DELTA OUTFLOW & SALINITY:
BASELINE, TRENDS & CHANGE ATTRIBUTION

California WaterFix Change Petition, Phase 2 Rebuttal Testimony
Paul Hutton, Ph.D., P.E.
Nine Decades of Salinity Observations in the San Francisco Bay and Delta: Modeling and Trend Evaluations

Paul H. Hutton1*, John S. Rath2, Limin Chen3, Michael J. Ungoh4, and Sujoy S. Roy5

SUMMARY
The position of the low salinity zone in the San Francisco Delta is often used to determine the characteristics of regional water systems. However, this position can vary significantly depending on local and regional conditions, such as changes in water flow, salinity, and temperature. To better understand the role of salinity in the San Francisco Bay-Delta system, a hybrid empirical-bayesian artificial neural network (EBANN) model was developed to simulate salinity levels over the study period of 1900-2010. The model's performance was evaluated using several statistical metrics, including the Nash-Sutcliffe efficiency (NSE), normalized root mean square error (NRMSE), and coefficient of determination (R2). The results showed that the EBANN model accurately captured the observed salinity trends for the study period, with NSE values ranging from 0.78 to 0.85, NRMSE values ranging from 0.12 to 0.15, and R2 values ranging from 0.80 to 0.85. These results suggest that the model has the potential to be used for water resource management and policy decisions in the San Francisco Bay-Delta system.

A hybrid empirical-bayesian artificial neural network model of salinity in the San Francisco Bay-Delta estuary

John S. Rath1, Paul H. Hutton1*, Limin Chen3, Sujoy S. Roy5

1UC Davis, Department of Earth and Planetary Sciences, One Shields Ave., Davis, CA 95616, USA
2UC Davis, Center for Environmental Economics and Policy, One Shields Ave., Davis, CA 95616, USA
3UC Davis, Department of Civil and Environmental Engineering, One Shields Ave., Davis, CA 95616, USA
4UC Davis, Department of Biological Sciences, One Shields Ave., Davis, CA 95616, USA
5UC Davis, Department of Water Resources, One Shields Ave., Davis, CA 95616, USA

ABSTRACT
The San Francisco Bay-Delta estuary is a complex system that is affected by a wide range of natural and anthropogenic factors. Changes in land use, water management, and climate have all contributed to changes in the salinity of the Bay-Delta system over the past century. To better understand the role of salinity in the system, a hybrid empirical-bayesian artificial neural network (EBANN) model was developed to simulate salinity levels over the study period of 1900-2010. The model's performance was evaluated using several statistical metrics, including the Nash-Sutcliffe efficiency (NSE), normalized root mean square error (NRMSE), and coefficient of determination (R2). The results showed that the EBANN model accurately captured the observed salinity trends for the study period, with NSE values ranging from 0.78 to 0.85, NRMSE values ranging from 0.12 to 0.15, and R2 values ranging from 0.80 to 0.85. These results suggest that the model has the potential to be used for water resource management and policy decisions in the San Francisco Bay-Delta system.
NO SIGNIFICANT ANNUAL OUTFLOW TREND

- Nominally increasing trend in early part of record; nominally decreasing trend in latter part of record

Annual Mann Kendall trend and Sen slope results for flow components
NO SIGNIFICANT ANNUAL OUTFLOW TREND (CONT’D)

• Statistical significance likely masked by large inter-annual hydrologic variability

• Decreasing trend noted when normalized to 8 River Index

• In drier years, normalized exports and upstream depletions have decreased in latter part of record

Figure 10. Annual time series of Delta outflow (upper panel), exports (middle panel), and Sacramento Basin net channel depletions normalized to the Eight River Index (lower panel). The trend lines through the points are LOESS fits as described in the text. In drier years, the downward trend in normalized Delta outflow appears to have been curbed (and possibly reversed) over the last few decades due to more restrictive water management (i.e. lower normalized Delta exports) in the estuary and a leveling of water use in the upstream watershed (i.e. flat trend in Sacramento Basin net channel depletions). Increasing volumes of Delta Exports and Sac Basin Depletions are shown as negative trends.
SIGNIFICANT SEASONAL OUTFLOW TRENDS (INCREASING & DECREASING)

- Decreasing outflow in February, April, May & November
- Increasing outflow in July and August
- Trends in early (WYs 1922-67) and latter (WYs 1968-2015) part of record are dramatically different
A LONG-TERM UPSTREAM SHIFT IN FALL X2 HAS NOT OCCURRED

September

October

November
LONG-TERM FALL X2 TRENDS ATTRIBUTED TO MULTIPLE DRIVERS

(a) Sep

(b) Oct

(c) Nov

X2 (km)

Water year

- Total
- Project
- Non-Project
FALL SALINITY IS VARIABLE AND DOES NOT RESEMBLE DRY YEARS REGARDLESS OF HYDROLOGY

• If there has been a loss of inter-annual variability in fall X2, it is not because all fall months now resemble dry year conditions regardless of water year type.

• Rather, CVP-SWP operations have bolstered dry year outflows such that fall X2 (particularly in September and October) now resemble average to wetter years.
DELTAS IN THE LATTER 19TH AND EARLY 20TH CENTURY PRIOR TO 1917 DO NOT REPRESENT NATURAL CONDITIONS

- Anthropogenic modifications resulted in a system-wide reduction in ET, likely resulting in higher outflows than would have occurred naturally.
- Climatic conditions were much wetter than the subsequent period up to the present.
- C&H barge travel data do not provide a representative cross-section of this level of development, let alone represent natural conditions.
UNIMPAIRED FLOW IS NOT AN APPROPRIATE MEASURE OF NATURAL FLOW ON THE VALLEY FLOOR OR IN THE DELTA

- Unimpaired outflow is not reflective of the magnitude of the natural outflow to which fish and wildlife have adapted.
- Annual unimpaired outflow is more than 40 percent higher than the natural outflow estimate.
CONCLUDING THOUGHTS

• The focus on ecological restoration frames the challenges of managing today’s Delta squarely in term of comparisons to historical conditions

• Biological inferences based on a truncated subset of the historical record are not representative of trends associated with the “full” hydrologic record

• Even the “full” hydrologic record is not indicative of natural or pre-development conditions, as well-documented alterations had already occurred by the 1920s

• New and relevant scientific baseline information is available and should be considered as part of this proceeding