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Conservative Mixing: Implications for Selecting Salinity Transport Model Constituents in the San Francisco Estuary (Part 1)

CWEMF Annual Meeting

Session 32

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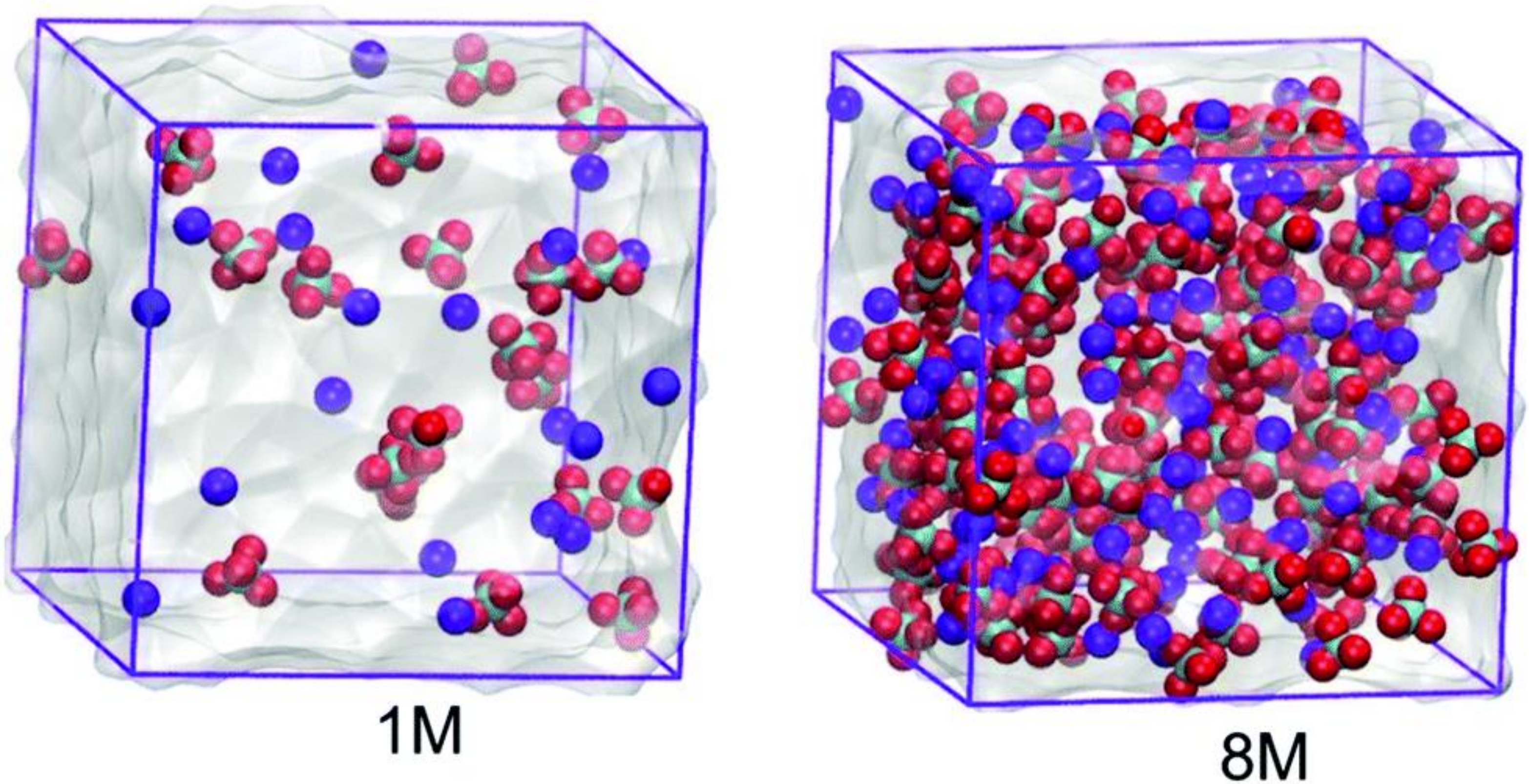
Motivation & Introductory Remarks

- Purpose
  - Explore implications of EC non-conservative behavior for modeling Delta salinity transport
  - Raise some questions for future research on the implications of modeling transport of other conservative and non-conservative constituents in the Delta
  - Two-part presentation
- Salt (i.e. conservative) transport is calibrated to EC in the DSM2 model
- Standard modeling practice addresses EC non-conservative behavior by translating EC into Practical Salinity
- However, Practical Salinity has practical limitations in characterizing waters with complex ionic signatures

Motivation & Introductory Remarks (cont'd)

- EC non-conservative behavior is demonstrated here using measured and simulated data
  - theoretical mixing analysis
  - DSM2 output example
- A promising alternate to Practical Salinity is discussed in Part 2 of this presentation
- This work has been accepted for publication in June 2023 edition of San Francisco Estuary & Watershed Science

Specific Conductance (EC) Exhibits Non-Conservative Behavior



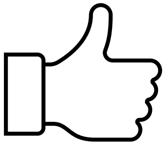
- As salt concentration in a water sample increases,
  - the mobility of individual ions in the sample decreases and
  - the ability of individual ions to conduct electricity decreases

Credit: da Silva et al. (2022) DOI: 10.1039/D1MA00890K (Paper) Mater. Adv., 2022, 3, 611-623

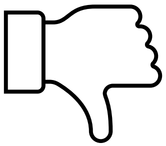
Balancing Tradeoffs in Selection of a Salinity Transport Model Constituent

Specific Conductance (EC)

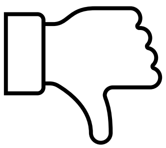
No data translation error



Non-conservative



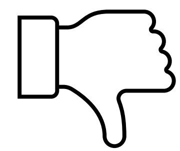
Non-standard practice



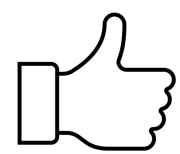
Balancing Tradeoffs in Selection of a Salinity Transport Model Constituent (cont'd)

Practical Salinity

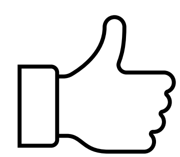
Subject to data translation error



Conservative



Standard practice



Balancing Tradeoffs in Selection of a Salinity Transport Model Constituent (cont'd)

- Selecting EC as a transport constituent assumes a tradeoff relationship that hasn't been formally evaluated
- How significant is error associated with EC's non-conservative behavior?
- How significant is error associated with data translation between EC and practical salinity?

Seawater Mixing Ratio
Steady State Two-Source Mixing

Consider the following mixing relationship:

$$S_n = S_s * M_n + S_f * (1 - M_n)$$

where:

S_n = constituent value for sample *n*

S_s = seawater end member constituent value

S_f = freshwater end member constituent value

M_n = seawater mixing ratio ($0 \le M_n \le 1$) for sample

Rearranging terms and solving for M_n yields:

$$M_n = \frac{S_n - S_f}{S_s - S_f}$$

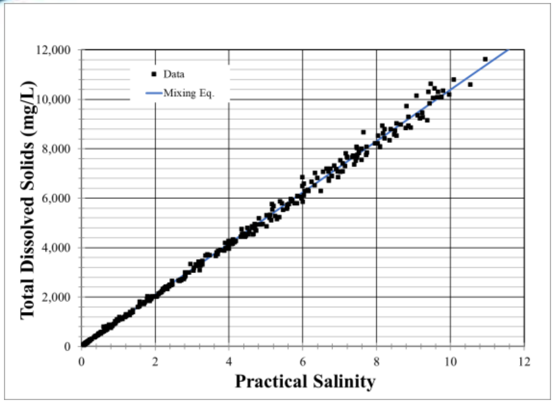
Seawater Mixing Ratio Matrix
Steady State Two-Source Mixing (cont'd)

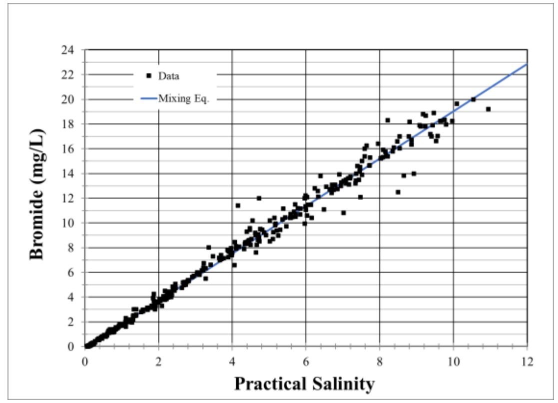
M_n

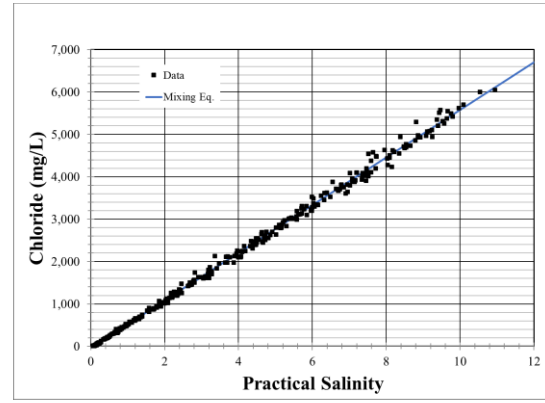
S_s (arrow pointing to the first row: 100 / 0)

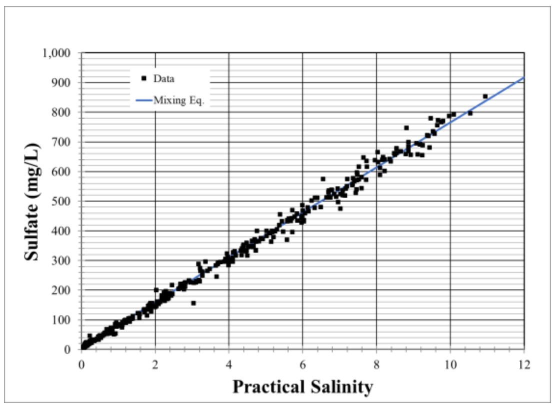
S_f (arrow pointing to the last row: 0 / 100)

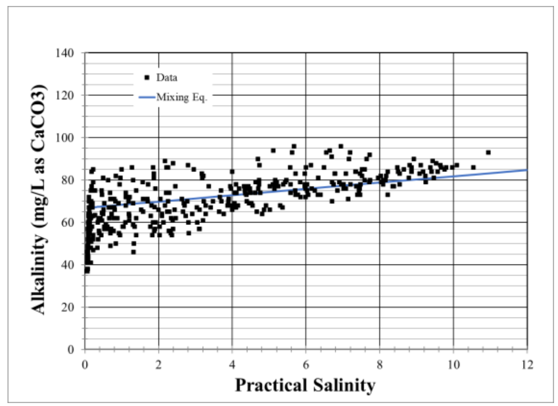
High Salinity Seawater %	Low Salinity Seawater %	Mixing Ratio	EC (uS/cm)	PSS-78	Na	Ca	Mg	K	Cl	SO4	Alkalinity	Br	TDS	Ion Sum
100	0	1.00	52300	35.00	10600	420	1295	405	19630	2660	119	67.00	36300	35148
90	10	0.90	47095	31.51	9542	379	1166	365	17670	2396	114	60.31	32685	31647
80	20	0.80	41890	28.02	8484	339	1038	324	15709	2131	109	53.62	29069	28145
70	30	0.70	36685	24.54	7427	298	909	284	13749	1867	104	46.93	25454	24643
60	40	0.60	31480	21.05	6369	257	781	244	11788	1603	98	40.23	21838	21141
50	50	0.50	26275	17.56	5311	217	652	203	9828	1339	93	33.54	18223	17639
40	60	0.40	21070	14.07	4253	176	523	163	7867	1074	88	26.85	14607	14137
30	70	0.30	15865	10.59	3195	136	395	123	5907	810	83	20.16	10992	10635
20	80	0.20	10660	7.10	2138	95	266	83	3946	546	77	13.47	7376	7133
10	90	0.10	5455	3.61	1080	54	137	42	1986	282	72	6.78	3761	3631
9	91	0.09	4935	3.26	974	50	125	38	1790	255	72	6.11	3399	3281
8	92	0.08	4414	2.91	868	46	112	34	1594	229	71	5.44	3037	2931
7	93	0.07	3894	2.56	762	42	99	30	1398	202	71	4.77	2676	2581
6	94	0.06	3373	2.22	657	38	86	26	1202	176	70	4.10	2314	2231
5	95	0.05	2853	1.87	551	34	73	22	1006	150	70	3.43	1953	1880
4	96	0.04	2332	1.52	445	30	60	18	810	123	69	2.76	1591	1530
3	97	0.03	1812	1.17	339	26	47	14	614	97	69	2.09	1230	1180
2	98	0.02	1291	0.82	234	22	35	10	417	70	68	1.43	868	830
1	99	0.01	771	0.47	128	18	22	6	221	44	68	0.76	507	480
0.9	99.1	0.01	718	0.44	117	17	20	6	202	41	67	0.69	470	445
0.8	99.2	0.01	666	0.40	107	17	19	5	182	39	67	0.62	434	410
0.7	99.3	0.01	614	0.37	96	16	18	5	163	36	67	0.56	398	375
0.6	99.4	0.01	562	0.33	85	16	17	4	143	33	67	0.49	362	340
0.5	99.5	0.01	510	0.30	75	16	15	4	123	31	67	0.42	326	305
0.4	99.6	0.00	458	0.26	64	15	14	4	104	28	67	0.35	290	270
0.3	99.7	0.00	406	0.23	54	15	13	3	84	25	67	0.29	253	235
0.2	99.8	0.00	354	0.19	43	14	11	3	65	23	67	0.22	217	200
0.1	99.9	0.00	302	0.16	33	14	10	2	45	20	67	0.15	181	165
0	100	0.00	250	0.12	22	14	9	2	25	17	67	0.09	145	130

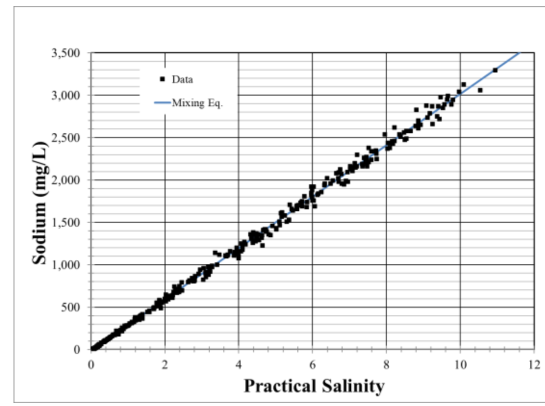

Total Dissolved Solids (mg/L)
0
2,000
4,000
6,000
8,000
10,000
12,000
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity

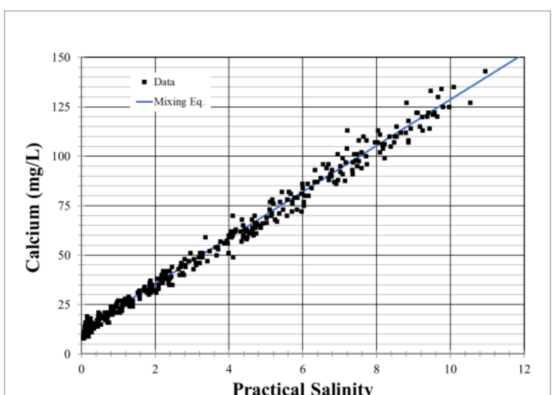

Bromide (mg/L)
0 2 4 6 8 10 12 14 16 18 20 22 24
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity

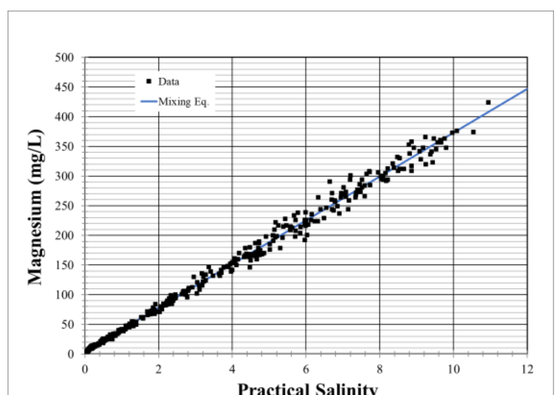

Chloride (mg/L)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity

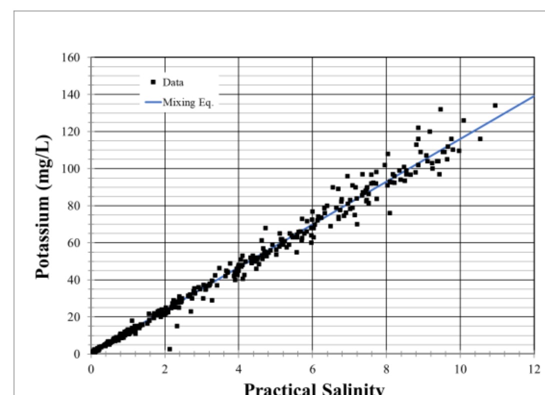

Sulfate (mg/L)
0 100 200 300 400 500 600 700 800 900 1,000
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity


Alkalinity (mg/L as CaCO3)
0 20 40 60 80 100 120 140
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity


Sodium (mg/L)
0 500 1,000 1,500 2,000 2,500 3,000 3,500
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity


Calcium (mg/L)
0 25 50 75 100 125 150
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity


Magnesium (mg/L)
0 50 100 150 200 250 300 350 400 450 500
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity


Potassium (mg/L)
0 20 40 60 80 100 120 140 160
Data
Mixing Eq.
0 2 4 6 8 10 12
Practical Salinity

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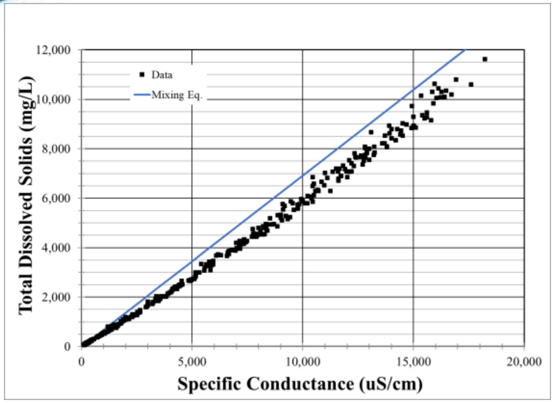
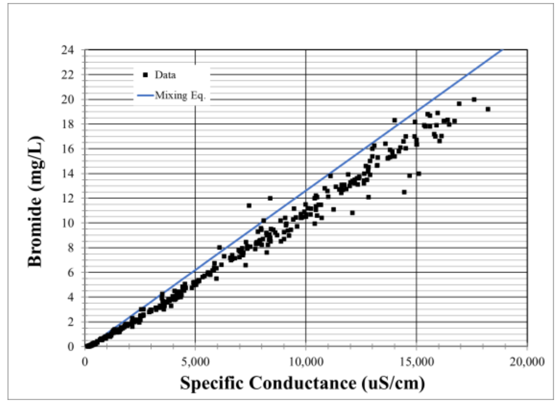
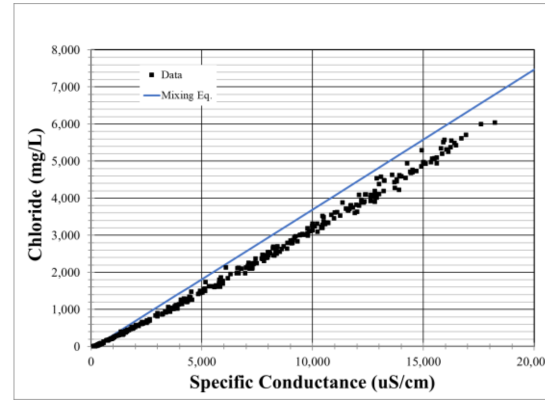


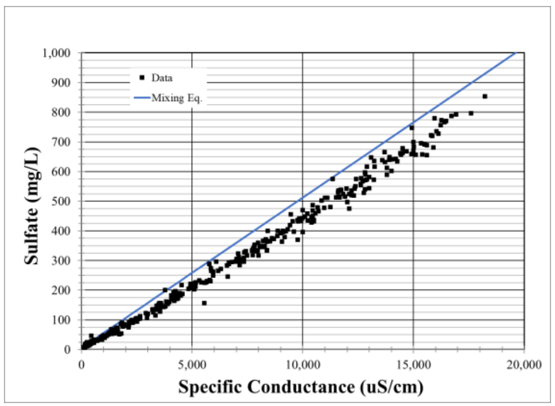
Data
Mixing Eq.
Total Dissolved Solids (mg/L)
Specific Conductance (uS/cm)



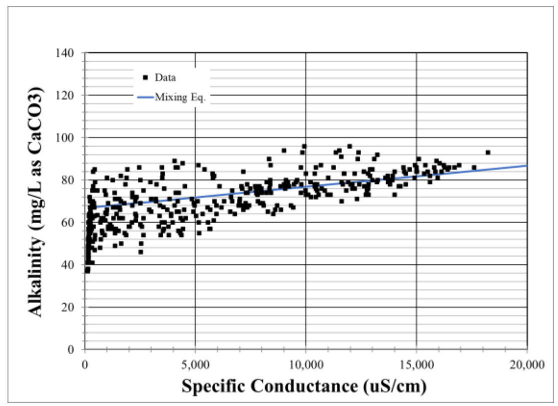
Data
Mixing Eq.
Bromide (mg/L)
Specific Conductance (uS/cm)



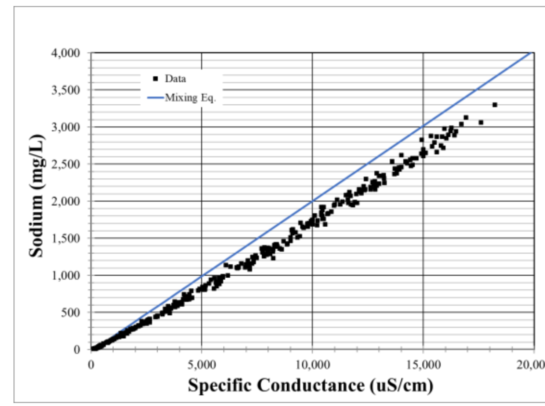
Data
Mixing Eq.
Chloride (mg/L)
Specific Conductance (uS/cm)



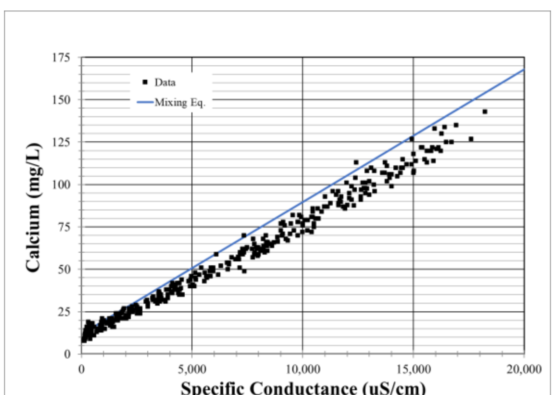
Data
Mixing Eq.
Sulfate (mg/L)
Specific Conductance (uS/cm)



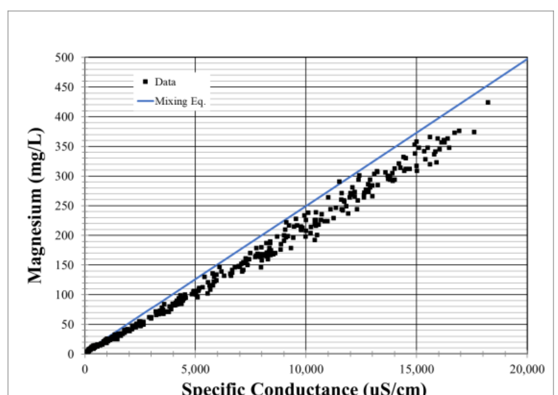
Data
Mixing Eq.
Alkalinity (mg/L as CaCO3)
Specific Conductance (uS/cm)



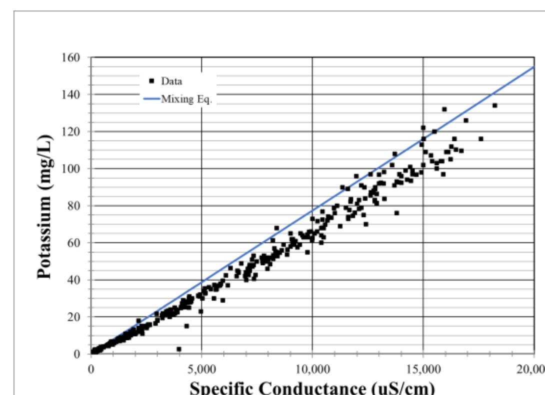
Data
Mixing Eq.
Sodium (mg/L)
Specific Conductance (uS/cm)



Data
Mixing Eq.
Calcium (mg/L)
Specific Conductance (uS/cm)



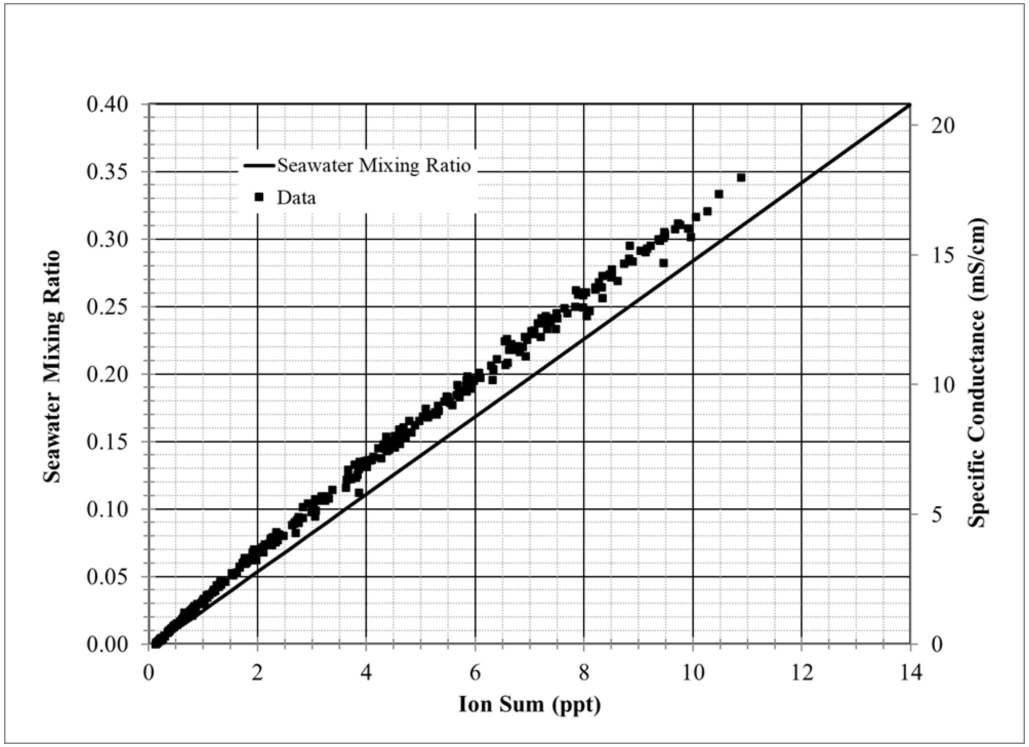
Data
Mixing Eq.
Magnesium (mg/L)
Specific Conductance (uS/cm)



Data
Mixing Eq.
Potassium (mg/L)
Specific Conductance (uS/cm)

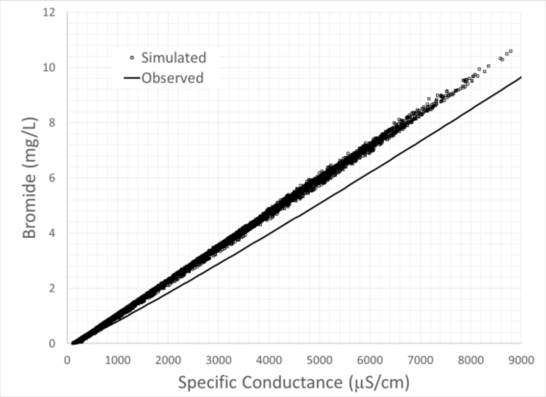
Deviation of Specific Conductance from Conservative Behavior

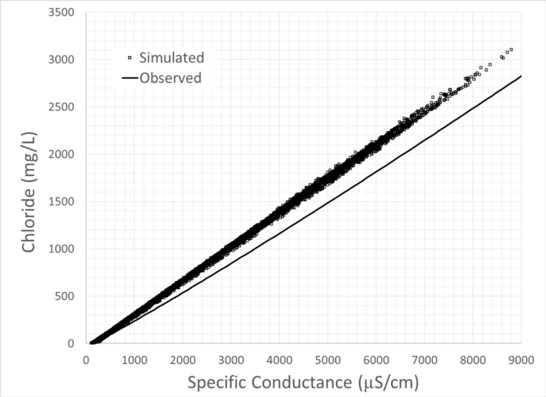
Steady State Two-Source Mixing

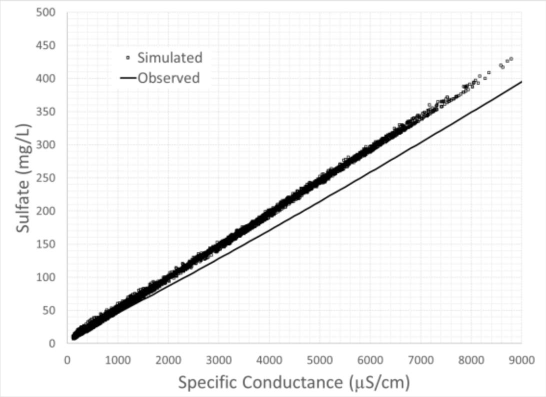


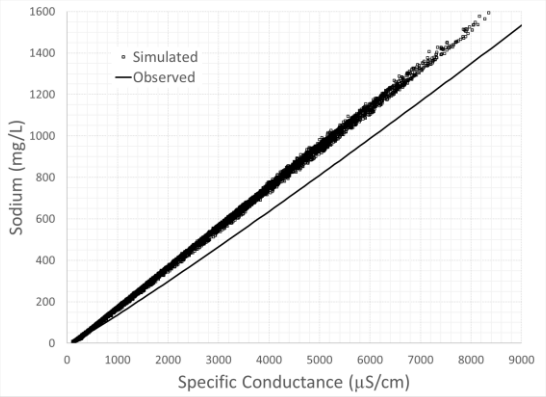
- Using EC as a measure of transport in the estuary artificially amplifies the actual seawater mixing ratio (i.e., it suppresses the dilution effect associated with freshwater flows to the estuary).

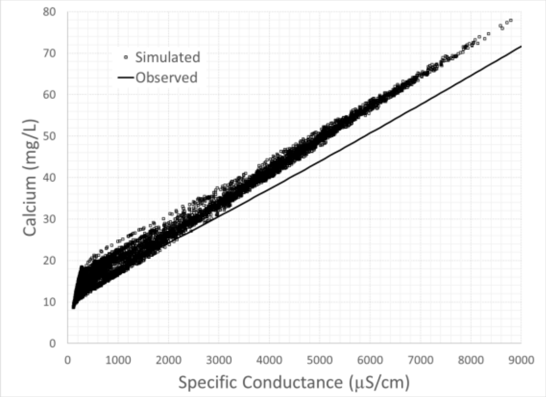
DSM2 Results Confirm Mixing Analysis Conclusions
Results at Antioch (RSAN007)

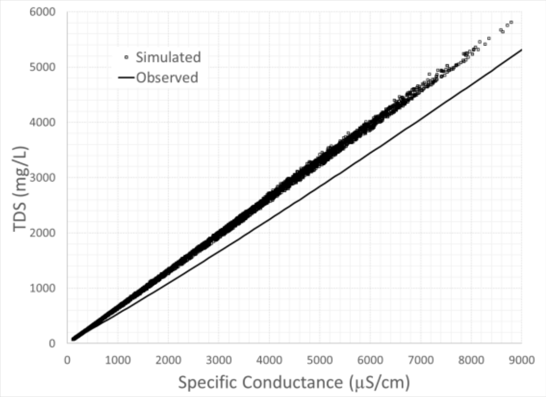




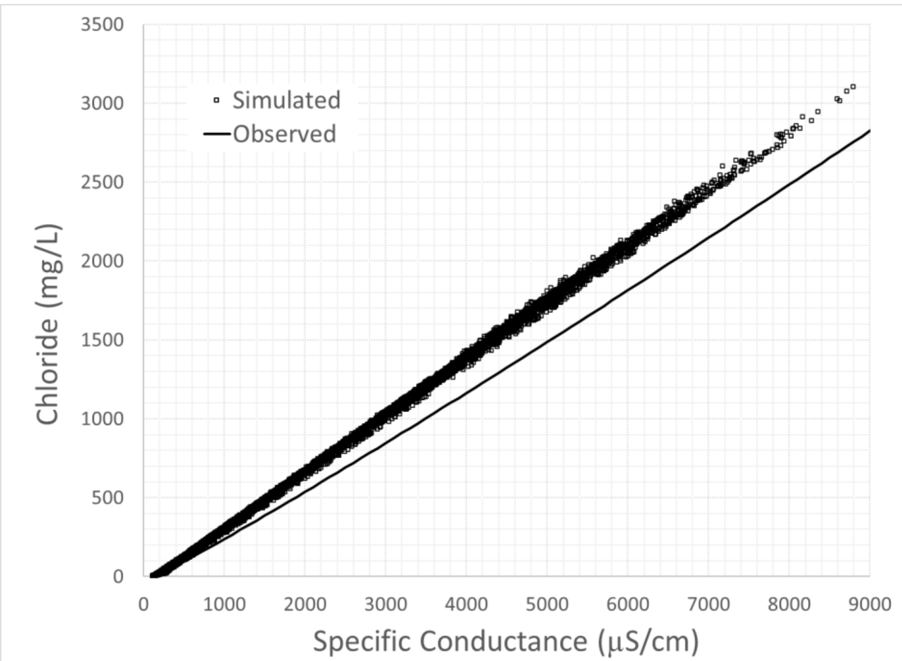


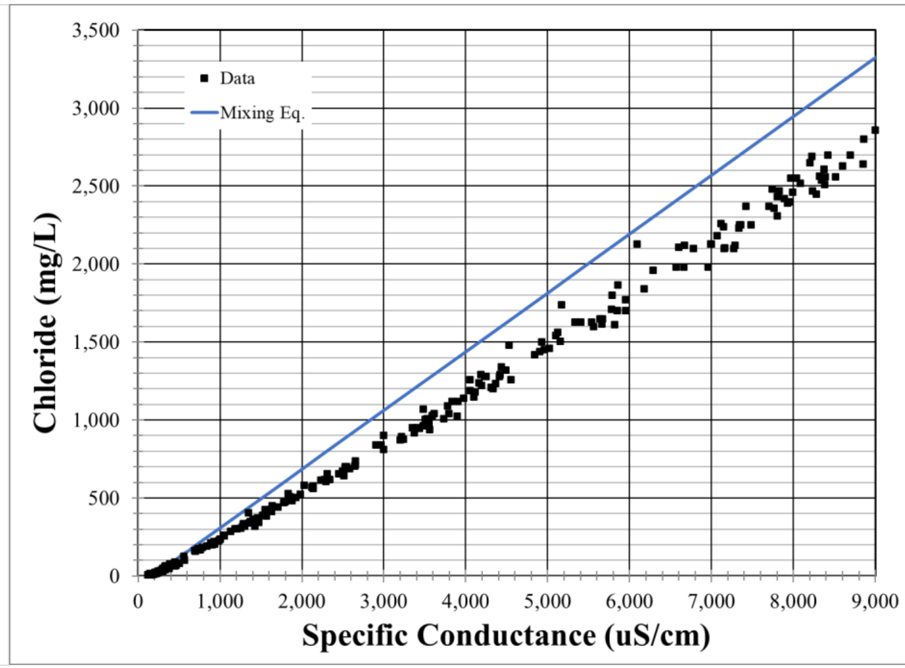






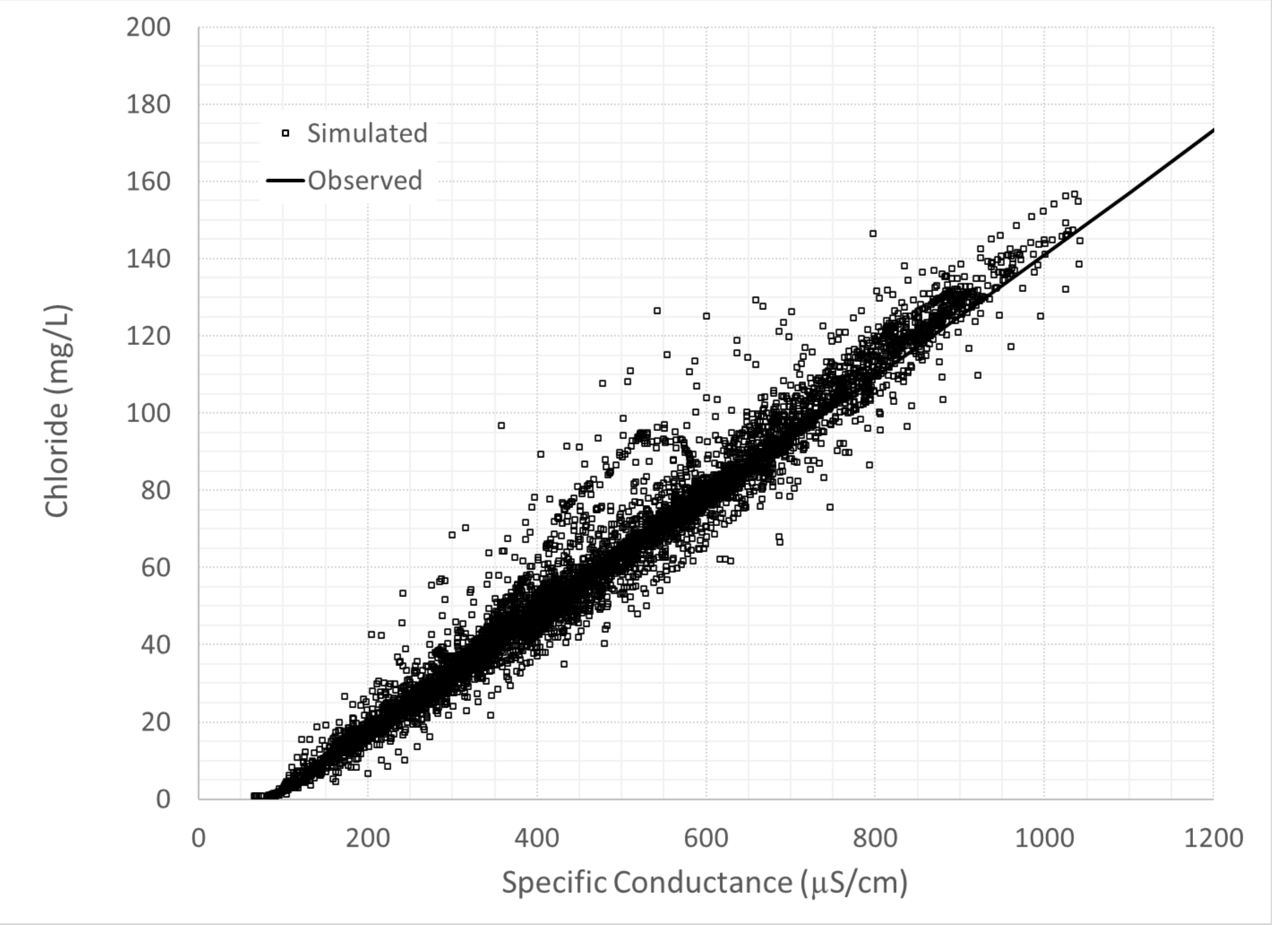
DSM2 Results Confirm Mixing Analysis Conclusions Results at Antioch (RSAN007) (cont'd)





DSM2 Results at Stockton (RSAN058)

Consistent with San Joaquin River EC-Cl Relationship



Potential Impacts of Biased Dispersion Factors

- Impact by Region?
  - Suisun Bay
  - Suisun Marsh
  - Western Delta
  - Interior Delta (what about under extreme seawater intrusion?)
- Impact by Constituent?
  - Salt ions
  - Dissolved nutrients
  - Dissolved organic carbon
  - Silica
  - Temperature
  - Dissolved oxygen
  - Chlorophyll
- Impact by Fingerprint?
  - Seawater
  - Other sources

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- The authors acknowledge Arushi Sinha's contribution to this work through data assembly and screening.