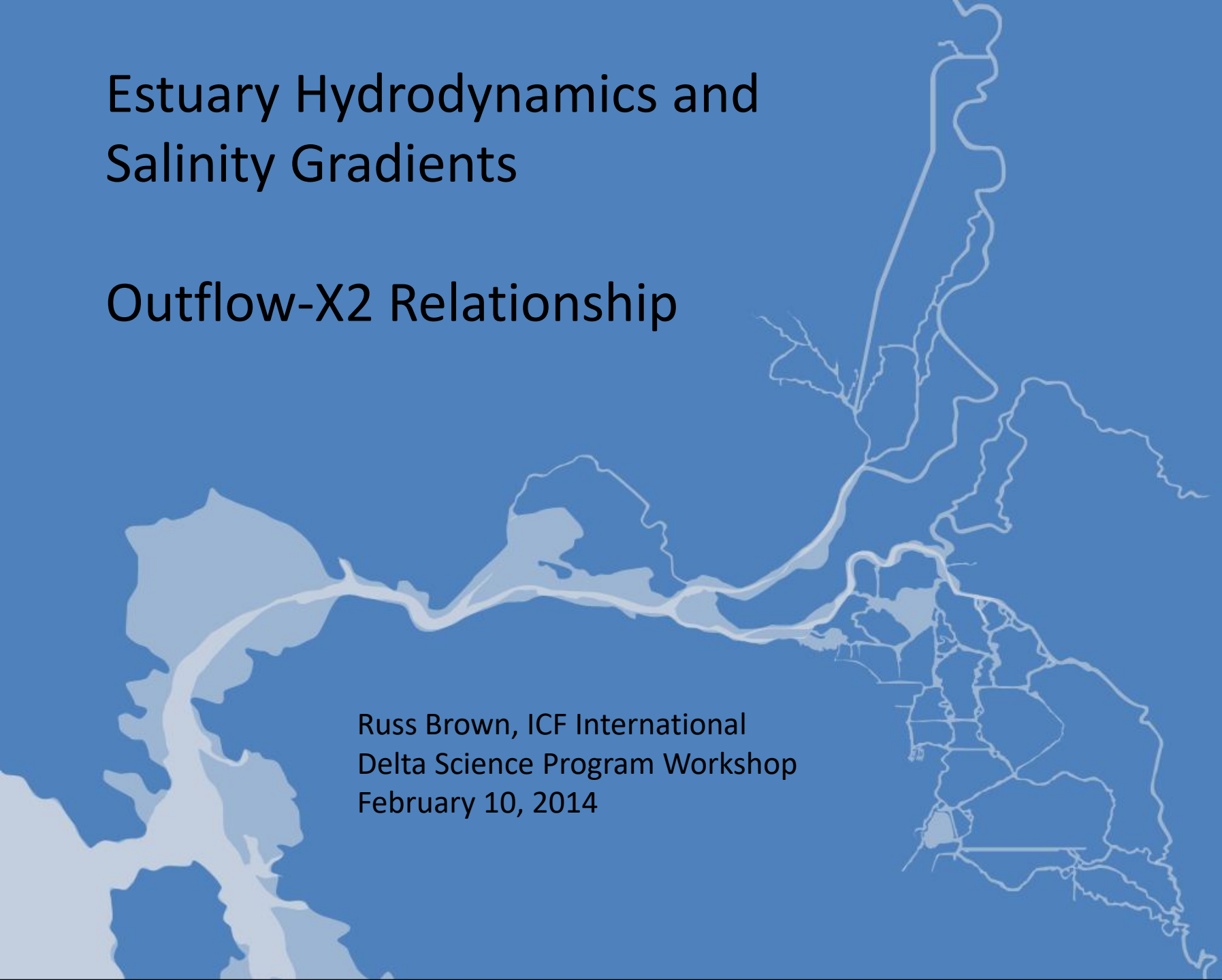
Estuary Hydrodynamics and Salinity Gradients

Outflow-X2 Relationship



Russ Brown, ICF International
Delta Science Program Workshop
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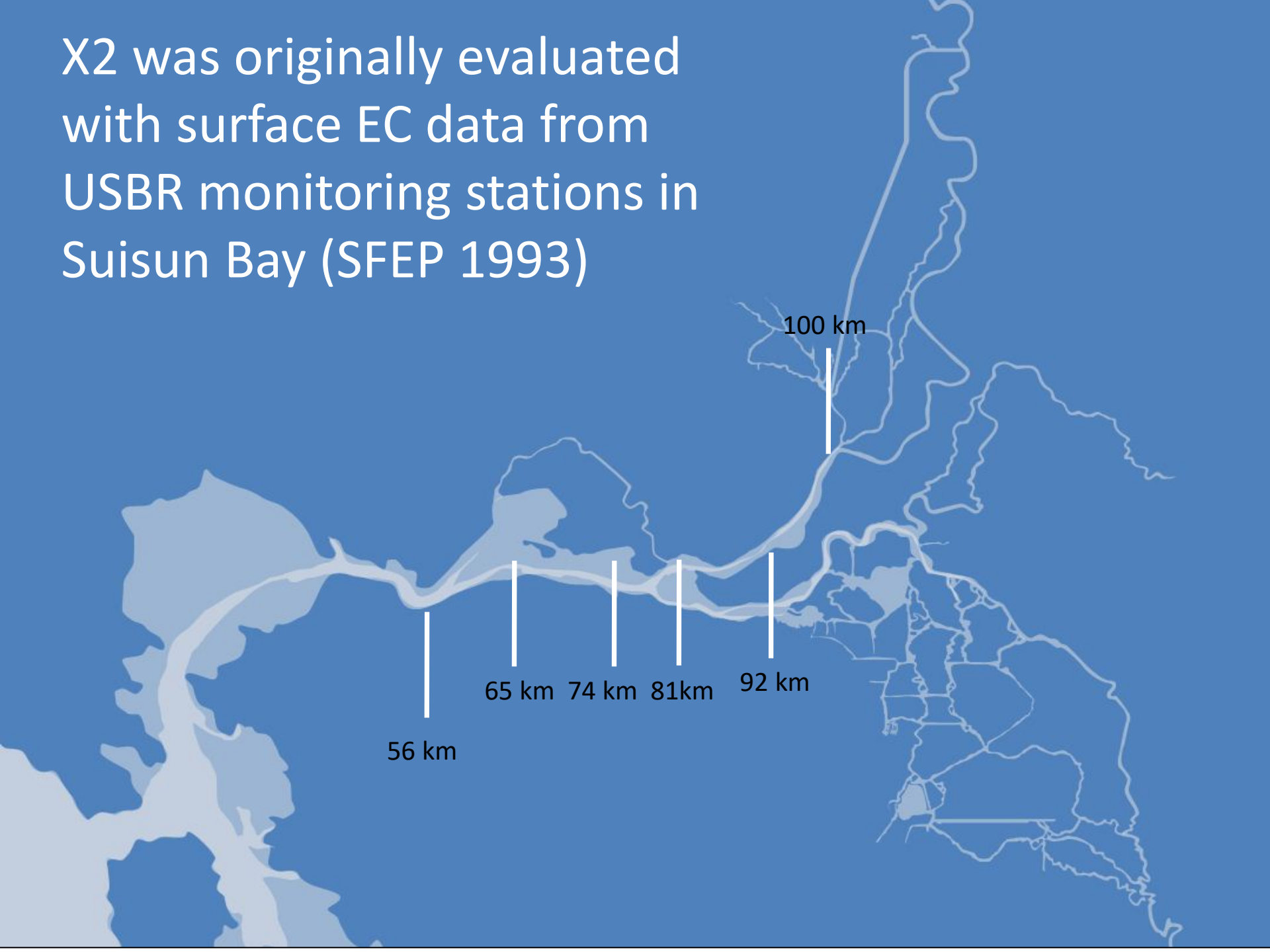
X2 is the upstream distance from the Golden Gate Bridge (kilometers) to the location of the daily average 2 parts per thousand bottom salinity (6% seawater)

X2 was originally evaluated with surface EC data from USBR monitoring stations in Suisun Bay (SFEP 1993)



How is X2 measured and estimated?

EC Measurements:

Surface EC at 15-minunte Monitoring Stations

Bottom EC at 15-minute Monitoring Stations

Monthly USGS Boat Surveys (psu)

Outflow-X2 regressions

DAYFLOW (SFEP 1993 for daily data):

$$X2(t) = 10.16 + 0.945 * X2[t-1] - 1.487 * \log [Outflow(cfs)]$$

Steady-State X2

$$X2 = 185 - 27 * \text{Log [outflow(cfs)]}$$

$$\text{Effective Outflow} = 10 \wedge [(185-X2)/27]$$

Effective Outflow- G-model (Denton 1993)

$$\text{Effective (cfs) [t]} = NDO / [1 + [NDO/\text{Effective [t-1]} -1] * \exp [- NDO/\text{G-Volume (cfs)}]$$

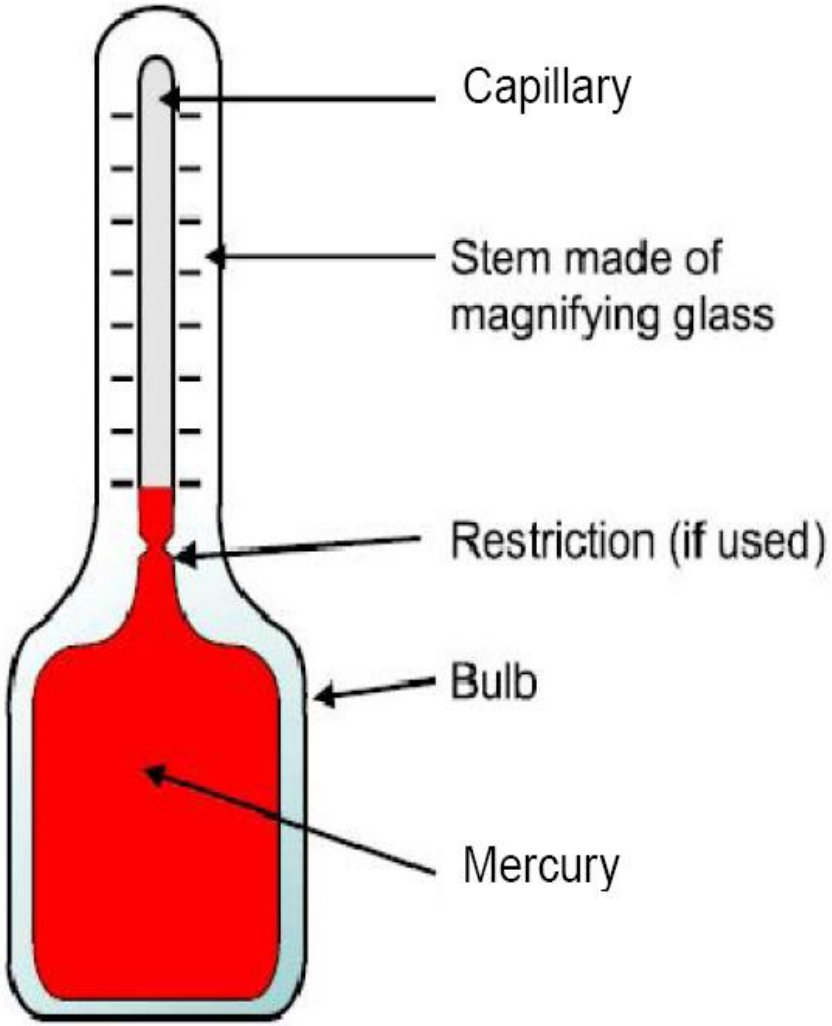
Hydrodynamic Model Results:

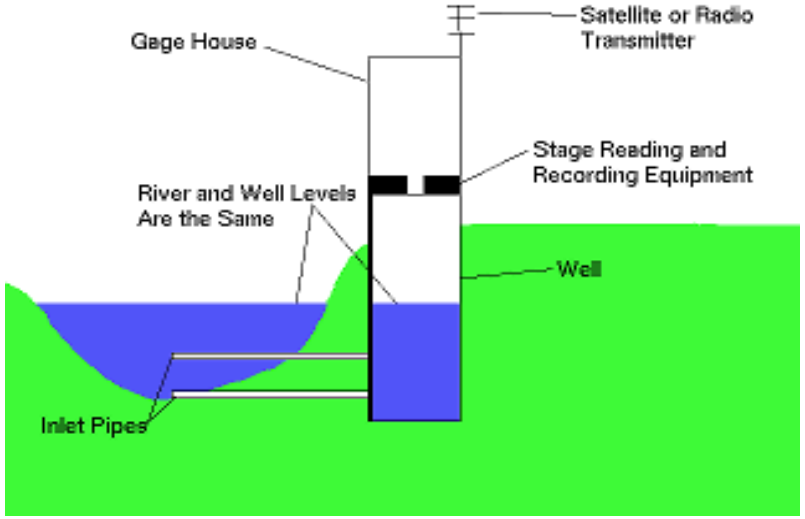
3-dimensional UnTRIM

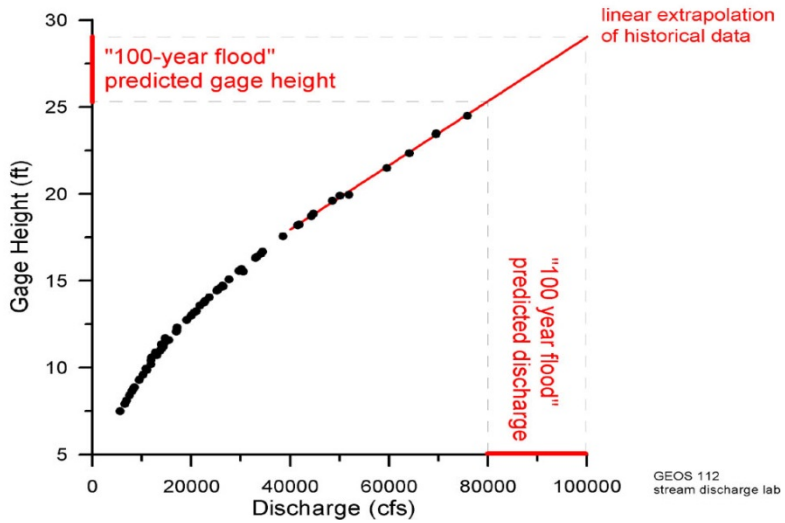
2-dimensional RMA

1-dimension DSM2

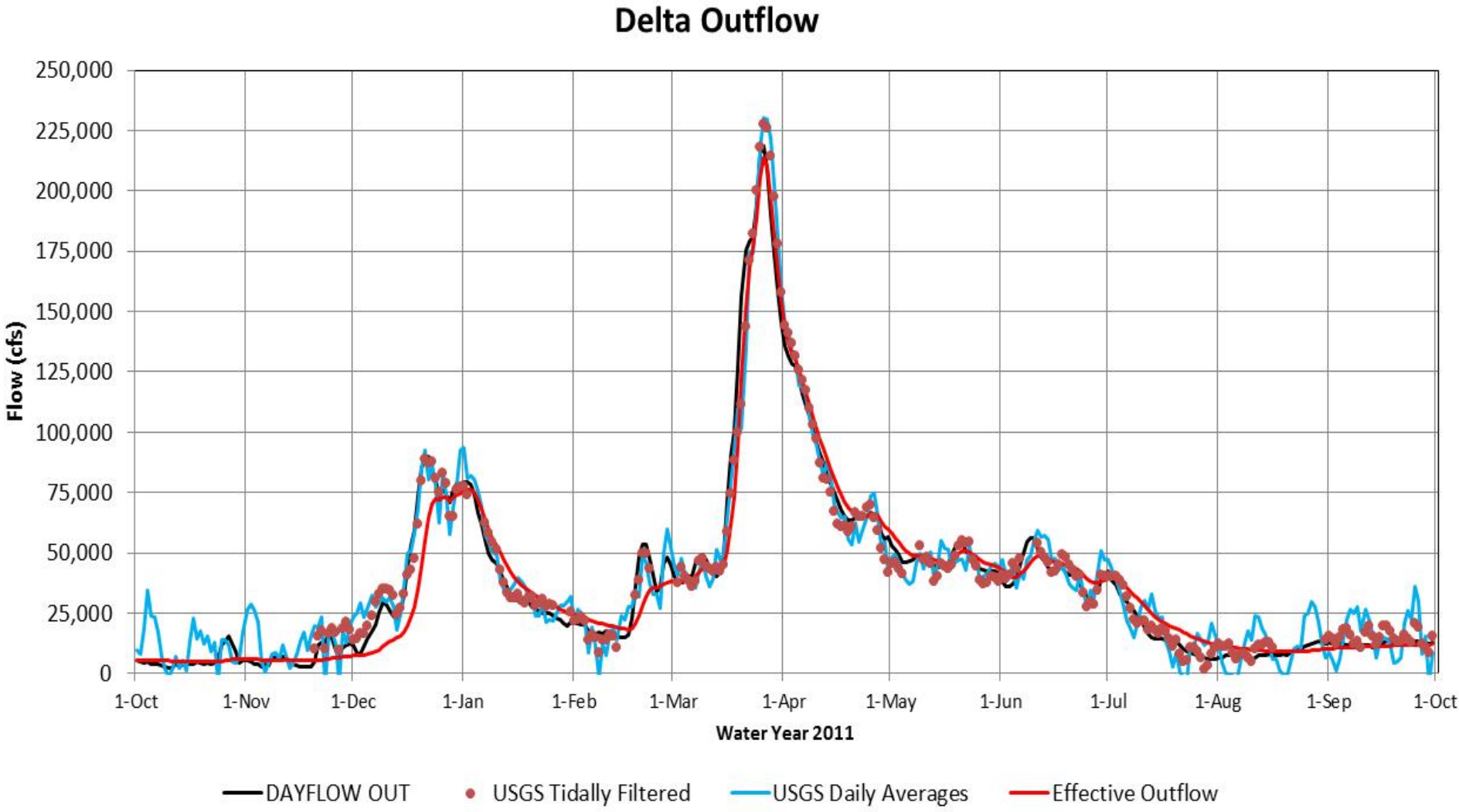
Just as a thermometer indicates the temperature, and just as a stream depth gage indicates the stream flow, so the X2 position indicates the effective outflow of the Central Valley Rivers to the San Francisco Estuary



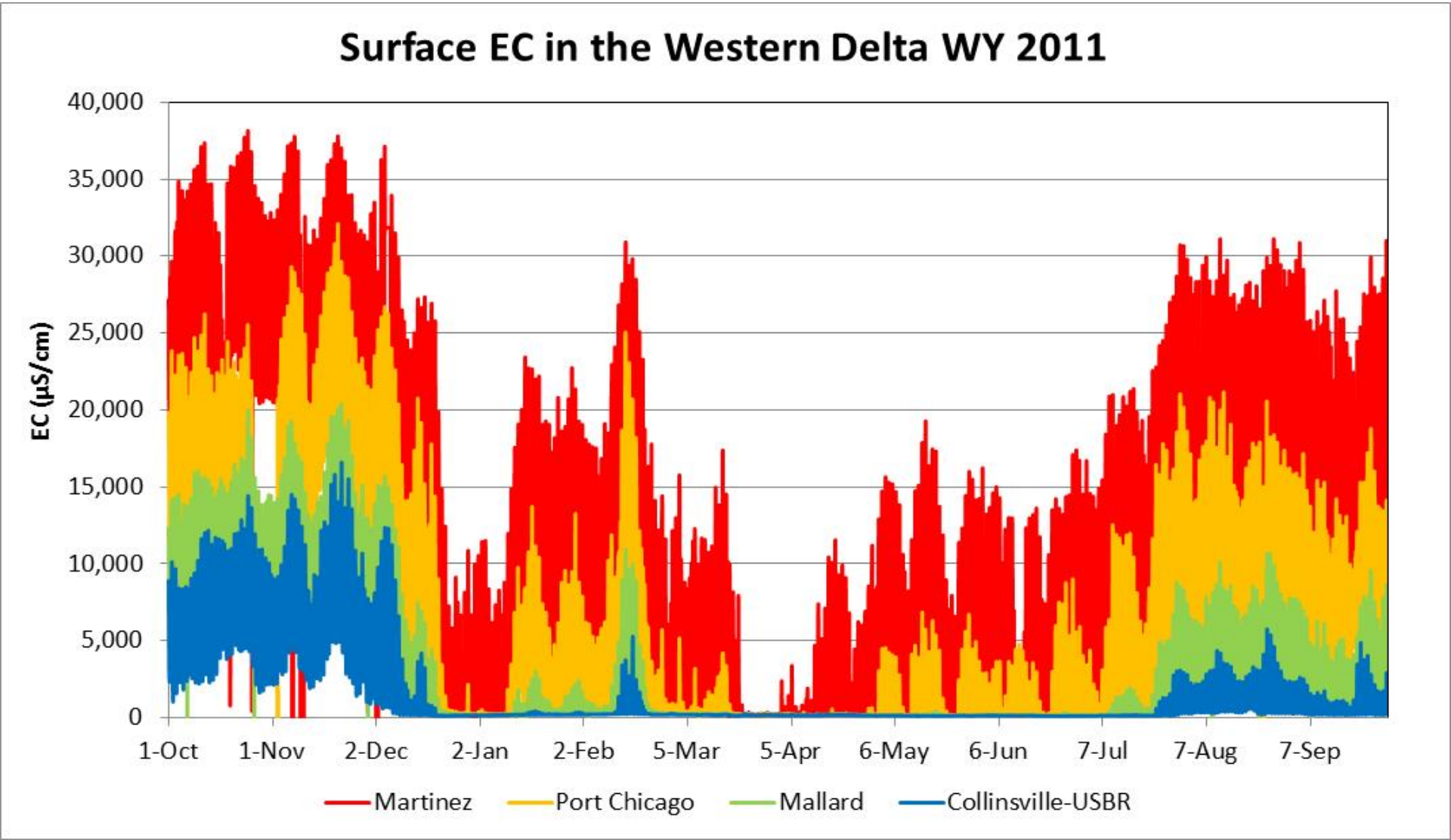




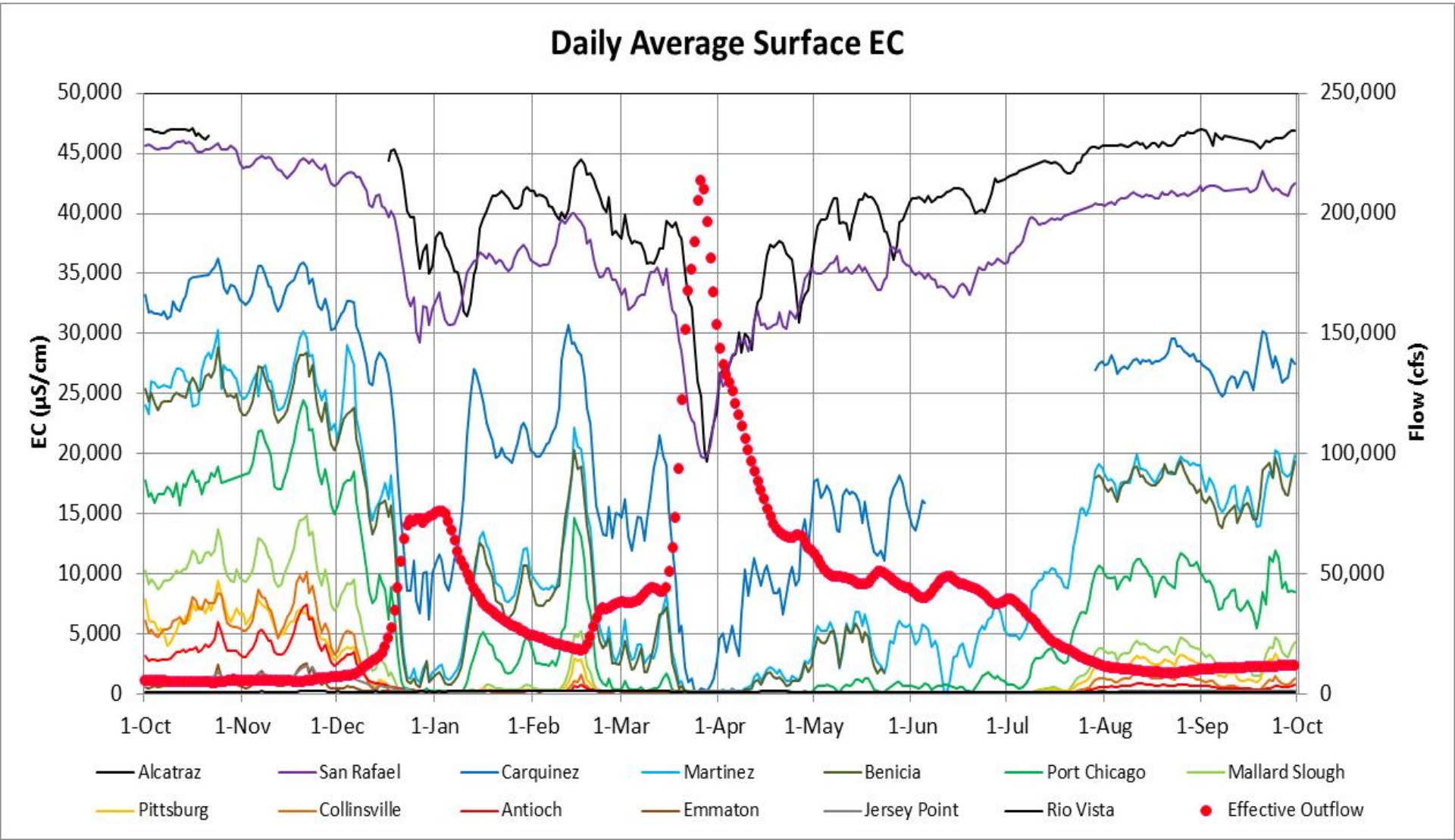
The Salinity Gradient in the SF Estuary is controlled by the channel geometry and the tidal flows and the Delta outflow. The Effective Outflow (volumetric averaging) controls the seawater intrusion.



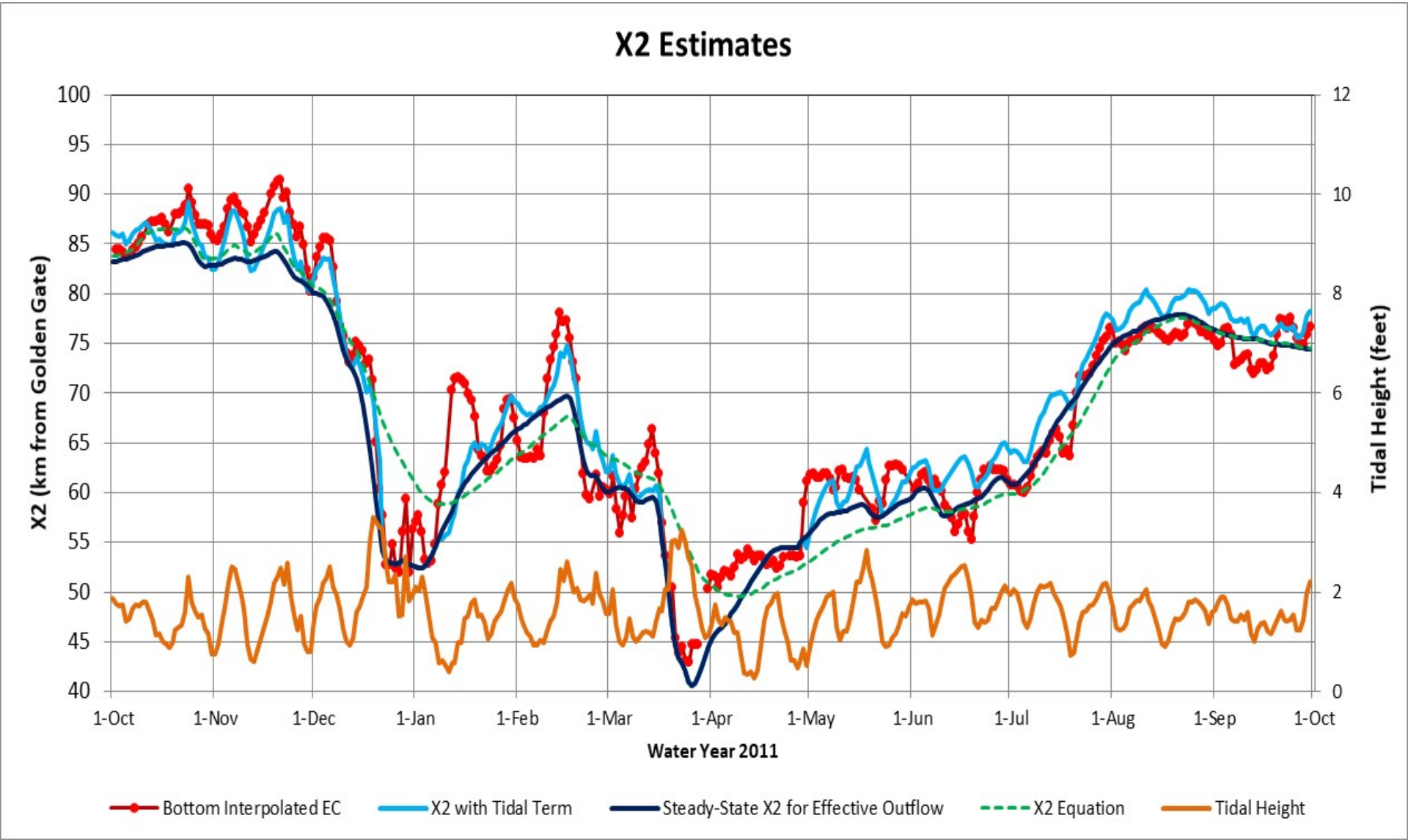
The 15-minute EC data from the Tidal Monitoring Stations shows considerable variation in tidal and seasonal salinity.



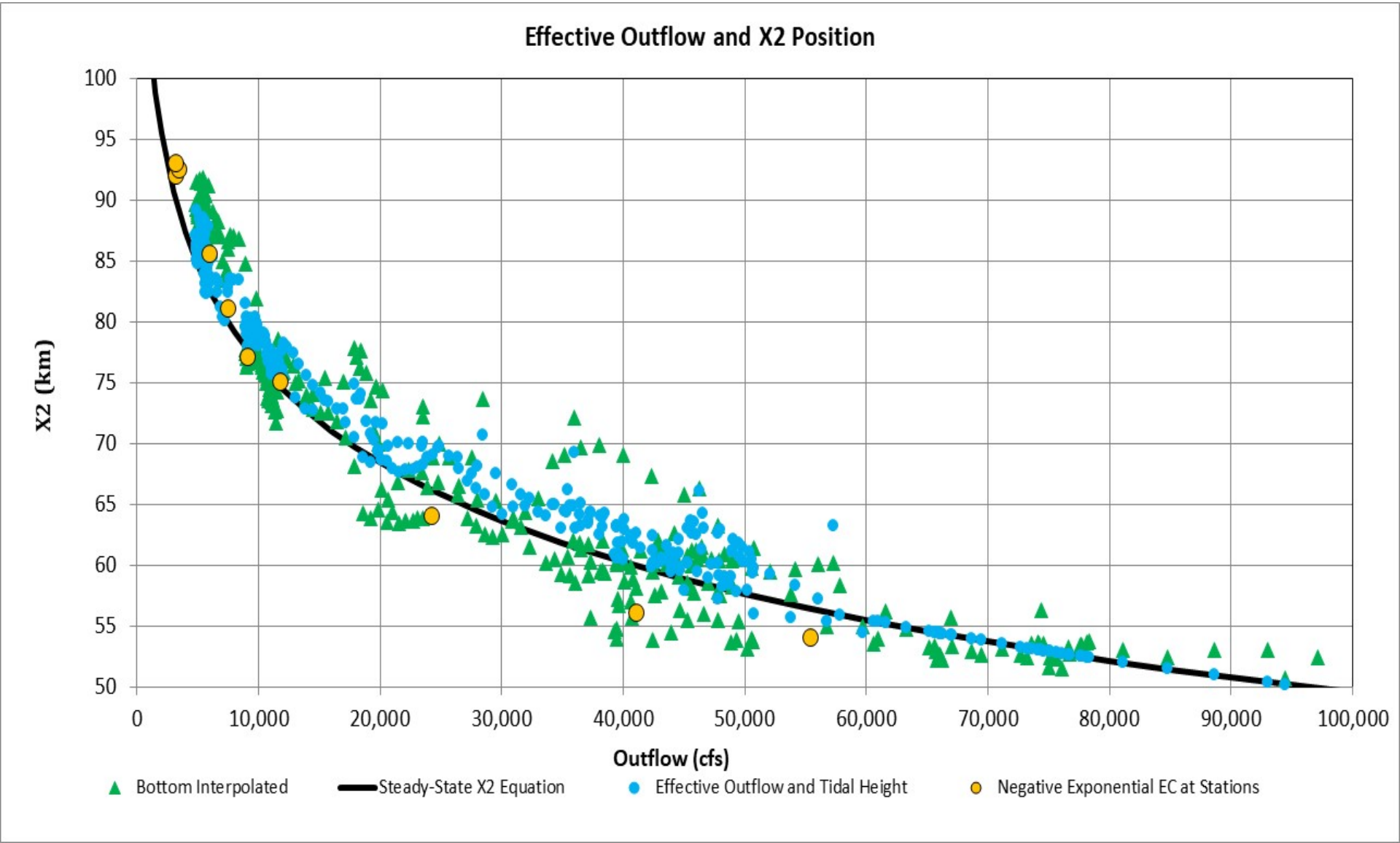
The effective outflow varied from about 5,000 cfs in October and November to about 75,000 at the end of December and to about 200,000 cfs at the end of March. The Estuary salinity responded.



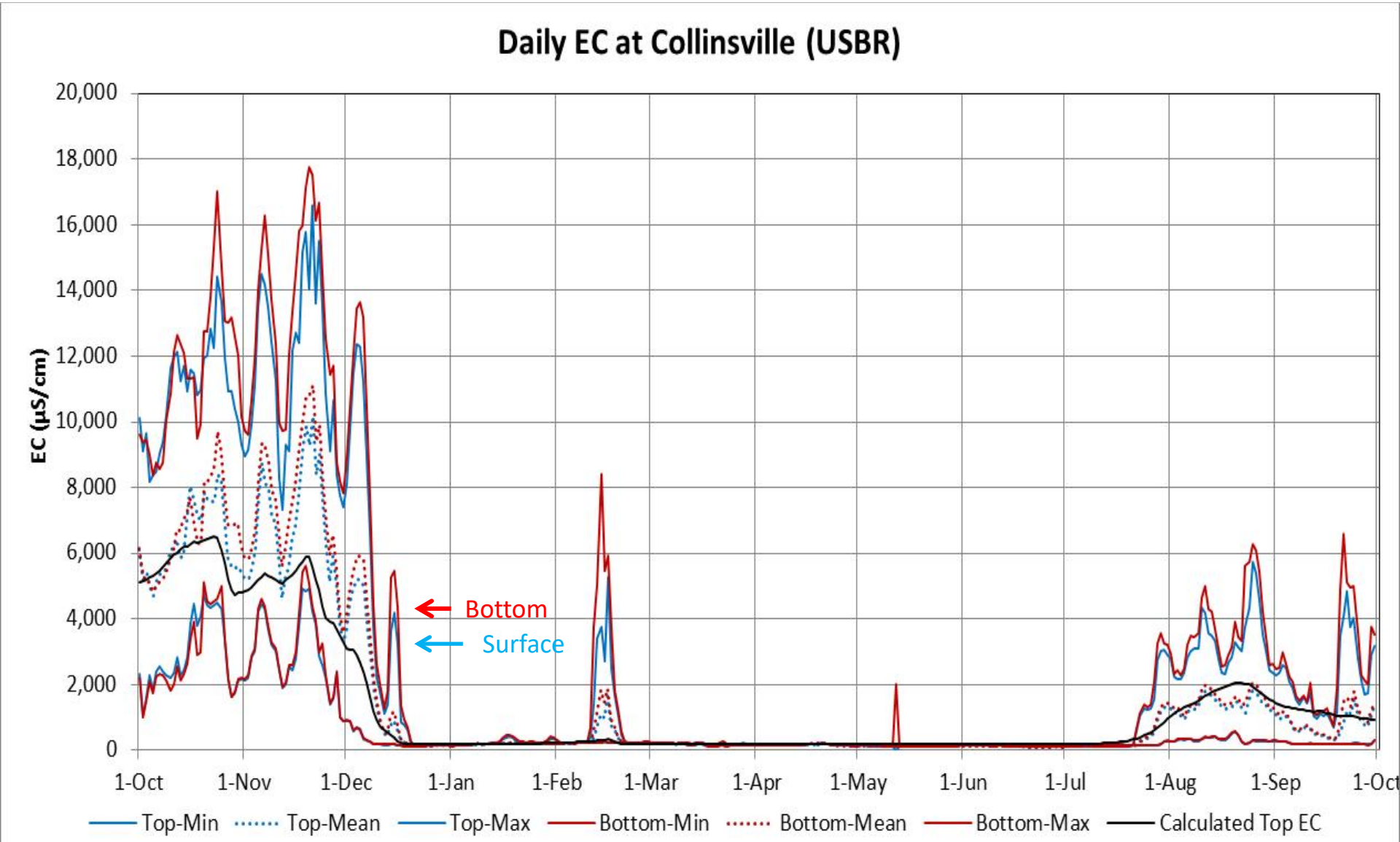
The X2 position can be interpolated from the daily average bottom EC measurements (red dots). The X2 position be estimated from the effective outflow (black line) and a term that increases X2 during spring tides (blue line). The daily X2 equation (dashed green line) does not respond fast enough to outflow changes.



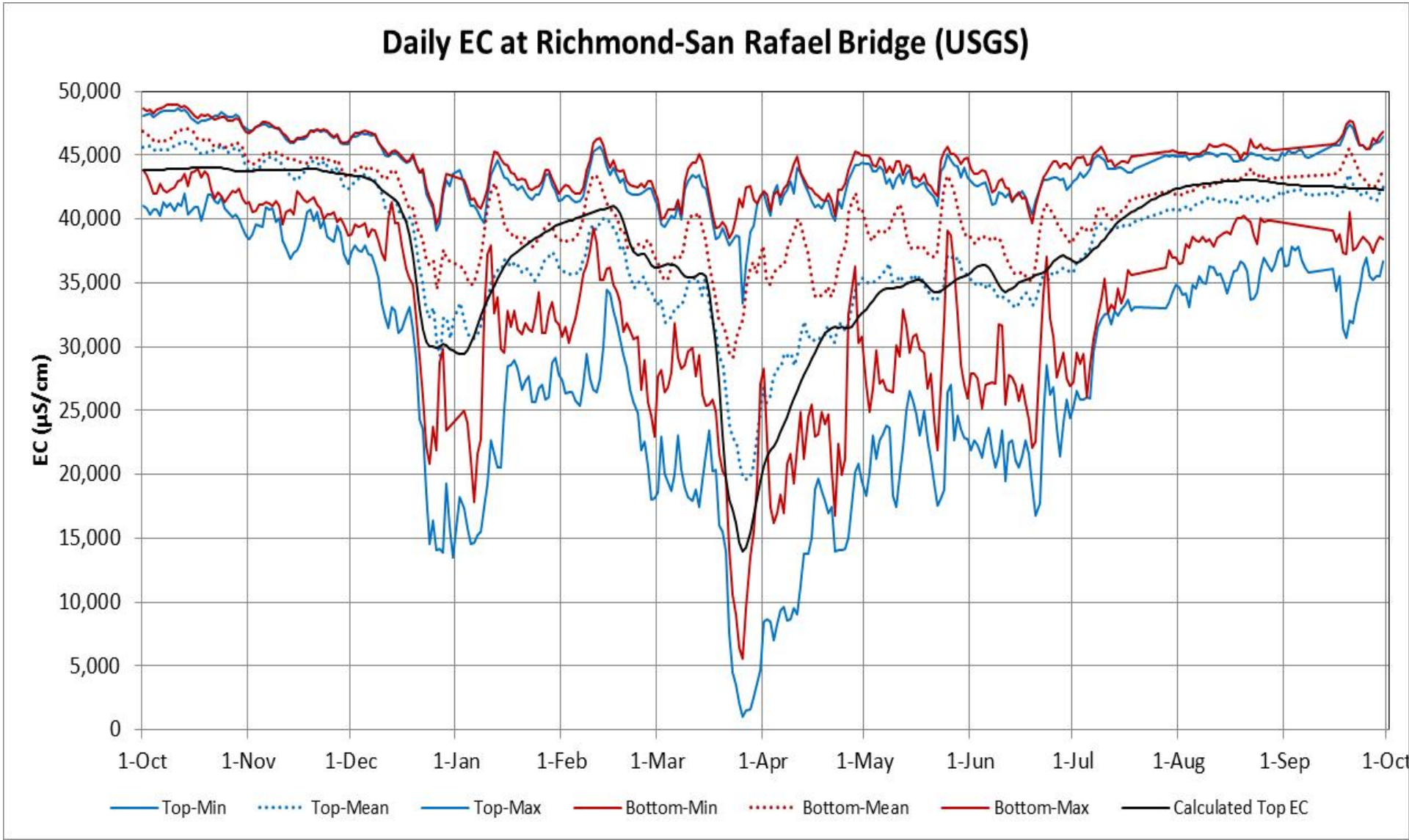
The effective outflow estimates of X2 (black line) can be adjusted to include the effects of higher tides (upstream movement of salinity gradient) during spring tides. The negative exponential EC equations at each station generally match the effective outflow estimate of X2.



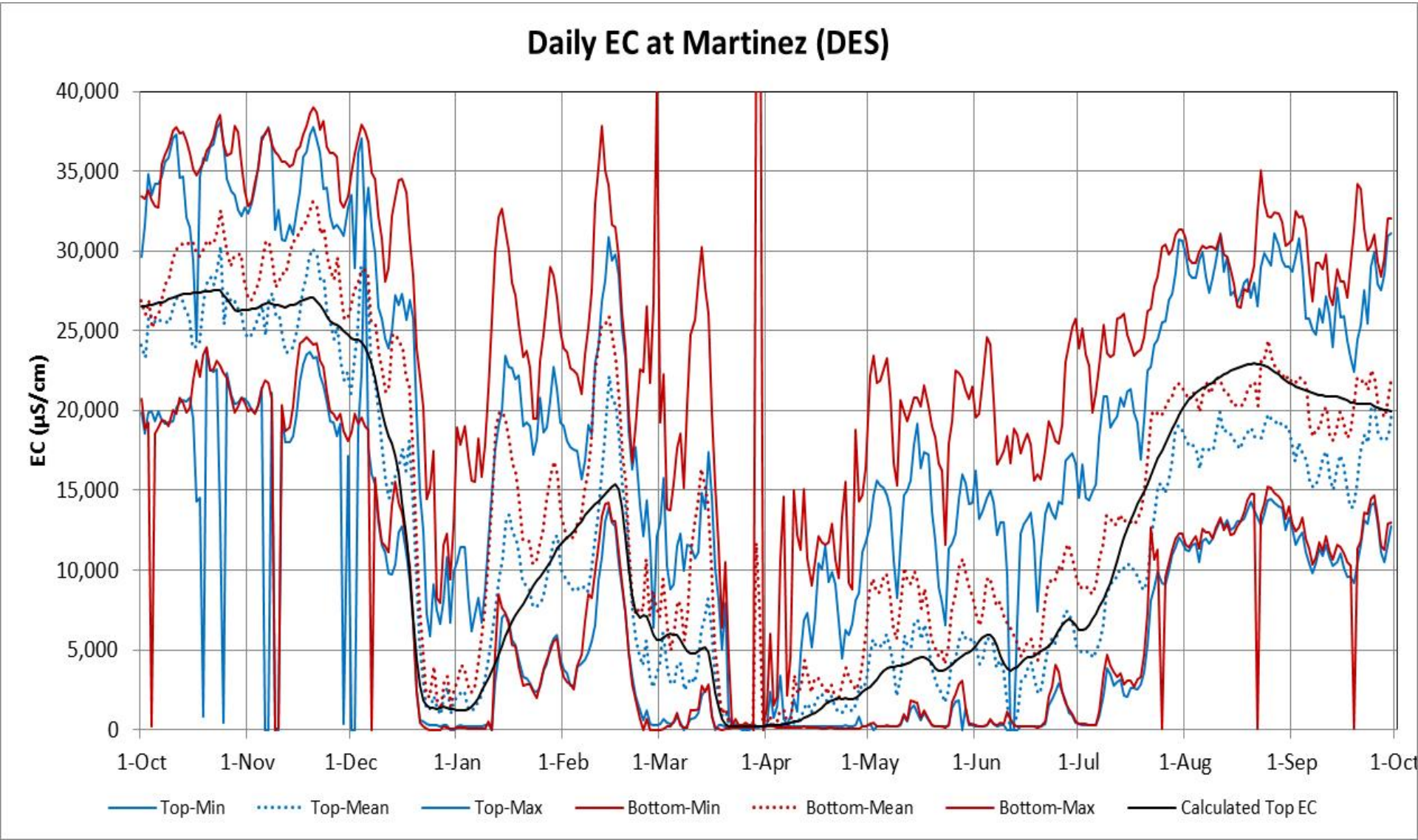
When the daily average bottom EC is 3,800 uS/cm or the daily average surface EC is 2,640 uS/cm, X2 is at the monitoring station location. The daily average EC can be estimated from the effective outflow with a negative exponential equation.



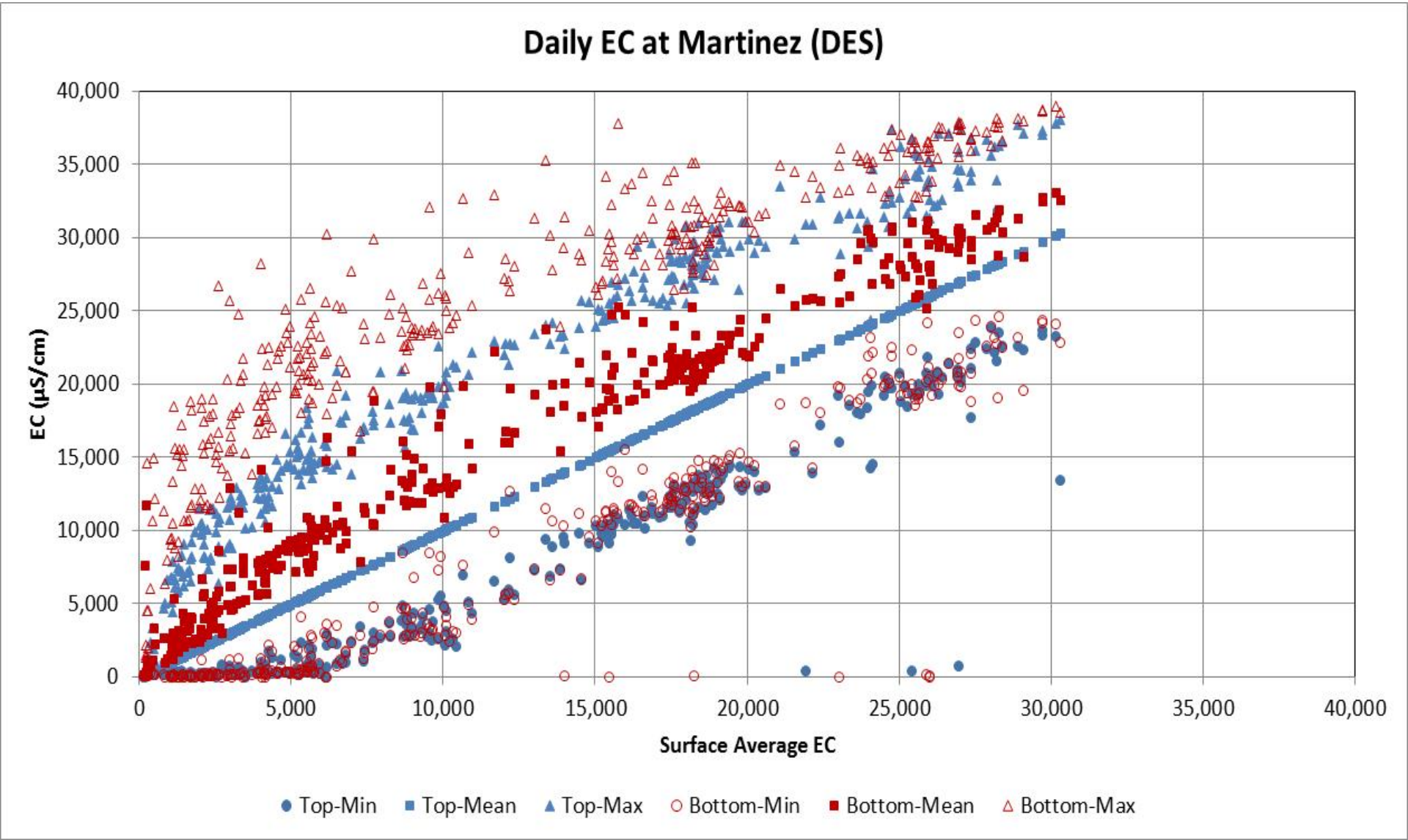
The effects of outflow on EC extend throughout the SF Estuary. The San Rafael Bridge is located 19 km upstream of the Golden Gate.



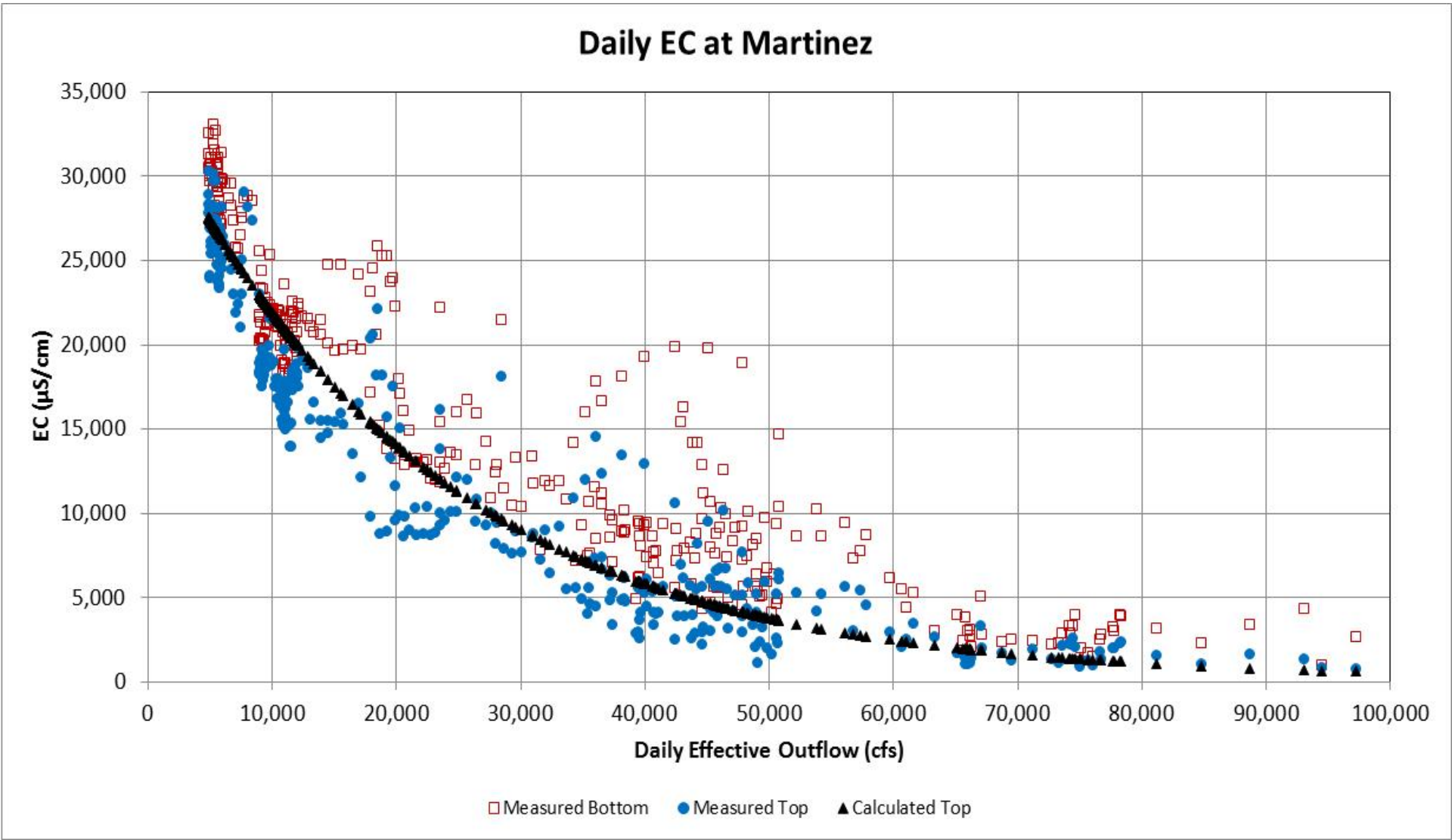
The daily tidal variation in EC at the Martinez Bridge is 15,000 to 20,000 uS/cm. Compared to the maximum salinity gradient of about 1,000 uS/cm per km the tidal excursion can be estimated as 15-20 km.



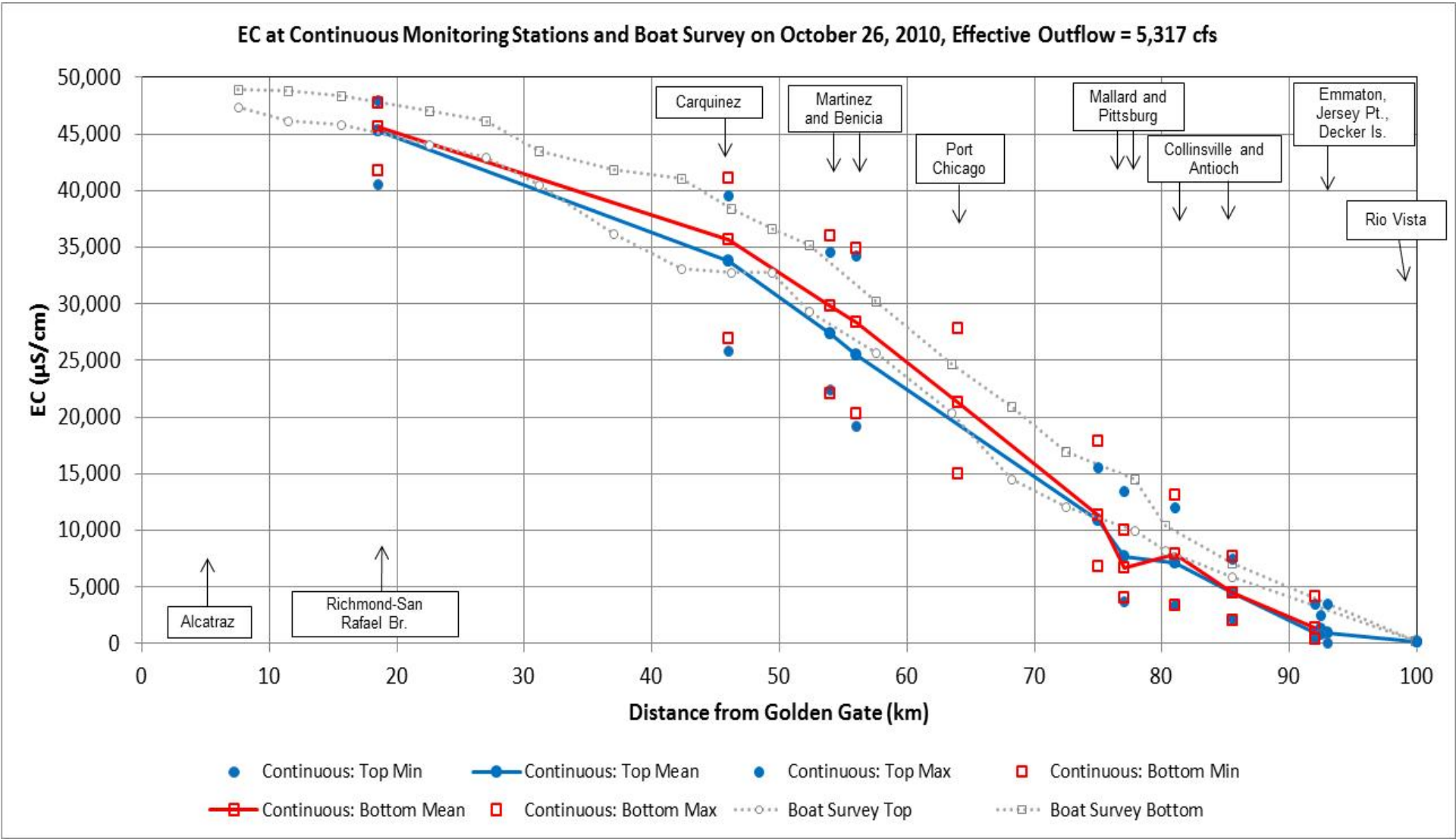
At Martinez, the bottom average EC is generally about 5,000 uS/cm higher than the surface EC. The maximum bottom EC is 5,000-10,000 uS/cm higher than the maximum surface EC.



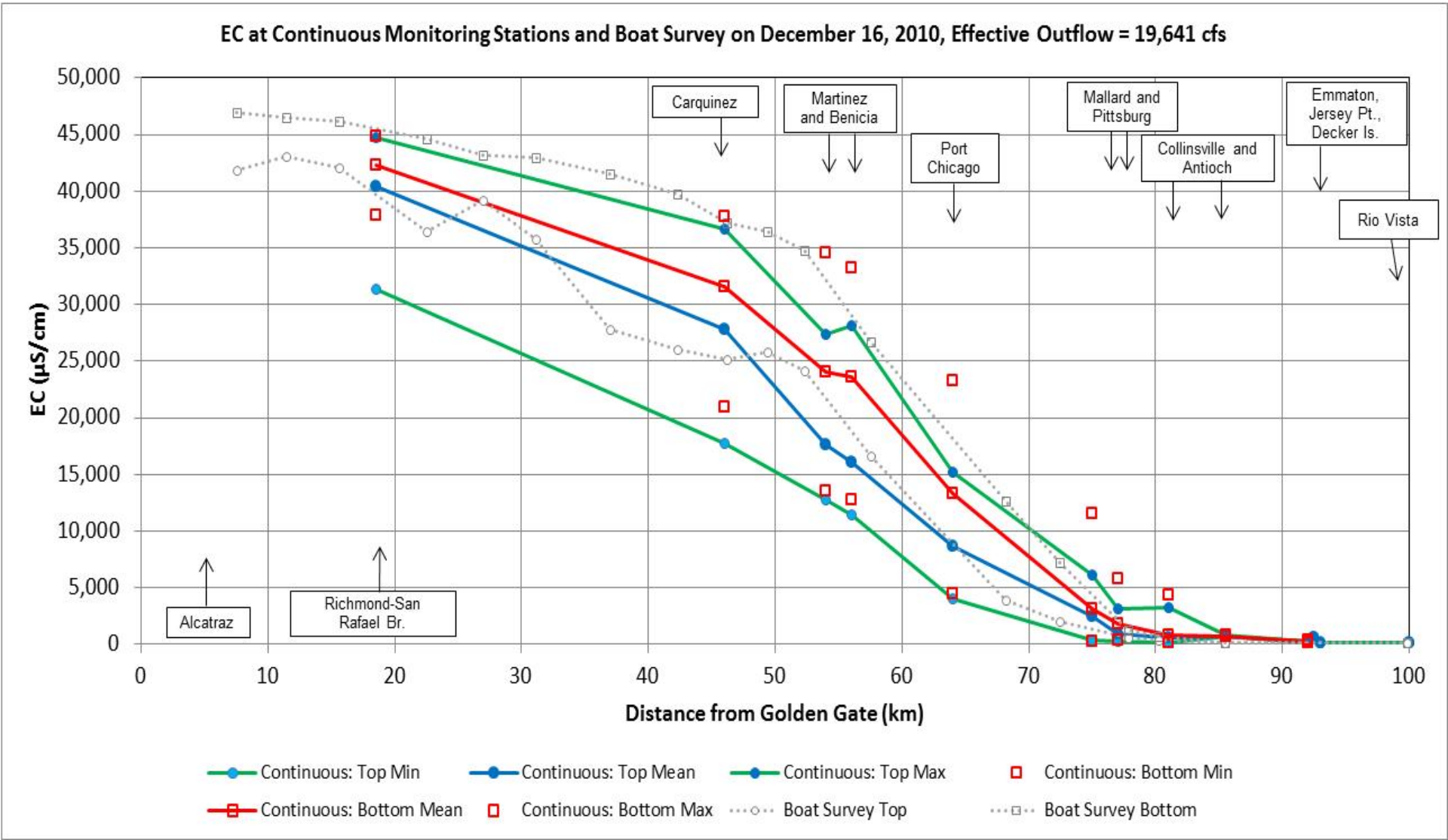
The daily average EC be estimated from effective outflow?. The daily average EC follows a negative exponential relationship. X2 (2,640 uS/cm) is near Martinez (54 km) with an effective outflow of 60,000 cfs.



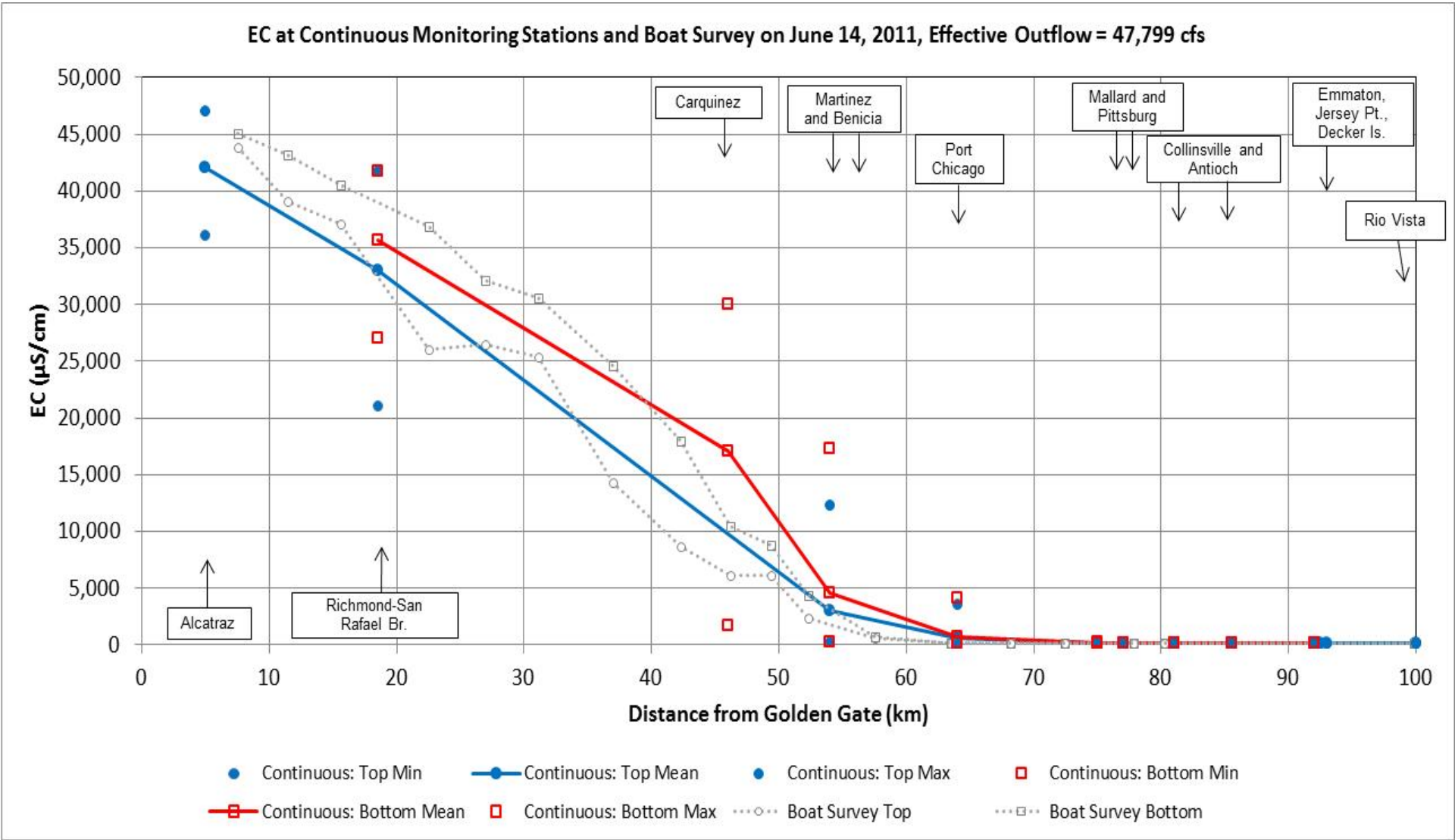
The combination of the EC monitoring stations and the USGS monthly boat surveys provide great information about the salinity gradients in the Estuary. X2 is about 90 km with an effective outflow of 5,000 cfs



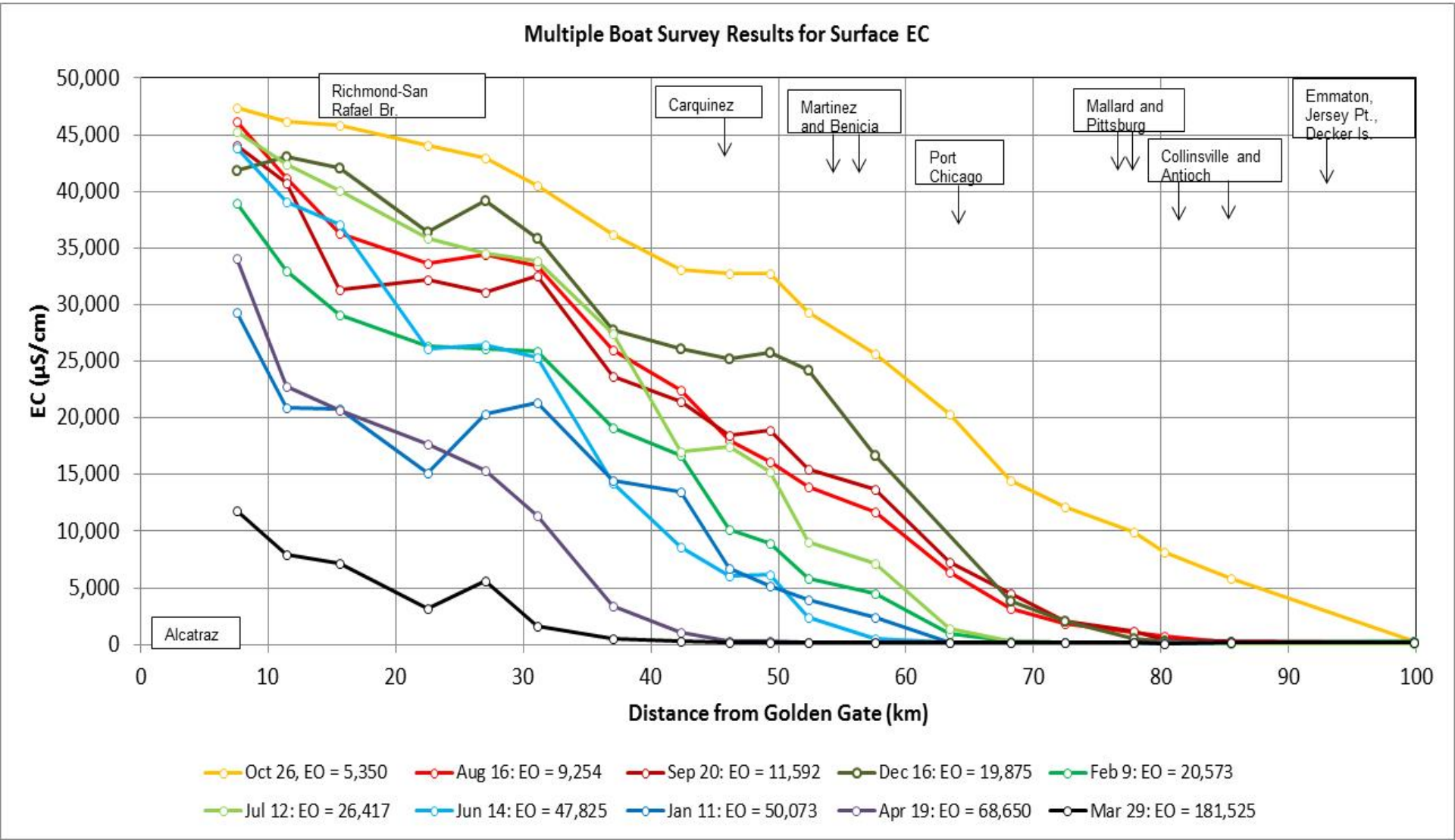
The salinity gradient moved downstream with an effective outflow of 20,000 cfs. X2 was about 75 km. The salinity wedge moved 10-20 km between high tide (high EC) and low tide (low EC)



The salinity gradient moved further downstream with an effective outflow of about 50,000 cfs. X2 is about 55 km. The boat survey data is collected at the different stations at different times during a tidal cycle.



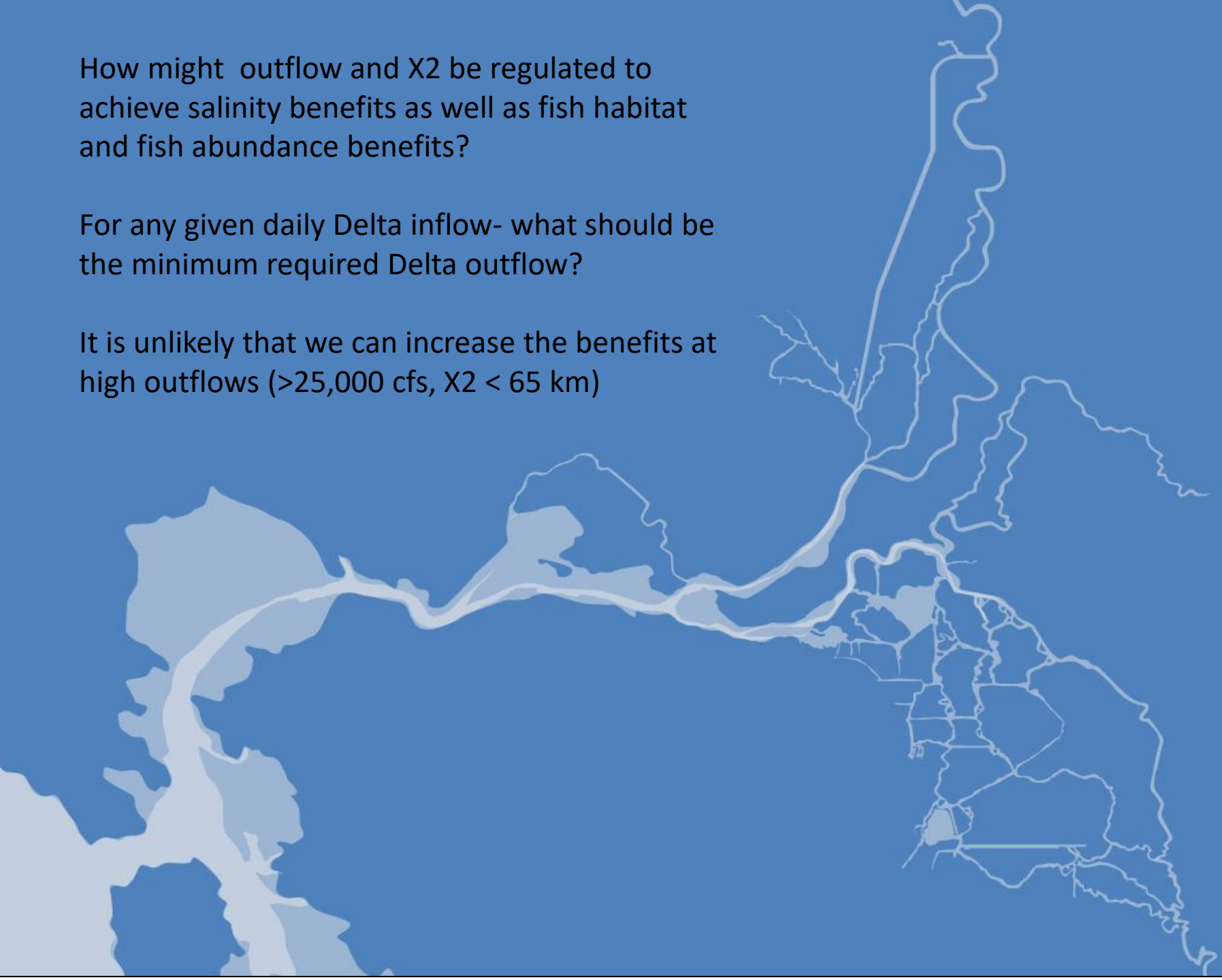
The salinity gradient looks like a salt wedge that is pushed downstream with outflow. But the longitudinal gradient remains about 1,000 uS/cm per km. The maximum salinity at Alcatraz is reduced at high outflow.



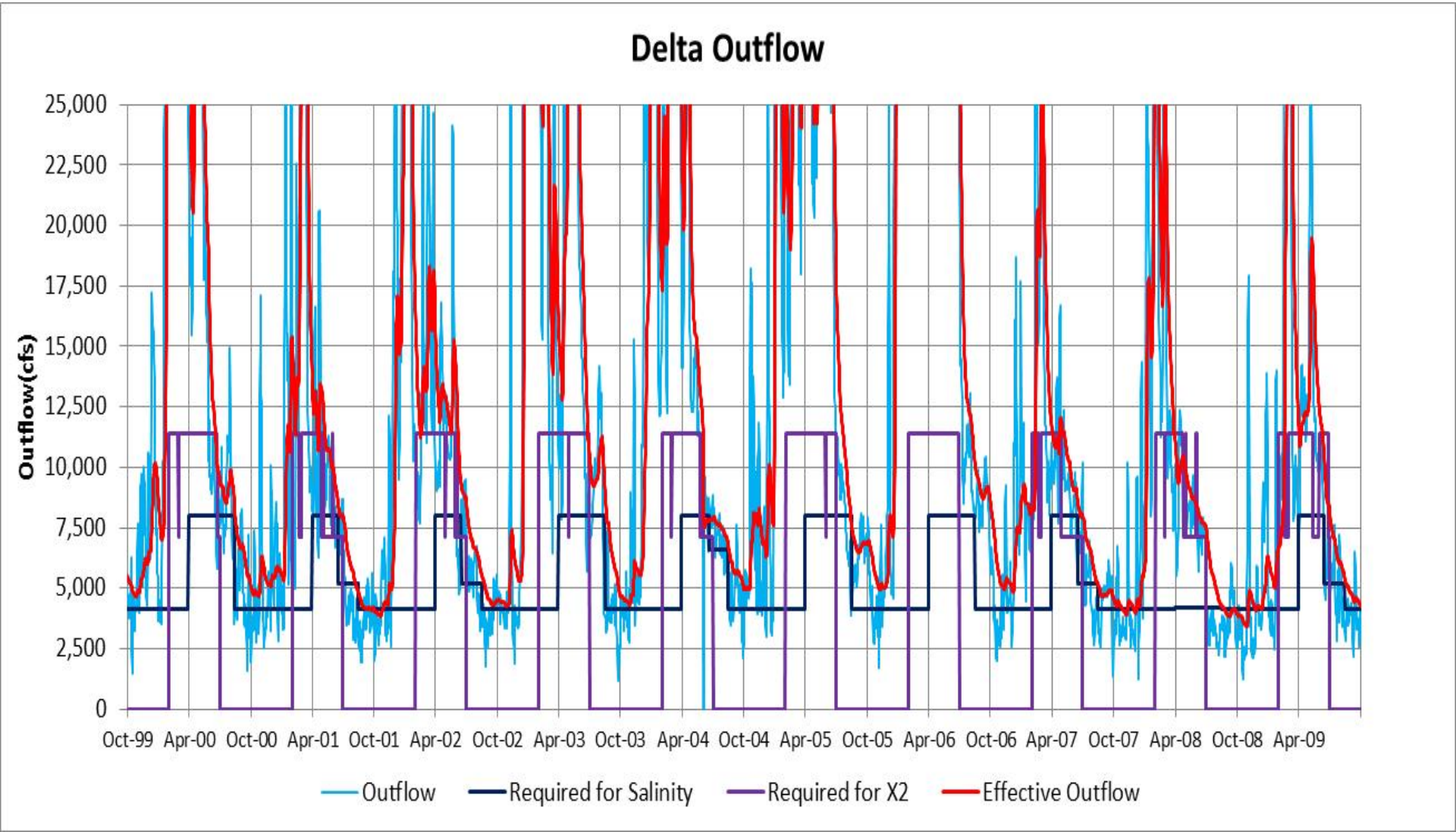
How might outflow and X2 be regulated to achieve salinity benefits as well as fish habitat and fish abundance benefits?

For any given daily Delta inflow- what should be the minimum required Delta outflow?

It is unlikely that we can increase the benefits at high outflows (>25,000 cfs, X2 < 65 km)

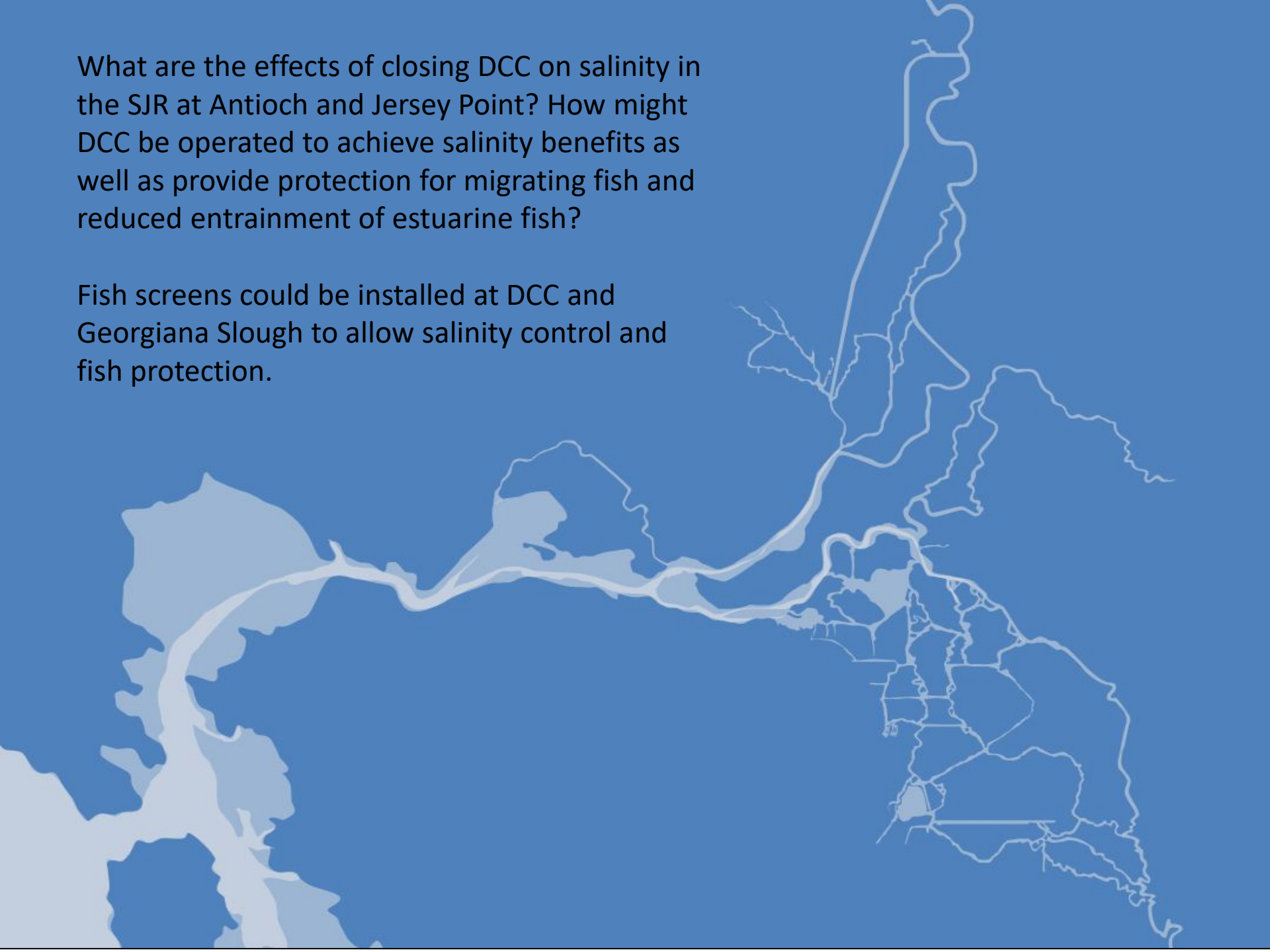


Here is a summary of the daily outflow and effective outflow for WY 2000-2009. The minimum required outflow and the X2-outflow requirements are shown. How often were the outflow and X2 objectives controlling outflow?



What are the effects of closing DCC on salinity in the SJR at Antioch and Jersey Point? How might DCC be operated to achieve salinity benefits as well as provide protection for migrating fish and reduced entrainment of estuarine fish?

Fish screens could be installed at DCC and Georgiana Slough to allow salinity control and fish protection.



Can we identify Delta outflow objectives that are adaptive for the full range of flow conditions?

The “month x water year type” format does not allow the full range of inflows to be regulated for maximum beneficial uses. The E/I objectives are more adaptive than fixed monthly outflows.

An outflow-inflow relationship for each month might provide a more adaptive framework for X2 objectives.