Delaware River Basin Commission

EFDC Model Development and Simulations

Fanghui Chen, PhD. , P.E.
Senior Water Resource Engineer

Team:

Water Resource Operations

Science and Water Quality Assessment

Presented to Water Quality Advisory Committee

July 28, 2020

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

EFDC 3-D Hydrodynamics Model Development

ongoing work since November 2019

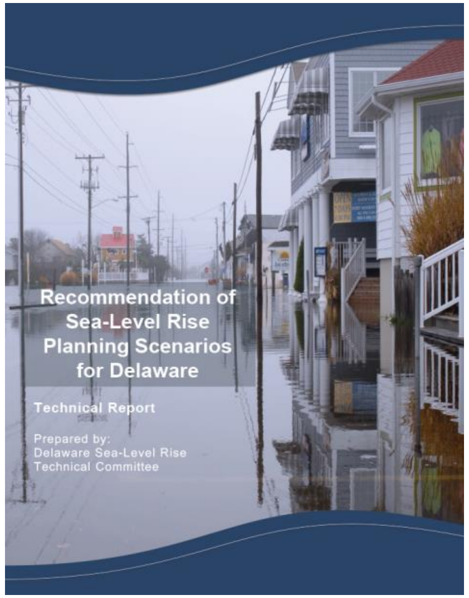
Model refinements and re-calibration

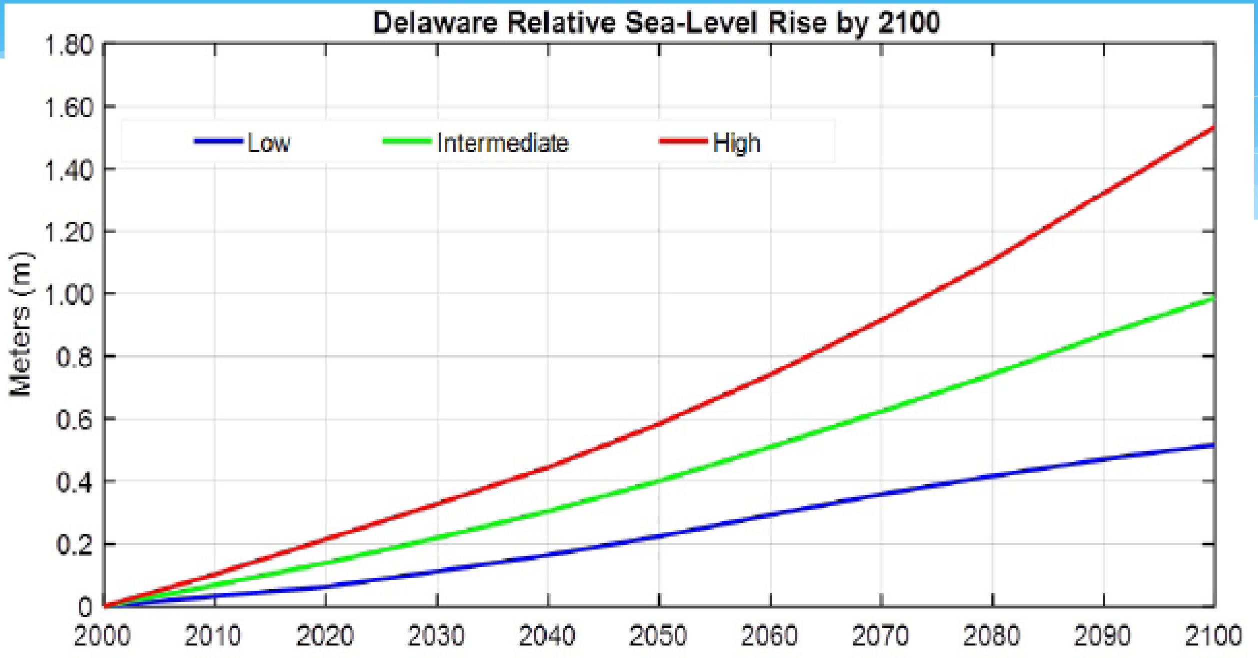
Sea level rise simulations

Sea level rise and increased flow simulations

Sea Level Rise Projections

Technical Report (2017)
Prepared by:
Delaware Sea-Level Rise Technical Committee.
Recommendation of Sea-Level Rise Planning Scenarios for Delaware (2017)





The Low, Intermediate and High planning scenarios correspond with the 5%, 50%, and 95% probability levels, under the IPCC AR5 RCP 8.5 emission scenario

Year	Delaware SLR Planning Scenarios		
	Low	Intermediate	High
2030	0.11 m / 0.36 ft	0.22 m / 0.72 ft	0.33 m / 1.08 ft
2050	0.22 m / 0.72 ft	0.40 m / 1.31 ft	0.58 m / 1.90 ft
2080	0.42 m / 1.38 ft	0.74 m / 2.43 ft	1.11 m / 3.64 ft
2100	0.52 m / 1.71 ft	0.99 m / 3.25 ft	1.53 m / 5.02 ft

SLR Scenario Simulations

- Three dimensional EFDC model was refined
- SLR modeling approach and assumptions – *Relative change in SL w.r.t. channel bottom*
- Simulations
  - SLR – (0, 0.3, 0.5, 1.0, 1.6 m)
  - Representative range of hydrologic conditions (10 years: *1964-1965, 2001-2002, 2011-2013, 2017-2019*)
  - One representative dry year (2002) under SLR conditions and with increased freshwater inflows (500 or 1,000 cfs for 2 months)

SLR and flow sensitivity simulations to develop basic understanding

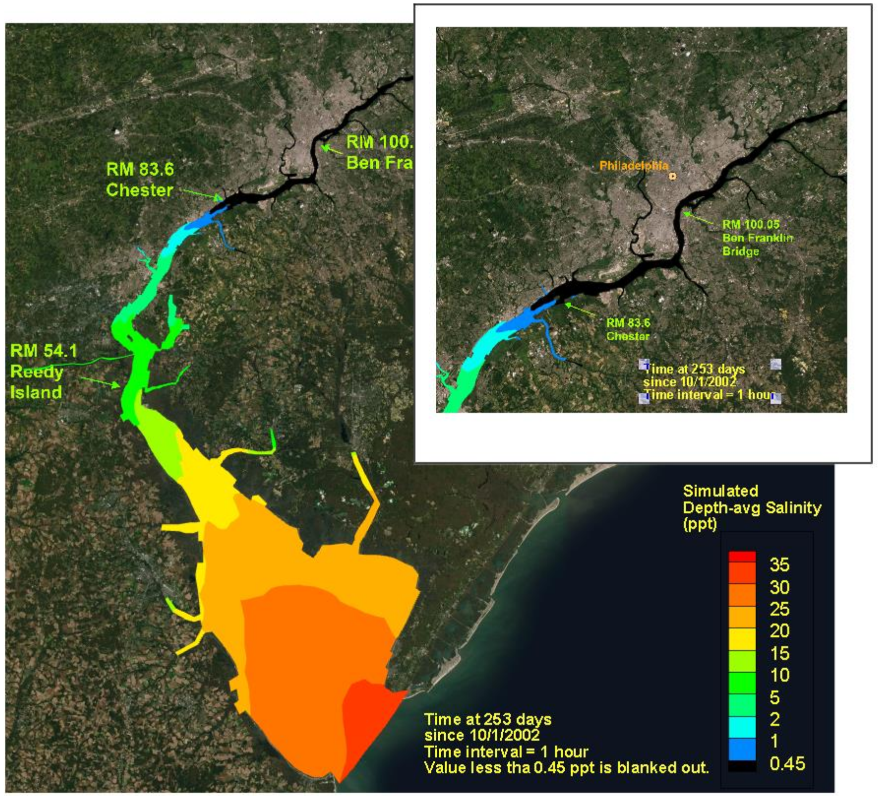
Example: 2002 hydrology with 1.6 m SLR

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

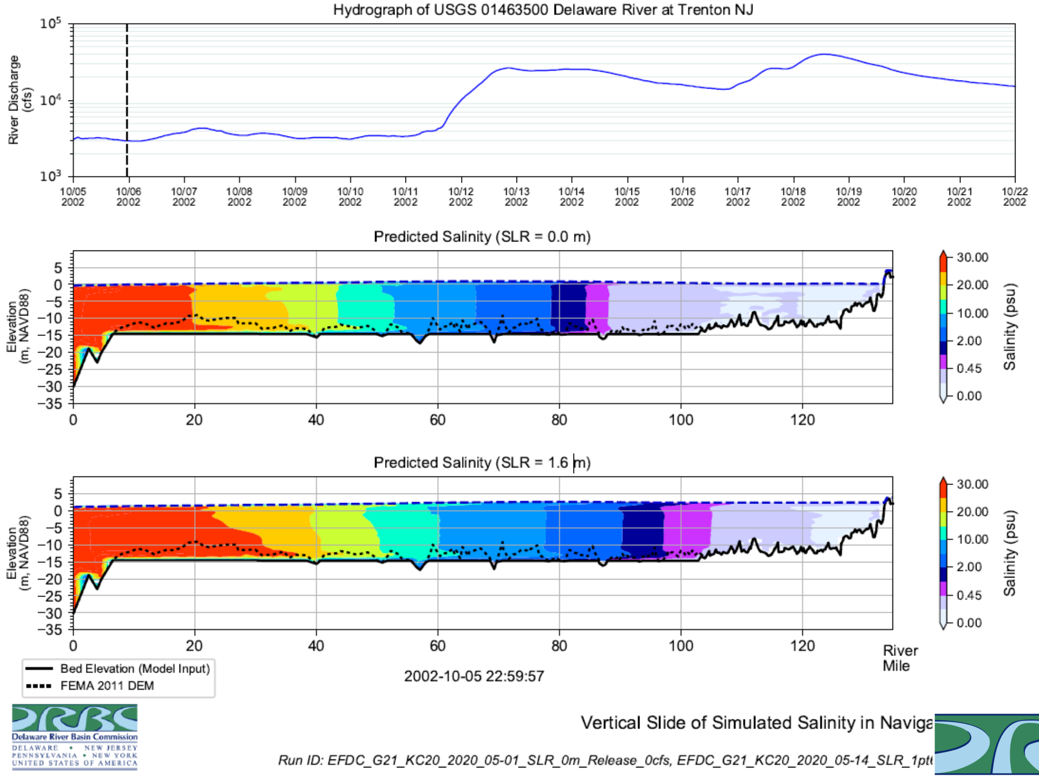
Animations

Simulation of 1.6 m of Sea Level Rise and with hydrological conditions from October 2002

Depth-averaged

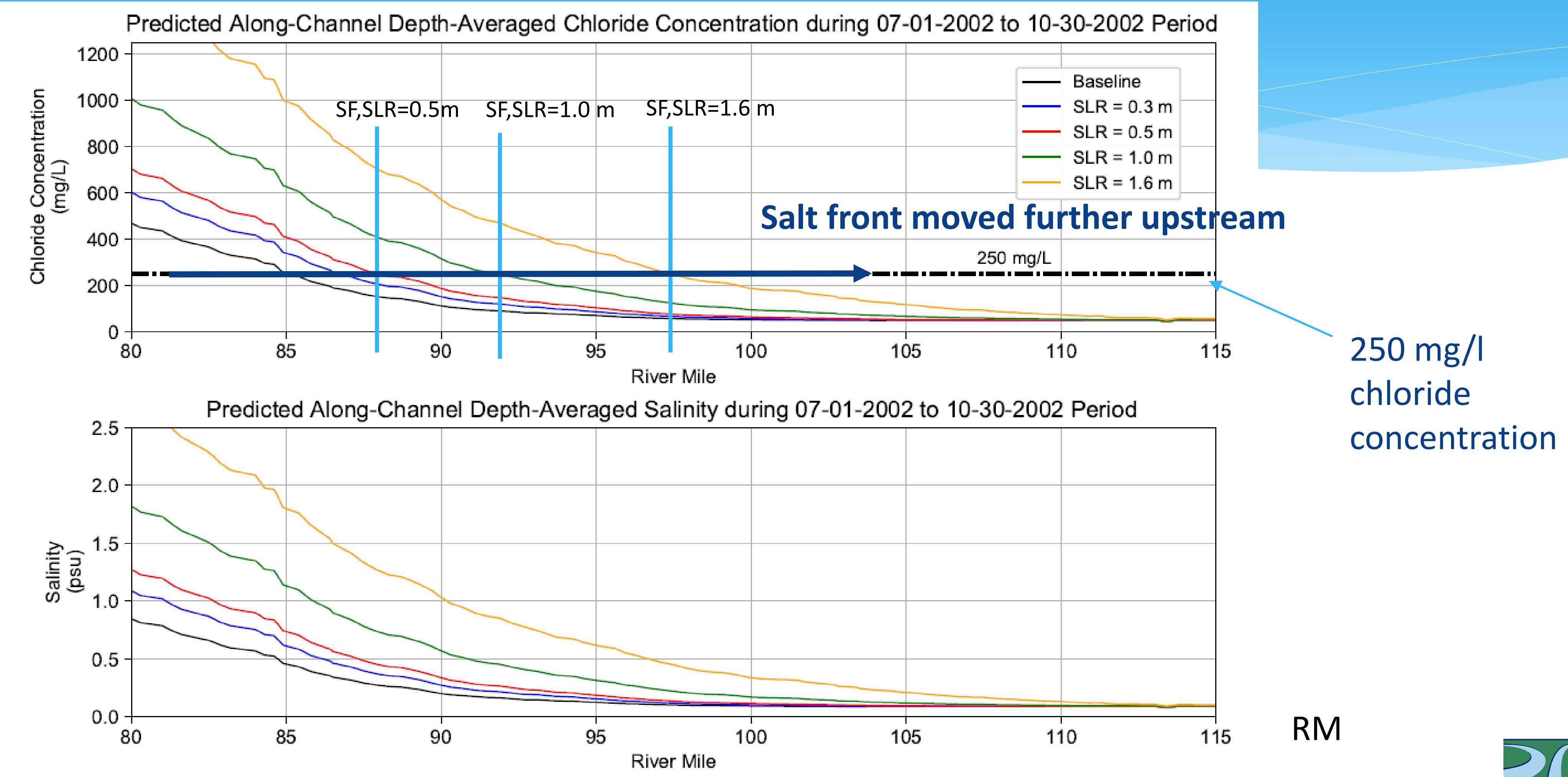


Vertical Profile



Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Change in Tidally-Averaged Salinity Profiles (Upstream of RM 80)



Simulated tidally-averaged salinity profiles indicate that as sea level rises, the saltwater intrusion moves farther upstream.

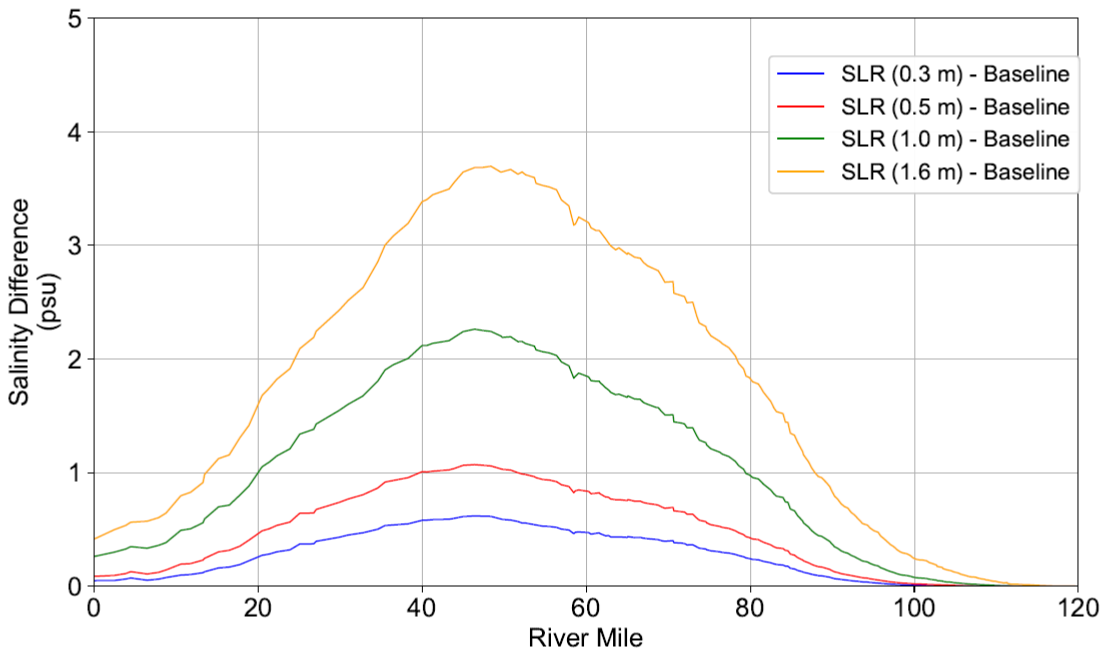
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Differences in Salinity along the Delaware Bay and Estuary

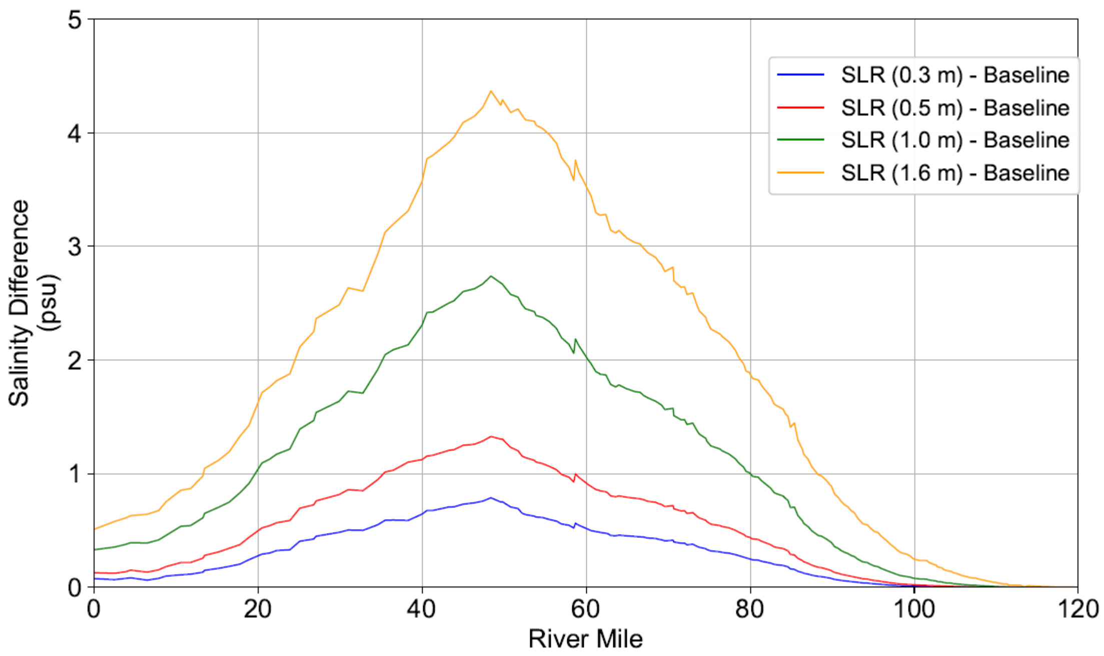
Simulations with hydrology from July - October, 2002

Differences in tidally averaged salinity over the four-month period

Change in Depth-averaged Salinity



Change in Near-bottom Salinity

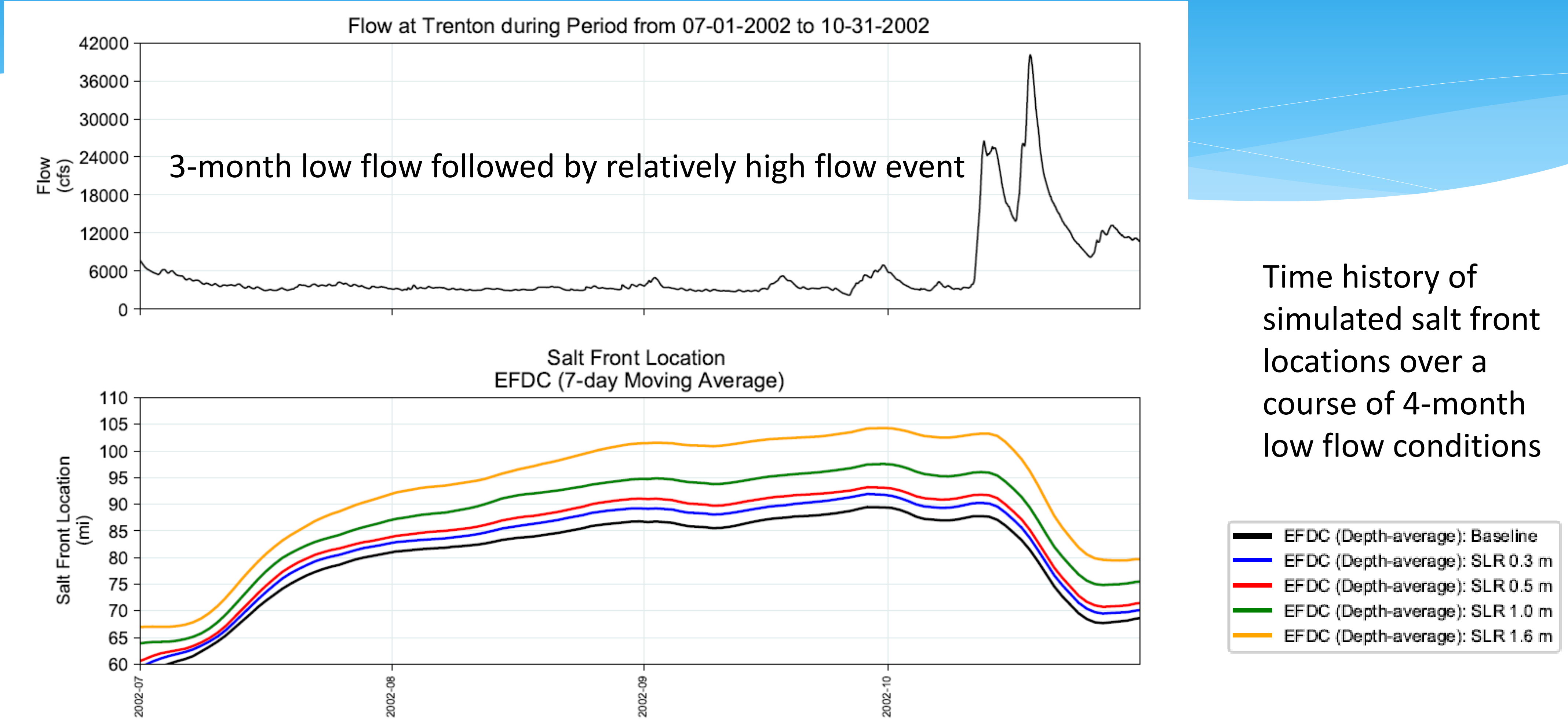


Ocean → Toward Trenton

The largest increase in salinity (1 to 4 ppt) occurs near RM 45 to 55, which may have significant impact on the health of the oyster habitats upstream of Ship John Shoal area.

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Time Series of the Salt Front Location during a Dry Period



Time history of simulated salt front locations over a course of 4-month low flow conditions

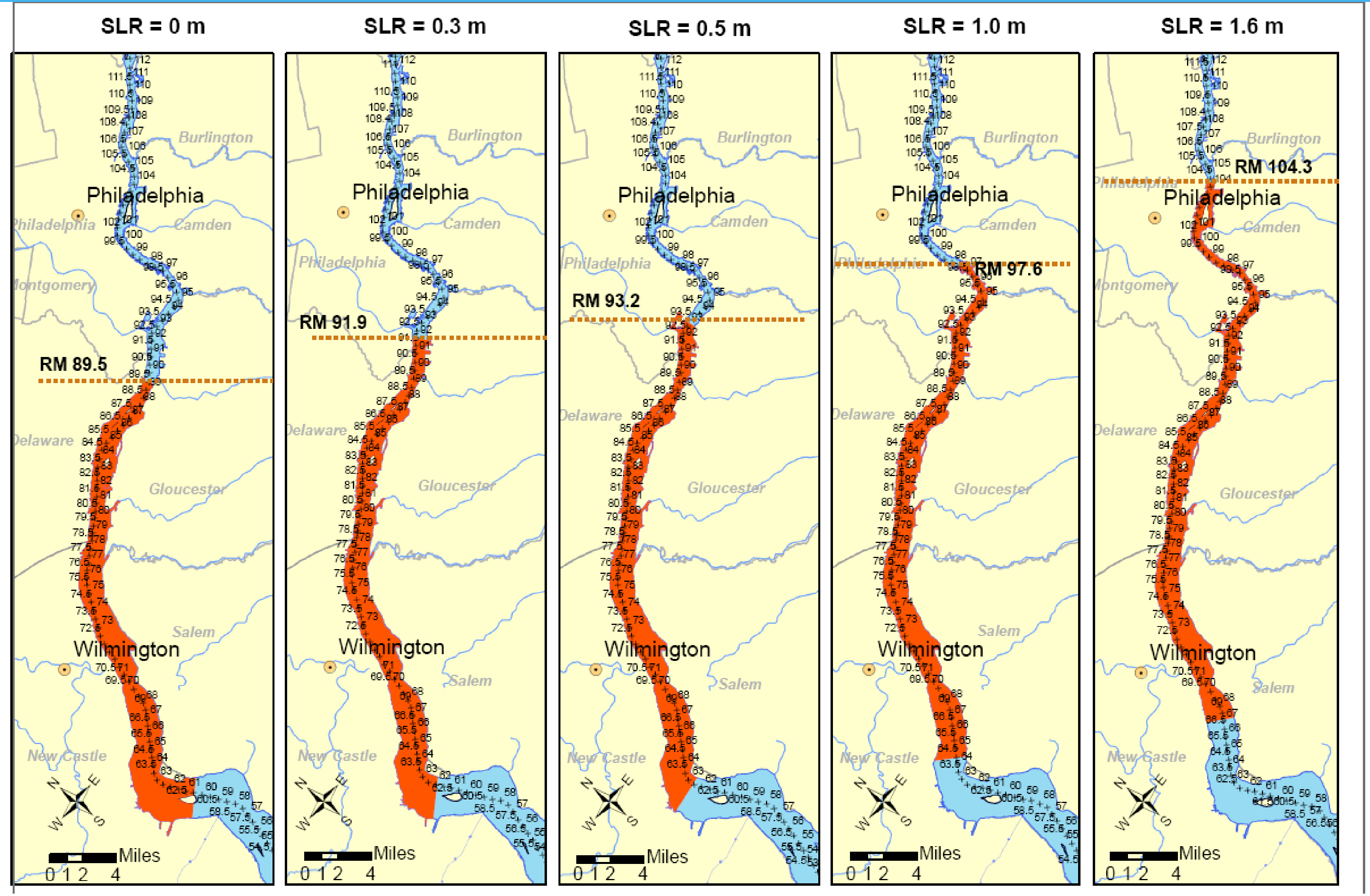
During a prolonged low-flow period (similar to that of 2002) and SLR of 1.0 m or higher, the salt front may move upstream of RM 92.5 (mouth of Schuylkill River) and remain there for a month or longer.

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Range of Salt Front during a Dry Period

Simulated salt front locations during 4-months of low flow conditions

With SLR of 0.5 m or higher, the range of salt front may pass the Schuylkill River with low flow conditions similar to those of 2002.



Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Range of Salt Front for Different SLR

Simulation of 2002 Dry Conditions

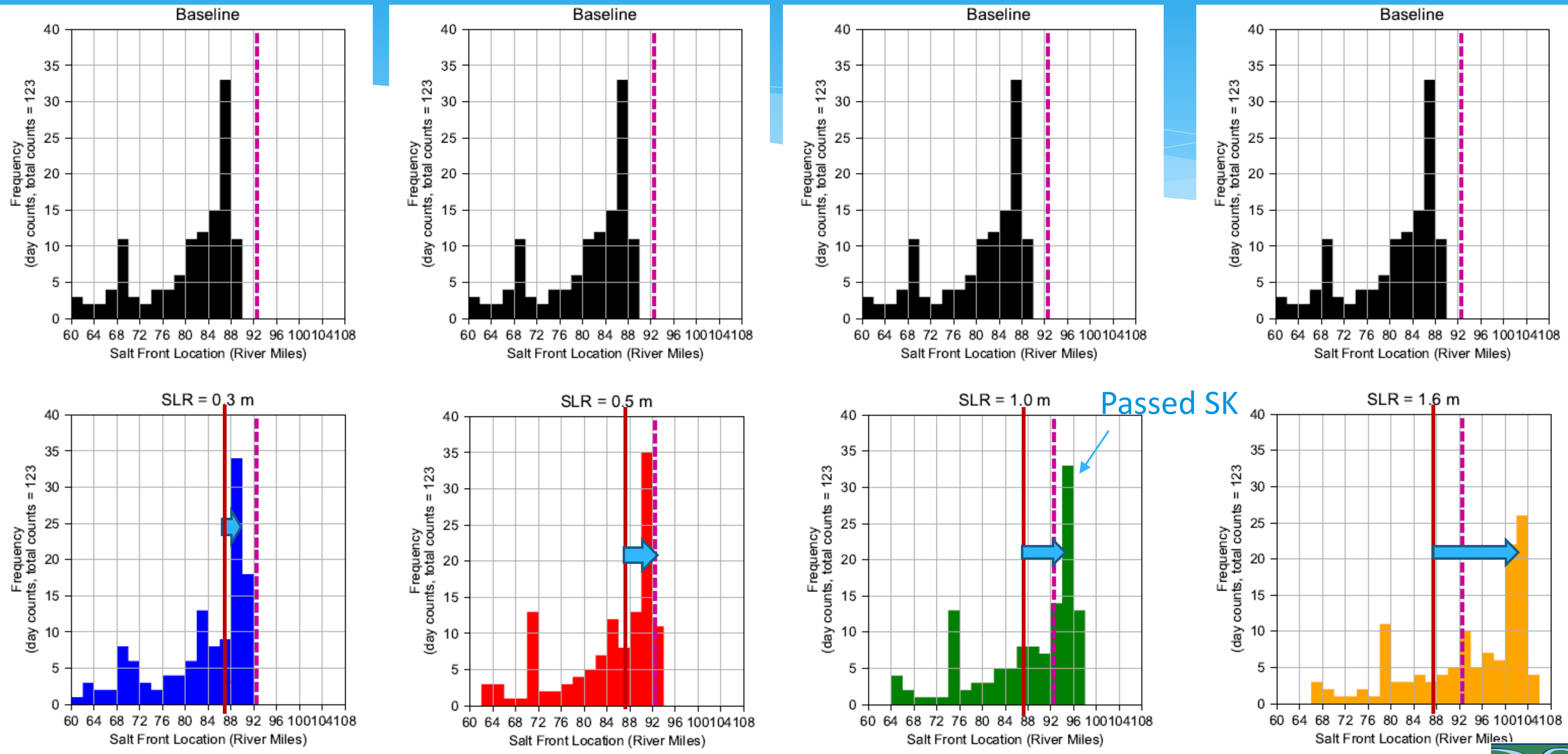
SLR (m)	Min	Max	Average
0	60.53	89.47	80.69
0.3	61.89	91.92	82.78
0.5	62.60	93.19	84.18
1	64.39	97.56	87.83
1.6	67.14	104.30	93.40

Simulated salt front locations during 4-months of low flow conditions

Simulated seven-day moving average salt front location

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

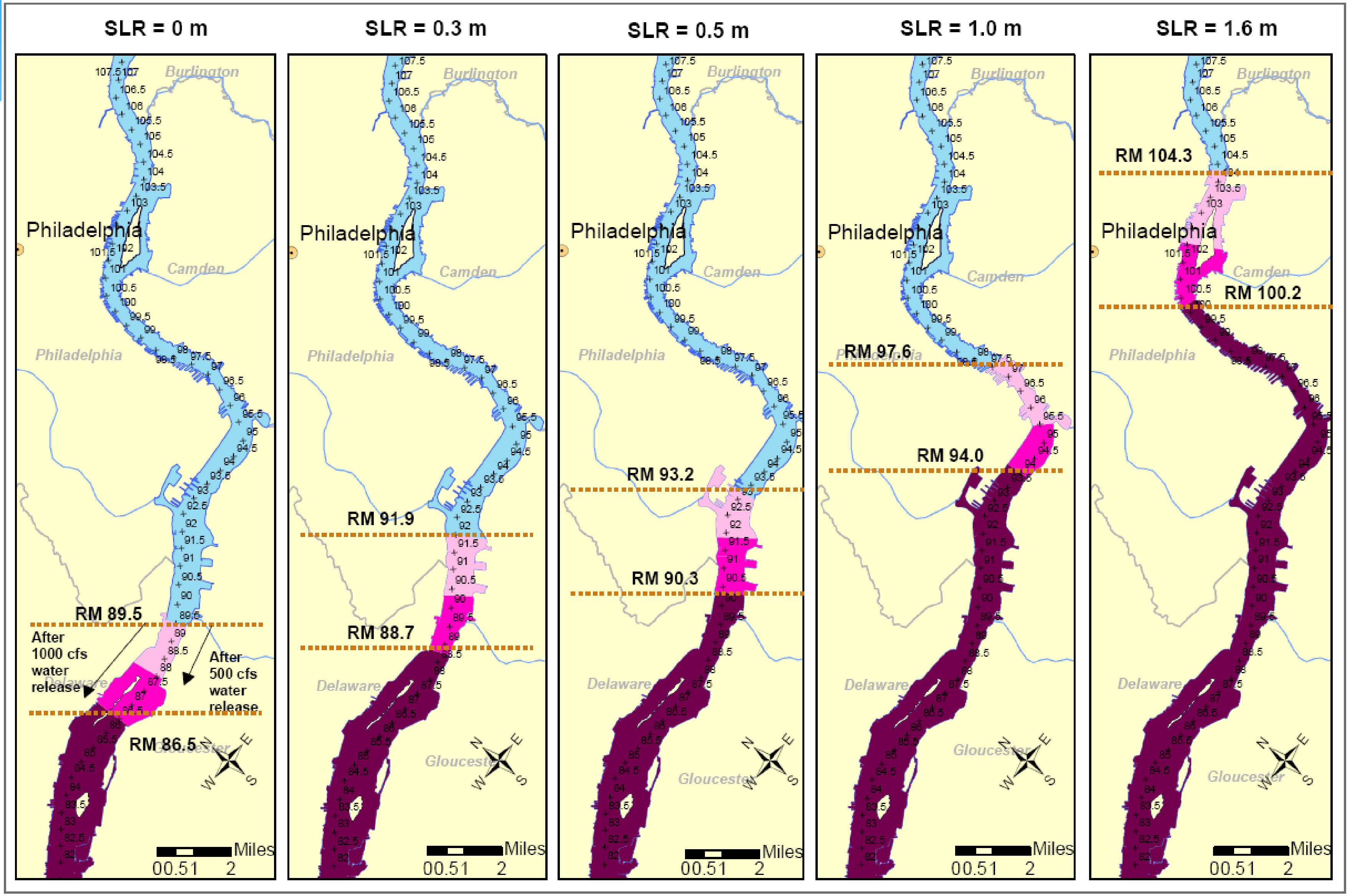
Salt Front Frequency Analysis (2002 Dry Conditions)



The SF location with highest frequency moved from RM **86-88** (base case) upstream to RM **88-90** (SLR=0.3m), RM **90-92** (SLR=0.5m), RM **94-96** (SLR=1.0m), and RM **102-104** (SLR=1.6 m).

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Range of Salt Front during Dry Conditions (2002)
Sensitivity to Additional Flow



Legend

Simulated SF Range (SLR = 1.6 m)

- No additional flow added
- 500 cfs for 2 months
- 1,000 cfs added for 2 months

Simulations of July-October 2002 conditions with additional water released in August and September. A significant amount of water may be needed to keep the salt front below RM 92.5.

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

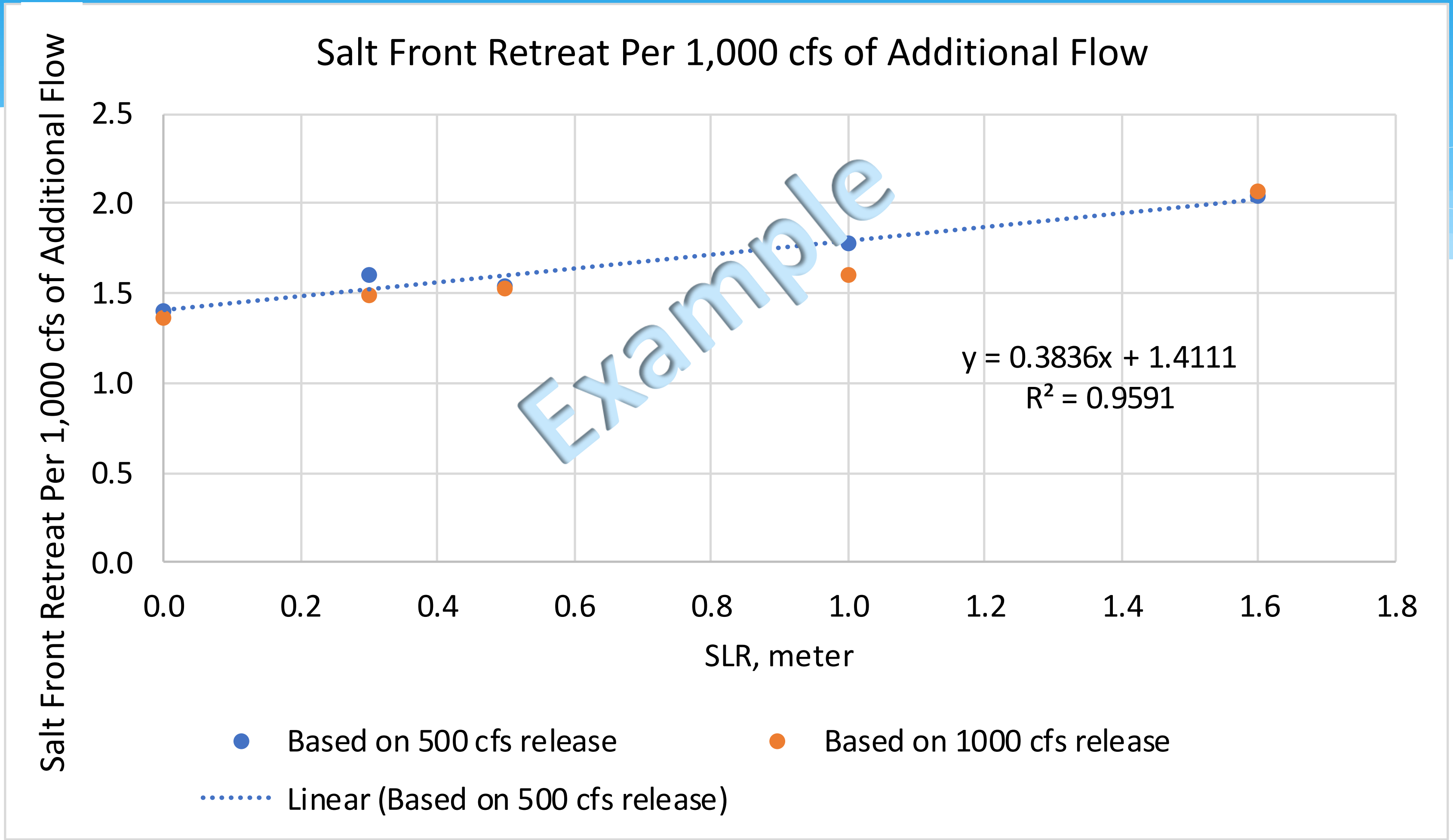
Range of Salt Front during Dry Conditions (2002) Sensitivity of adding 500 or 1,000 cfs for 2 months

	SLR (m)	Min	Max	Average
Add 500 cfs	0	60.48	88.02	79.99
	0.3	61.93	90.25	81.98
	0.5	62.60	91.84	83.41
	1	64.39	95.51	86.94
	1.6	67.14	102.13	92.38

	SLR (m)	Min	Max	Average
Add 1,000 cfs	0	60.49	86.47	79.33
	0.3	61.90	88.68	81.29
	0.5	62.59	90.29	82.65
	1	64.39	94.00	86.23
	1.6	67.14	100.22	91.33

Simulated seven-day moving average salt front location

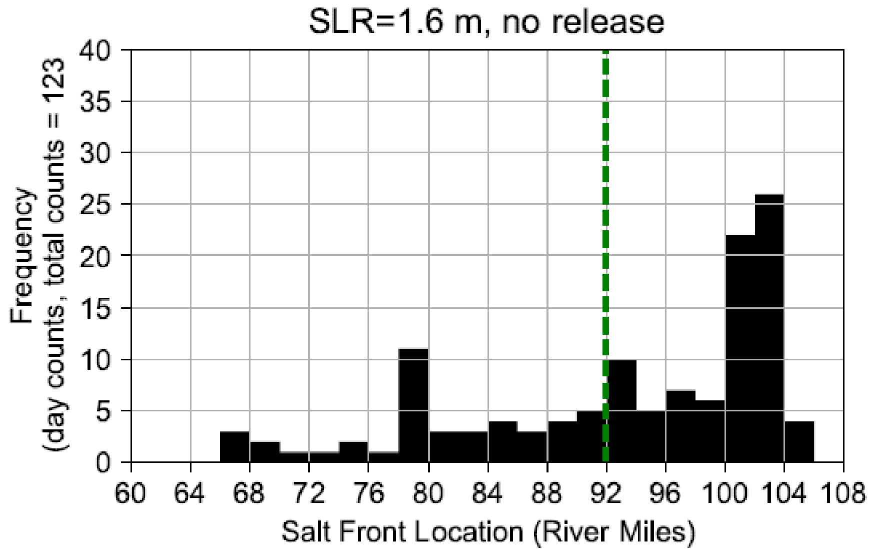
Evaluating the Effectiveness of Additional Freshwater Inflows

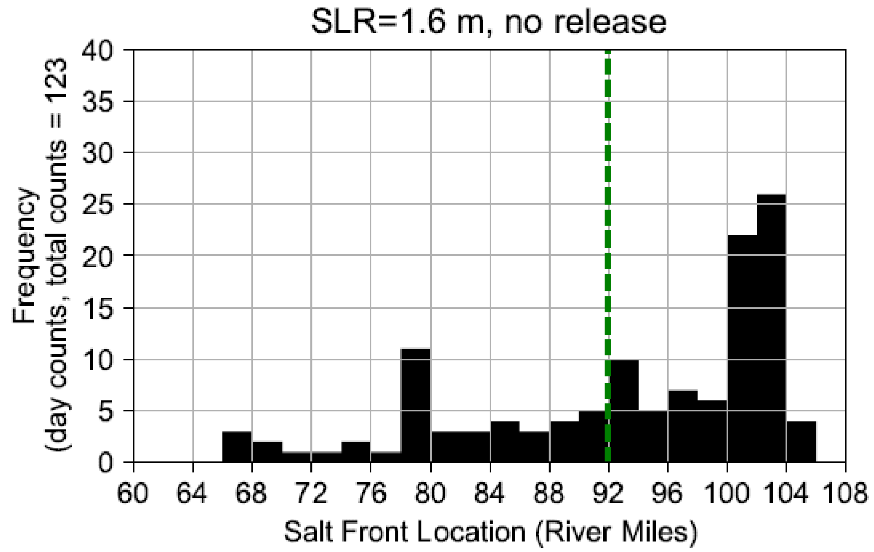


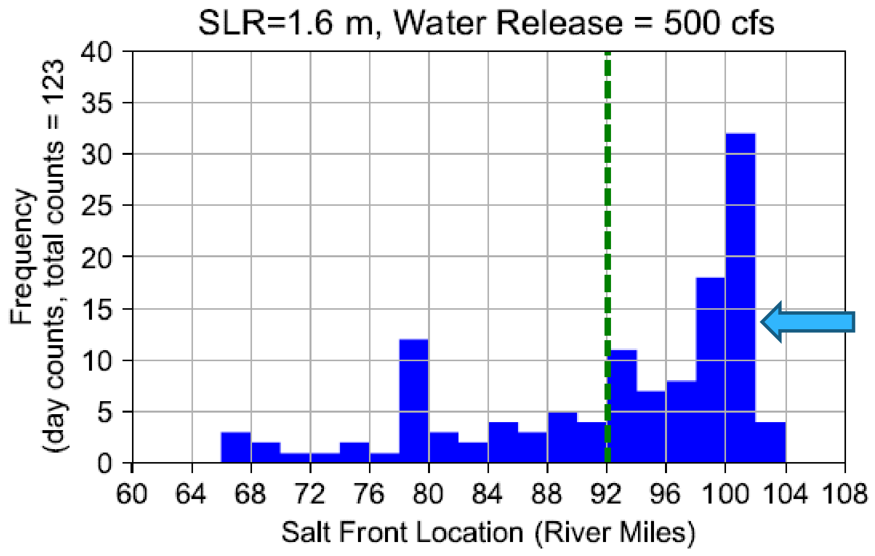
Relationships such as this may be helpful to inform decision-makers.

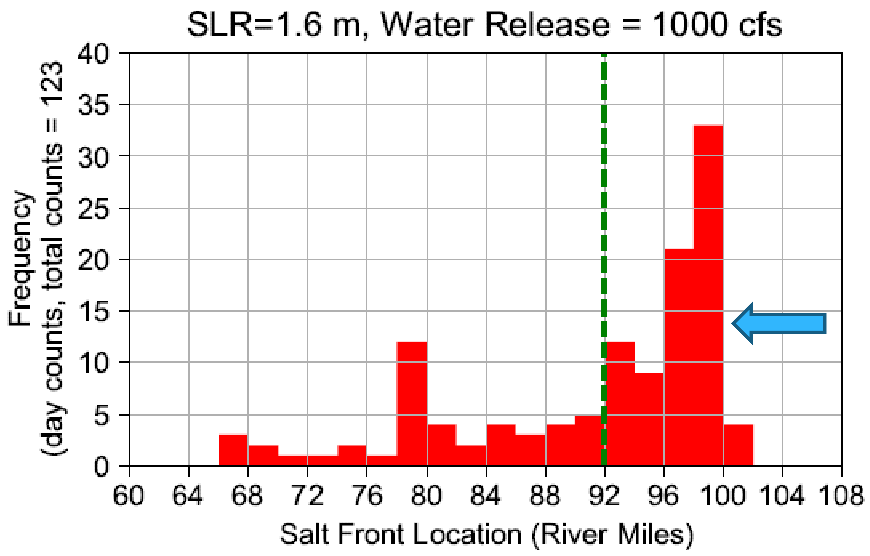
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Salt Front Frequency Analysis for Additional Flow
SLR = 1.6 m; 2002 Dry Conditions







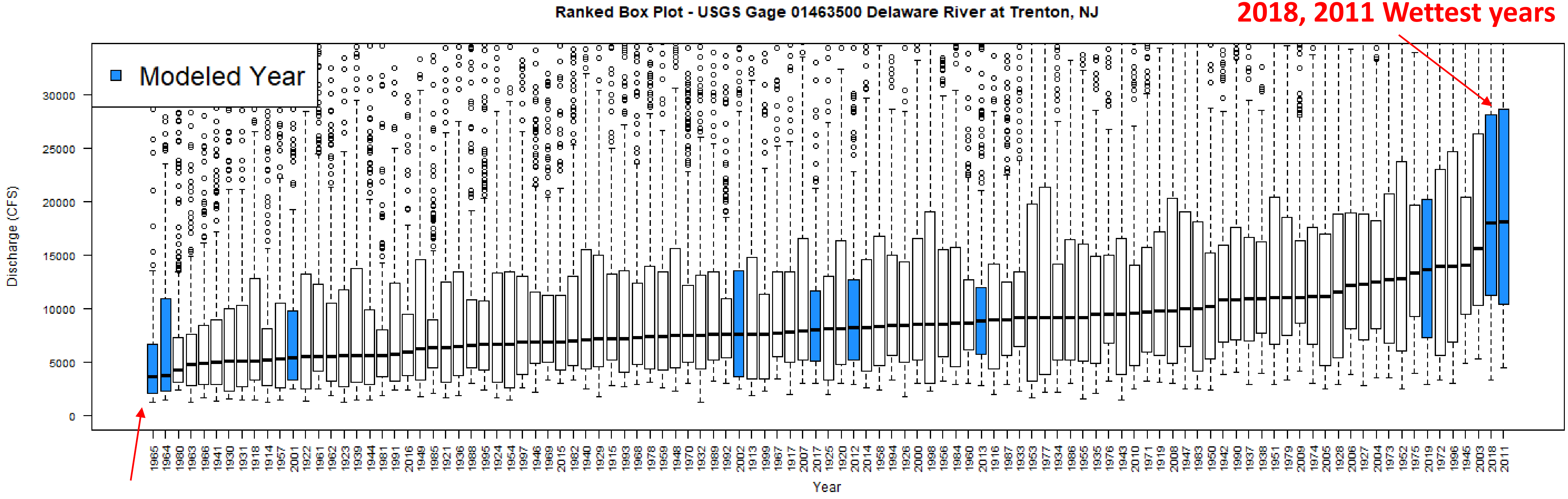


Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Scenario Simulations with Various Hydrologic Conditions

Ten Representative Years

2018, 2011 Wettest years



1964,1965
are the driest years

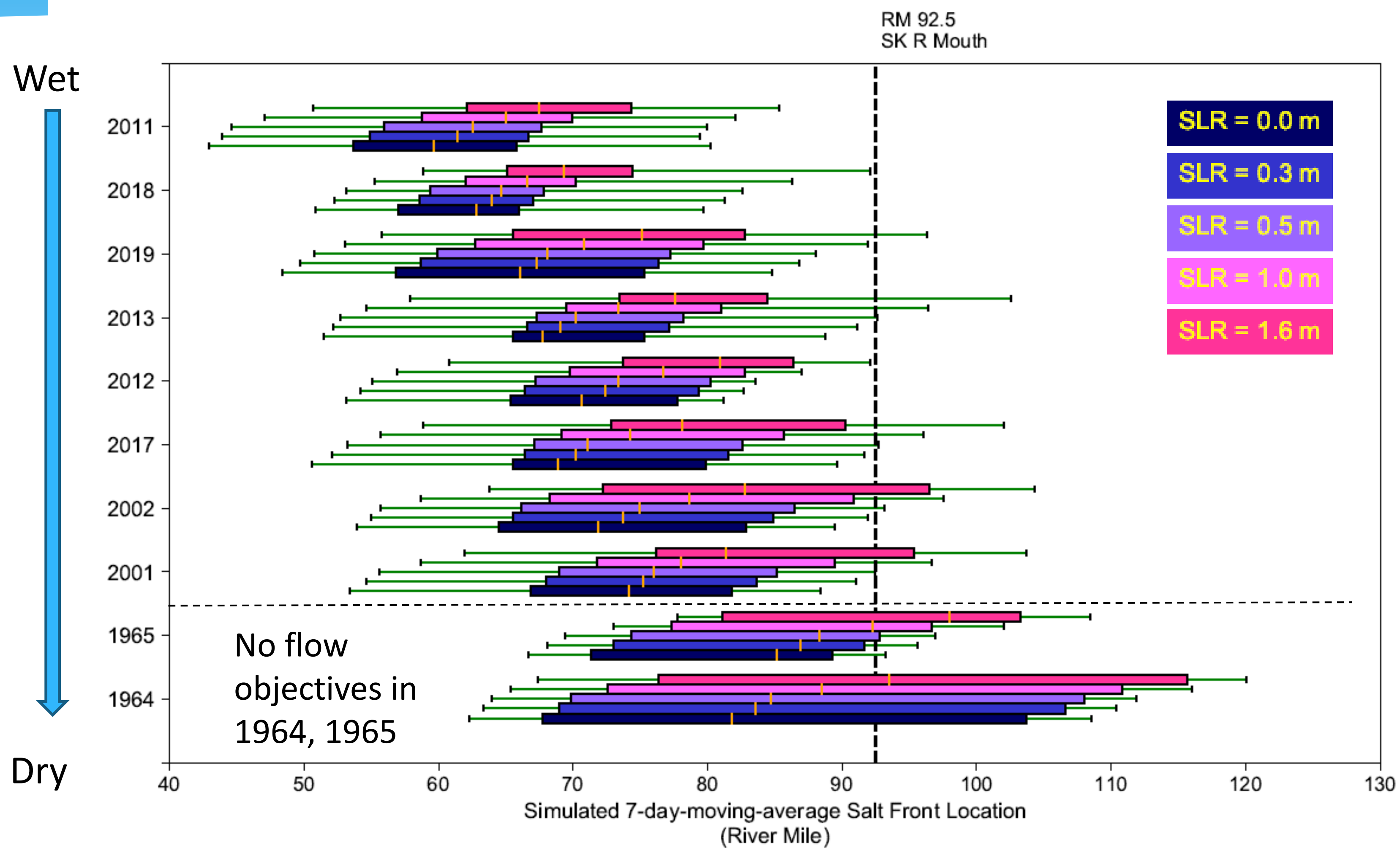
Ranked Flows at Trenton, NJ - Delaware River Mainstem

Median flow at Trenton from low to high: 1965, 1964, 2001, 2002, 2017, 2012, 2013, 2019, 2018, 2011

Simulations with current bathymetry of the Navigation Channel (45 feet below MLLW)

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Simulated Salt Front Location
Summarized based on Hydrological Conditions

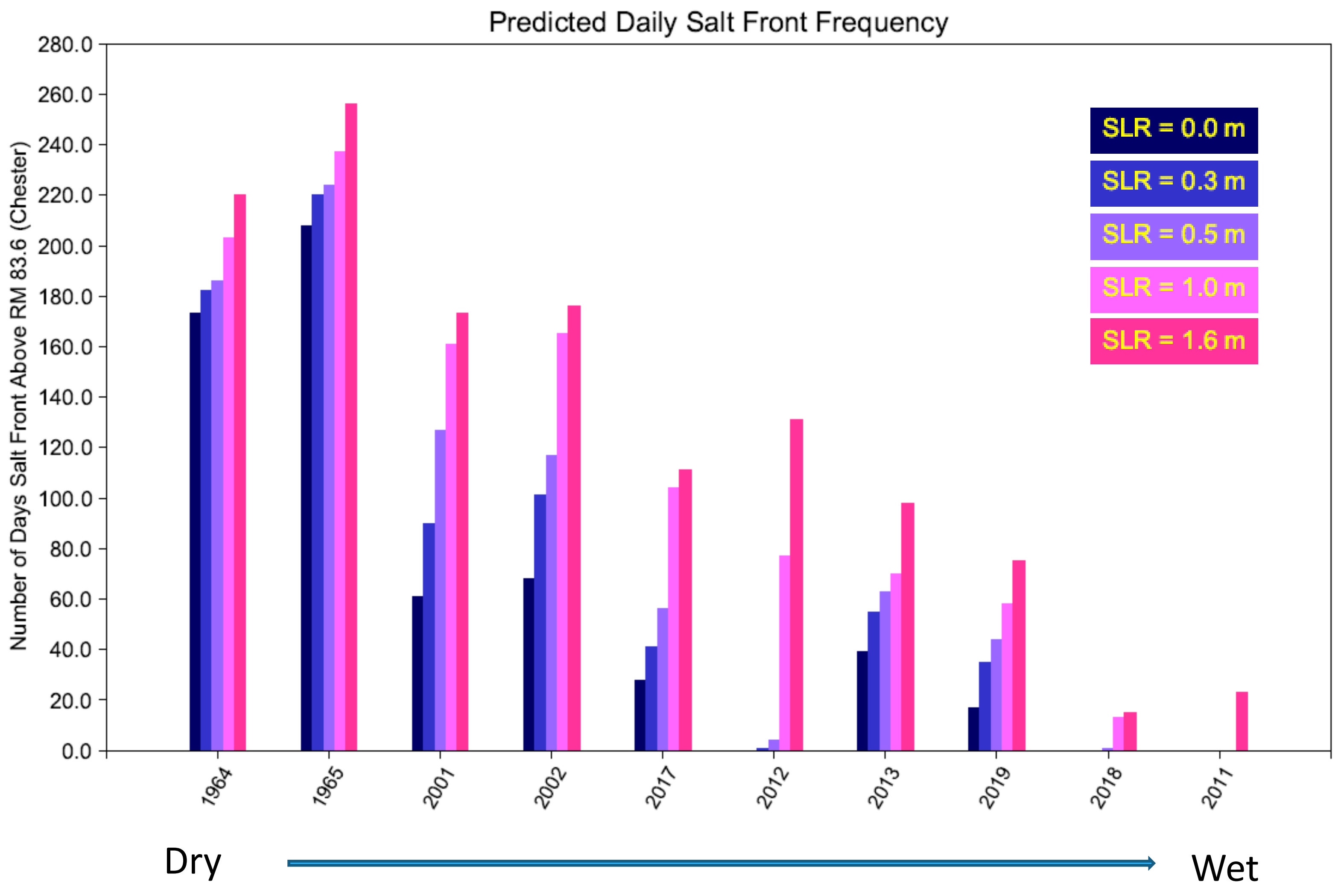


Middle orange line = median; Edge = 25, 75 percentile; Whiskers = the min and max (range).

Simulated 7-day average salt front locations were used.

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

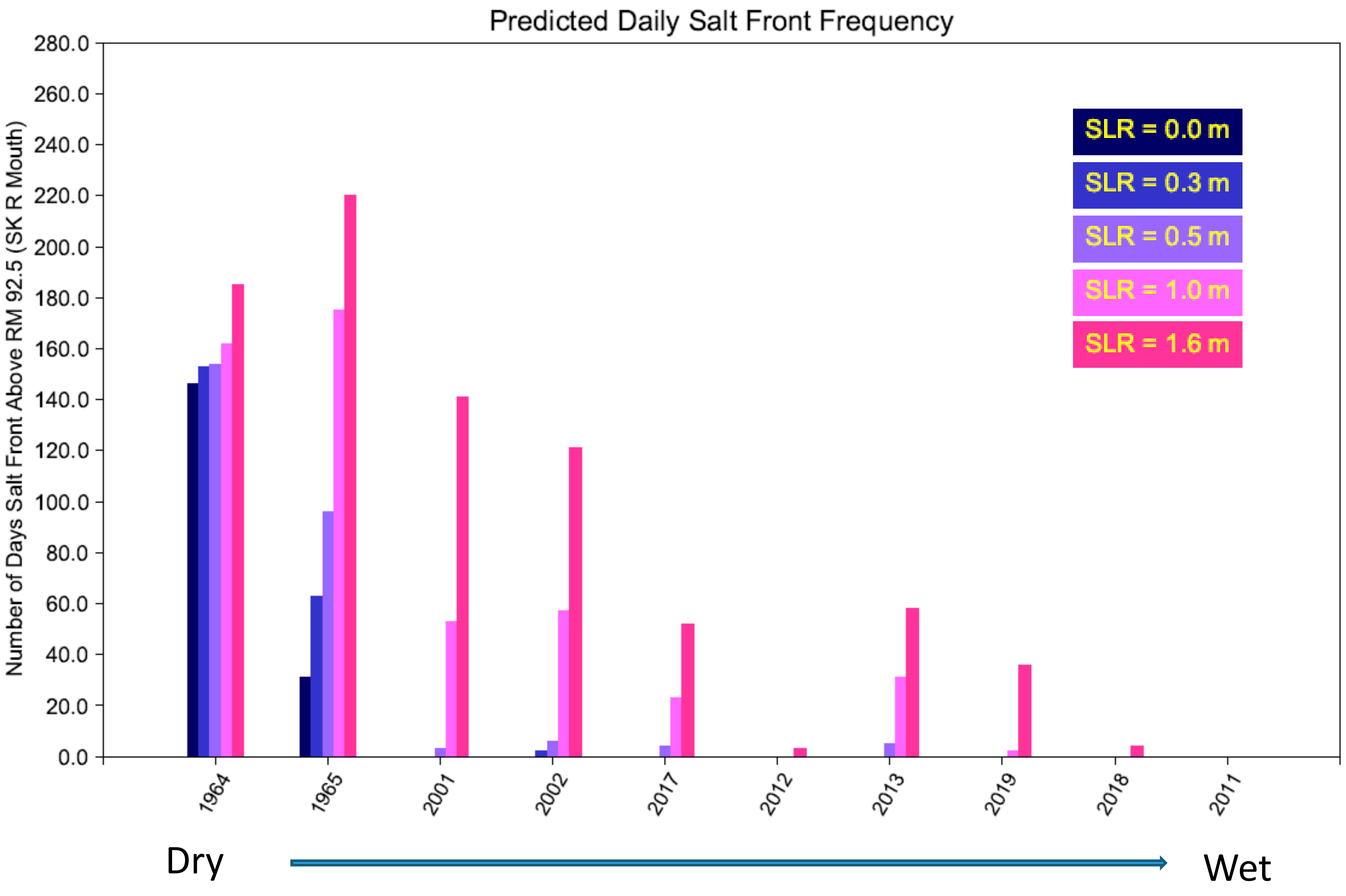
Frequency of Simulated Salt Front Location at Chester (RM 83.6) Summarized by Hydrological Conditions



Simulated daily average salt front locations were used.

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Frequency of Simulated Salt Front Location above the Schuylkill River (RM 92.5)



Simulated daily average salt front locations were used.

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Caveats

* These analyses demonstrate the impact on salinity intrusion due to sea level rise in relation to the existing bathymetry
* There are uncertainties related to future sea level rise that may require additional consideration
  * Sediment transport/Channel dredging
  * Average seasonal cycle/storm surge frequency/hurricanes
  * Ocean Salinity/ Sea surface temperature
  * Hydrology with increased temperature and precipitation
* DRBC's Advisory Committee on Climate Change (AC3) will advise on assumptions and avenues of investigation.

Summary

- Three dimensional EFDC model was refined
- Simulations were performed for different SLR, hydrology, and additional flow
  - SLR – (0, 0.3, 0.5, 1.0, 1.6 m)
  - Representative range of hydrologic conditions (*1964-1965, 2001-2002, 2011-2013, 2017-2019*)
  - One dry year (2002) with increased freshwater inflows
- Results may be used to inform formulation of FFMP2017 study alternatives
  - Sea Leve Rise of 1.0 m or greater will push the salt front above RM 92.5
  - Significant amounts of water will be needed to keep the salt front below RM 100 (based on 2002 hydrology)

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA