ESTIMATING SALINITY CONSTITUENT CONCENTRATIONS
IN SAN FRANCISCO BAY & THE WESTERN DELTA

2022 CWEMF Annual Meeting

Session 13 Pop-Up Talk

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PREDICTING SALINITY CONSTITUENT CONCENTRATIONS
FROM SPECIFIC CONDUCTANCE (EC)

$$S\ (mg/L) = A * EC^2 + B * EC + C$$

where S = ionic constituents such as Br^-, Cl^-, SO_4^{2-}, HCO_3^-, Na^+, Ca^{2+}, Mg^{2+} and K^+

A, B, C = constants typically determined through least squares regression

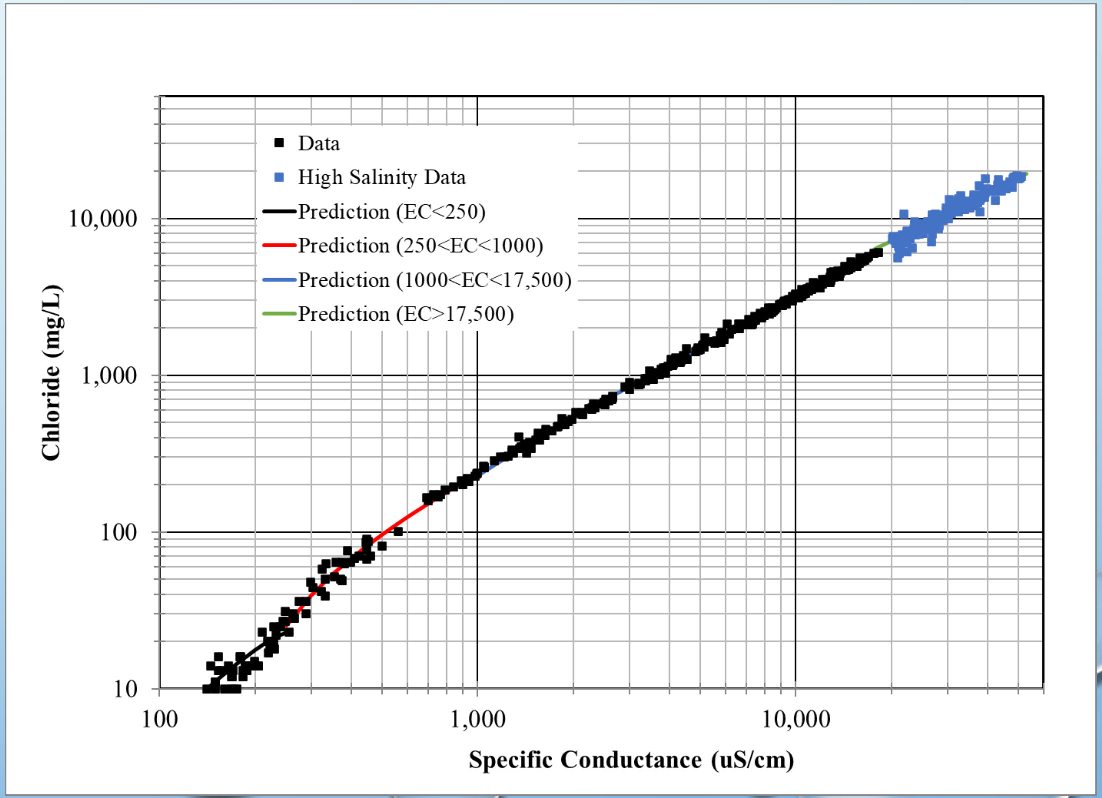
Constants Generally Determined through Least Squares Regression: 4 Data Ranges

X = EC	Y	Data Points	A	B	C	R^2	SE	Data Range
“Low” Salinity 100 ≤ [EC] < 250 μS/cm	TDS	68	0	0.593	0.8	0.957	4.5	67 – 151
	Br^-	64	0	0.000401	-0.03	0.604	0.01	0.01 – 0.1
	Cl^-	68	0	0.139	-10.9	0.781	2.6	7 – 31
	SO_4^{2-}	68	0	0.0716	-1.0	0.544	2.3	6 – 22
	Alkalinity	68	0	0.205	15.0	0.706	4.7	37 – 72
	Na^+	68	0	0.102	-4.9	0.892	1.3	7 – 22
	Ca^{2+}	68	0	0.0422	4.0	0.665	1.1	8 – 16
	Mg^{2+}	68	0	0.0355	0.1	0.836	0.6	4 – 9
	K^+	68	0	0.00484	0.6	0.221	0.3	0.9 – 2.5

X = EC	Y	Data Points	A	B	C	R^2	SE	Data Range
“Low-Medium” Salinity 250 ≤ [EC] < 1,000 μS/cm	TDS	51	0	0.527	13.3	0.996	8.3	151 – 541
	Br^-	50	0	0.000869	-0.13	0.786	0.11	0.07 – 0.83
	Cl^-	51	0	0.282	-45.1	0.984	8.6	23 – 235
	SO_4^{2-}	51	0	0.0342	8.9	0.755	4.7	14 – 47
	Alkalinity	51	0	0.00280	61.9	0.004	10.2	41 – 85
	Na^+	51	0	0.155	-16.8	0.988	4.2	21 – 137
	Ca^{2+}	51	0	0.00482	12.4	0.202	2.3	9 – 21
	Mg^{2+}	51	0	0.0188	4.1	0.900	1.5	8.9 – 26
	K^+	51	0	0.00583	0.5	0.924	0.4	1.9 – 6.8

X = EC	Y	Data Points	A	B	C	R^2	SE	Data Range
“Medium” Salinity 1,000 ≤ [EC] < 17,500 μS/cm	TDS	308	4.84E-06	0.544	-20.9	0.996	185	532 – 10,800
	Br^-	266	3.21E-10	0.00114	-0.46	0.982	0.7	0.08 – 19.65
	Cl^-	308	2.42E-06	0.299	-72.5	0.997	89	238 – 5,704
	SO_4^{2-}	308	3.60E-07	0.0400	1.3	0.992	19	40 – 793
	Alkalinity	308	-1.13E-08	0.00168	61.5	0.449	8	46 – 96
	Na^+	308	1.16E-06	0.163	-35.0	0.997	50	138 – 3130
	Ca^{2+}	308	5.06E-08	0.00619	10.9	0.987	4	15 – 135
	Mg^{2+}	308	9.13E-08	0.0207	-0.4	0.991	10	22 – 376
	K^+	308	5.01E-08	0.0062	-0.6	0.979	5	2.6 – 132

X = EC	Y	Data Points	A	B	C	R^2	SE	Data Range
“High” Salinity [EC] ≥ 17,500 μS/cm	TDS	103	0	0.659	-15.8	0.936	2,460	10,200 – 36,200
	Br^-	0	0	0.00123	-0.24	N/A	N/A	N/A
	Cl^-	228	0	0.364	-67.3	0.947	910	5,400 – 18,800
	SO_4^{2-}	0	0	0.0510	4.2	N/A	N/A	N/A
	Alkalinity	70	0	0.000950	66.0	0.509	9	47 – 108
	Na^+	0	0	0.202	-22.9	N/A	N/A	N/A
	Ca^{2+}	0	0	0.00735	12.7	N/A	N/A	N/A
	Mg^{2+}	0	0	0.0244	2.9	N/A	N/A	N/A
	K^+	0	0	0.00729	0.0	N/A	N/A	N/A



TWO-SOURCE LINEAR MIXING ASSUMPTION FITS THE DATA (EXCEPT FOR EC !)

High Salinity Seawater %	Low Salinity Seawater %	EC (uS/cm)	PSU	Na	Ca	Mg	K	Cl	SO4	Alkalinity	Br	TDS
100	0	52000	35.00	10900	423	1325	420	19817	2700	119	68.61	37000
90	10	46825	31.51	9812	382	1193	378	17838	2432	114	61.76	33315
80	20	41650	28.02	8724	341	1062	336	15859	2163	108	54.90	29629
70	30	36475	24.54	7637	300	930	295	13880	1895	102	48.05	25944
60	40	31300	21.05	6549	259	799	253	11901	1627	97	41.20	22258
50	50	26125	17.56	5461	218	667	211	9921	1359	91	34.35	18573
40	60	20950	14.07	4373	177	535	169	7942	1090	85	27.50	14887
30	70	15775	10.59	3285	136	404	127	5963	822	80	20.64	11202
20	80	10600	7.10	2198	95	272	86	3984	554	74	13.79	7516
10	90	5425	3.61	1110	55	140	44	2005	286	68	6.94	3831
9	91	4908	3.26	1001	50	127	40	1807	259	68	6.25	3462
8	92	4390	2.91	892	46	114	35	1609	232	67	5.57	3093
7	93	3873	2.56	783	42	101	31	1411	205	67	4.88	2725
6	94	3355	2.22	675	38	88	27	1213	178	66	4.20	2356
5	95	2838	1.87	566	34	75	23	1015	152	65	3.51	1988
4	96	2320	1.52	457	30	61	19	817	125	65	2.83	1619
3	97	1803	1.17	348	26	48	14	619	98	64	2.14	1251
2	98	1285	0.82	240	22	35	10	421	71	64	1.46	882
1	99	768	0.47	131	18	22	6	223	44	63	0.77	514
0.9	99.1	716	0.44	120	17	21	6	204	42	63	0.70	477
0.8	99.2	664	0.40	109	17	19	5	184	39	63	0.64	440
0.7	99.3	612	0.37	98	16	18	5	164	36	63	0.57	403
0.6	99.4	561	0.33	87	16	17	4	144	34	63	0.50	366
0.5	99.5	509	0.30	76	16	15	4	124	31	63	0.43	329
0.4	99.6	457	0.26	66	15	14	4	105	28	63	0.36	292
0.3	99.7	405	0.23	55	15	13	3	85	25	63	0.29	256
0.2	99.8	354	0.19	44	14	11	3	65	23	63	0.22	219
0.1	99.9	302	0.16	33	14	10	2	45	20	63	0.16	182
0	100	250	0.12	22	14	9	2	25	17	63	0.09	145

ALTERNATE SEAWATER BOUNDARY FORMULATION

(EC ≥ 250 µS/cm)

Practical Salinity Scale at standard pressure & temperature (Schemel, 2000)

S_i = practical salinity of sample i;
R = conductivity ratio of sample i (EC_i/EC_s)
EC_i = EC of sample i;
EC_s = EC of seawater;
K = fitting constants; ∑K = 35 psu

$$S_i = K_0 + K_1[R]^{0.5} + K_2[R] + K_3[R]^{1.5} + K_4[R]^2 + K_5[R]^{2.5}$$

ALTERNATE SEAWATER BOUNDARY FORMULATION

(EC ≥ 250 μS/cm) (CONT'D)

Two-Source Linear Mixing Equation

S_i = *practical salinity of sample i*
S_s = *practical salinity of seawater = 35 psu*
S_f = *practical salinity of freshwater*

C_i = *ion conc. of sample i*
C_s = *ion conc. of seawater*
C_f = *ion conc. of freshwater*

A_i = *proportionality constant*
$\sum C_i \approx S_i$; $\sum A_i \approx 1$; $\sum B_i \approx 0$

$$C_i = A_i S_i + B_i$$

$$A_i = \frac{C_s - C_f}{S_s - S_f}$$

$$B_i = C_f - [A_i S_f]$$

ALTERNATE SEAWATER BOUNDARY FORMULATION

(EC ≥ 250 µS/cm) (CONT'D)

Write $C_i = f(EC_i)$ through substitution

$$C_i = K_0' + K_1' EC_i^{0.5} + K_2' EC_i + K_3' EC_i^{1.5} + K_4' EC_i^2 + K_5' EC_i^{2.5}$$

$$K_0' = [A_i K_0] + B_i$$

$$K_1' = \frac{[A_i K_1]}{EC_s^{0.5}}$$

$$K_2' = \frac{[A_i K_2]}{EC_s}$$

$$K_3' = \frac{[A_i K_3]}{EC_s^{1.5}}$$

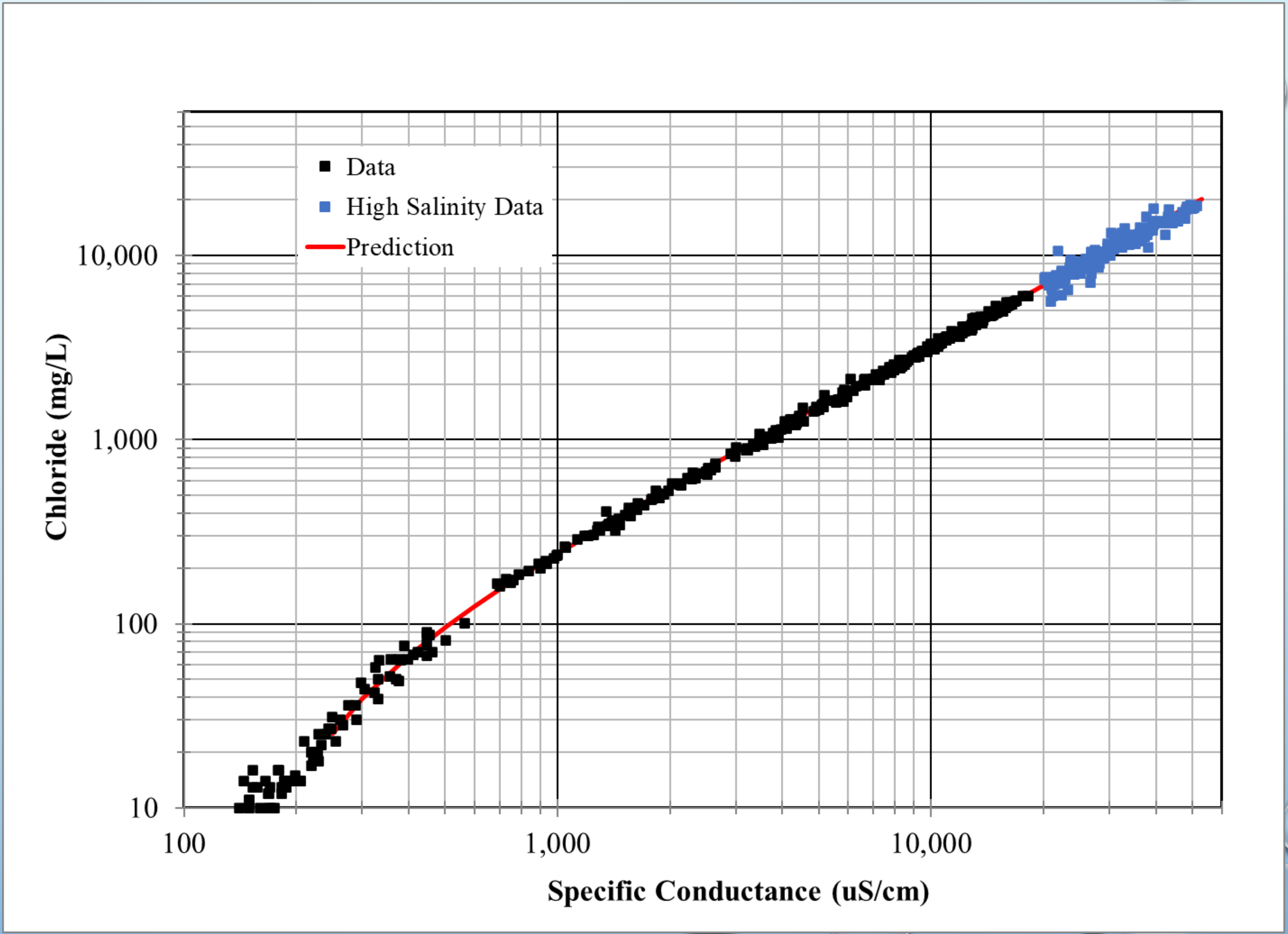
$$K_4' = \frac{[A_i K_4]}{EC_s^{2}}$$

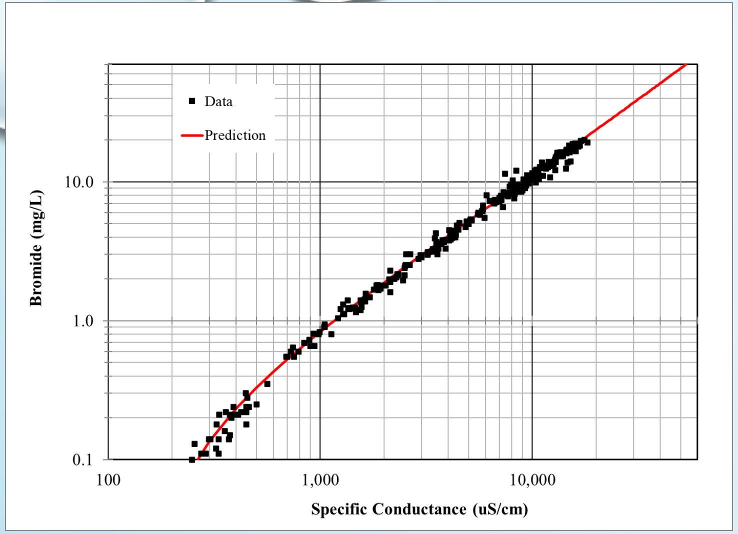
$$K_5' = \frac{[A_i K_5]}{EC_s^{2.5}}$$

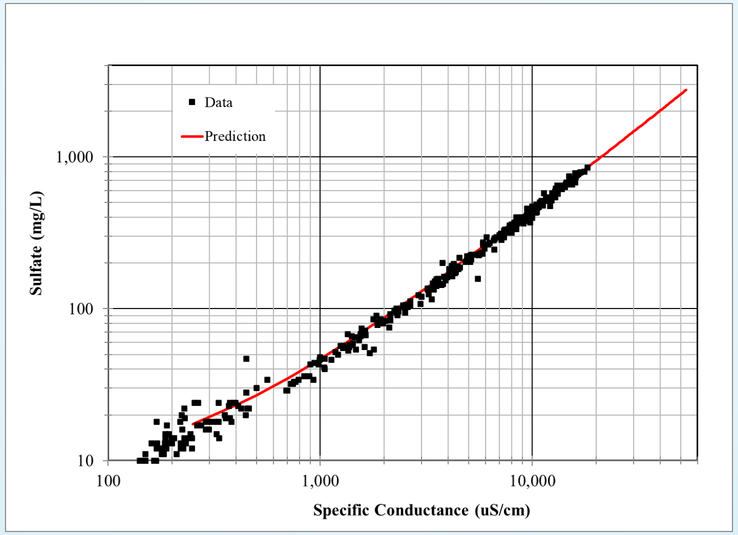
Valid for $EC_i \geq$ 250 µS/cm

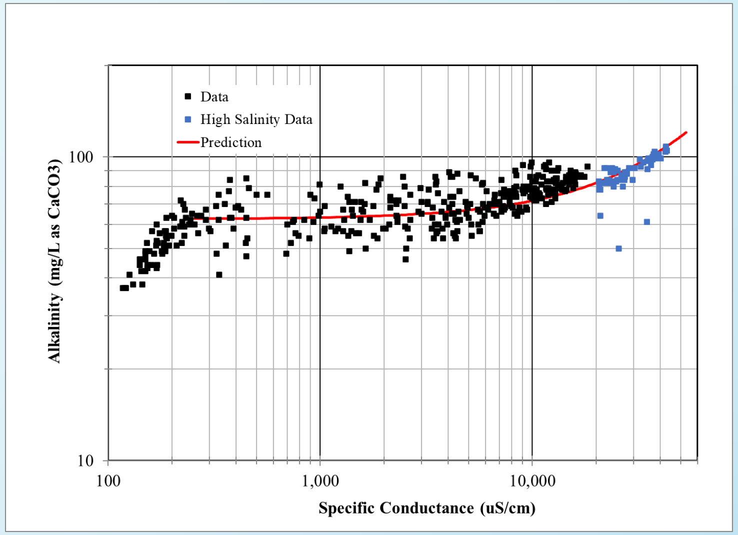
K'_0 = -3.77E+01
K'_1 = -5.41E-01
K'_2 = 2.76E-01
K'_3 = 6.59E-04
K'_4 = -1.36E-06
K'_5 = 2.38E-09

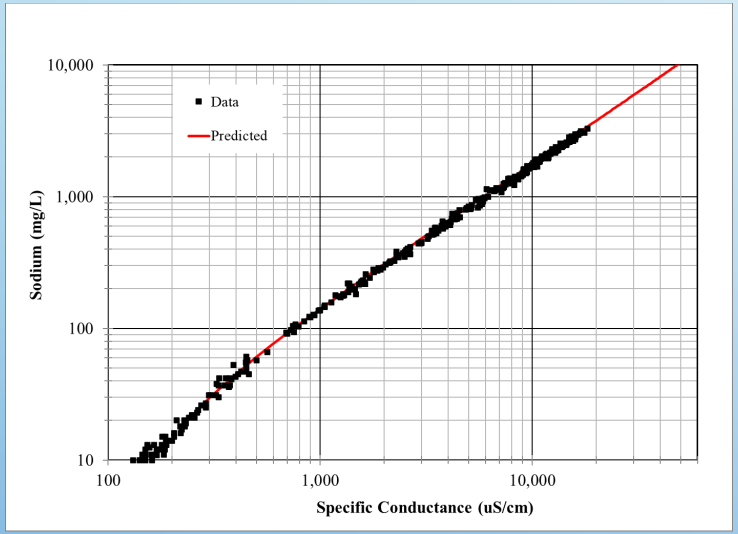
C_s = 19.35 ppt = 19.82 g/L
C_f = 0.025 ppt = 0.025 g/L
S_s = 35 psu
S_f = 0.123 psu
EC_s = 52 mS/cm

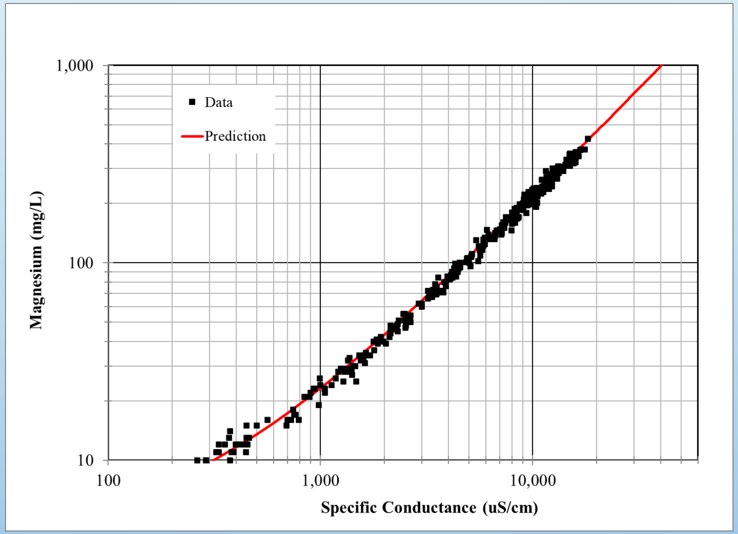


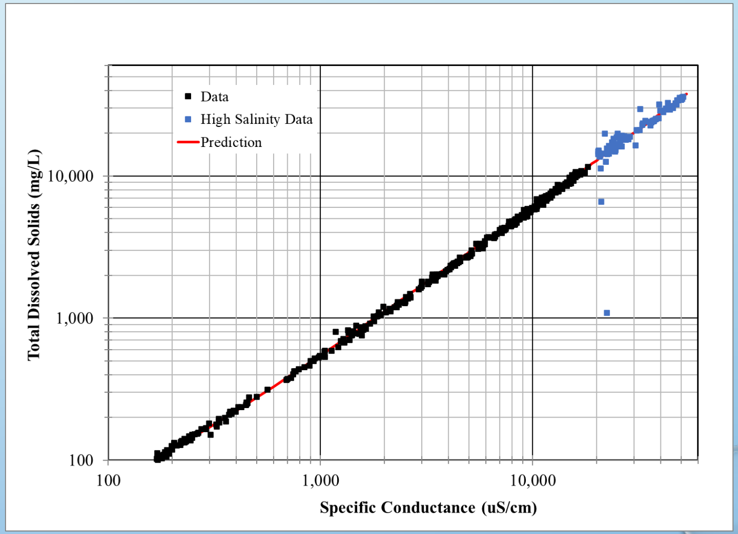

Data
Prediction
Bromide (mg/L)
10.0
1.0
0.1
100
1,000
10,000
Specific Conductance (uS/cm)

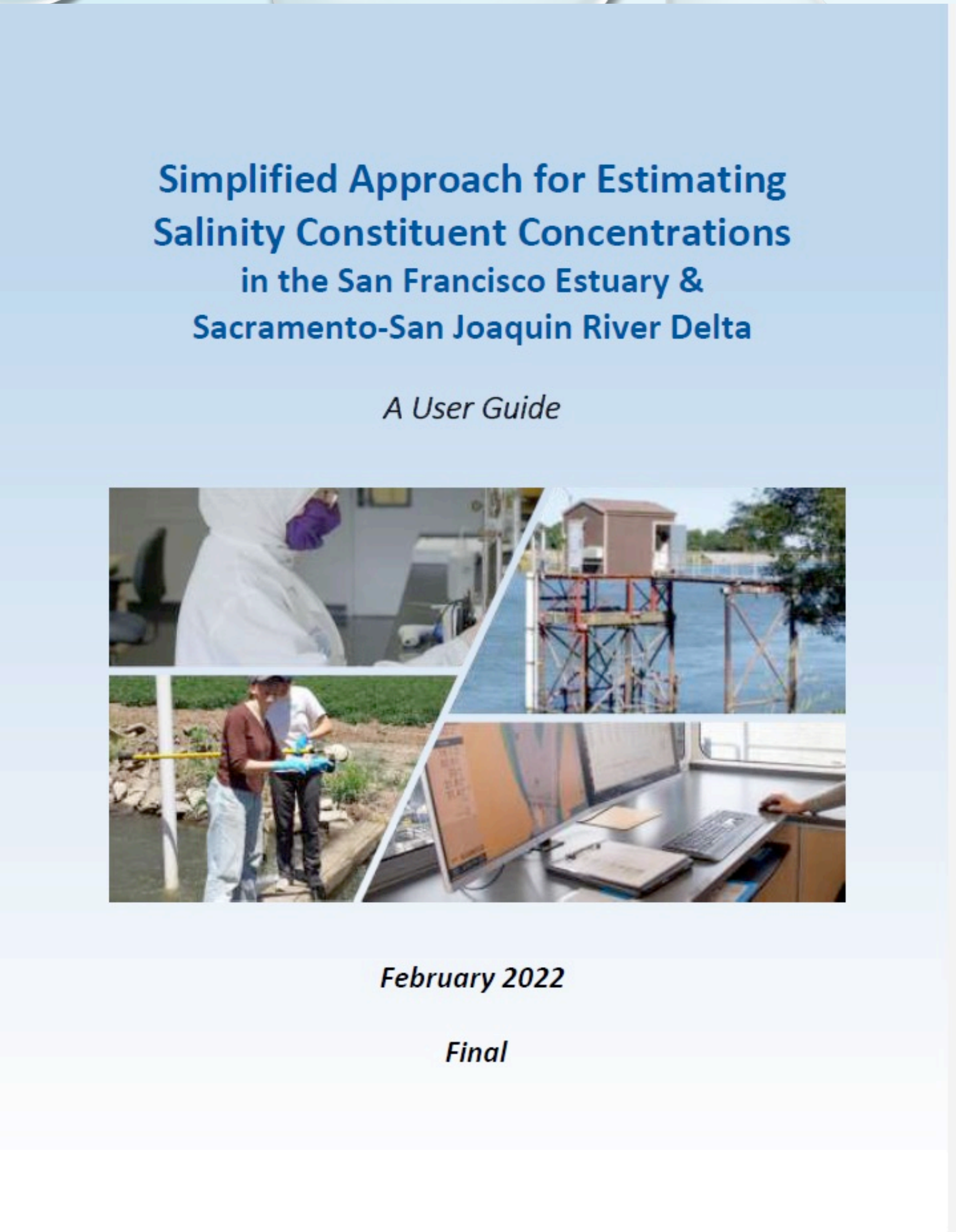

Data
Prediction
Sulfate (mg/L)
1,000
100
10
100
1,000
10,000
Specific Conductance (uS/cm)


Data
High Salinity Data
Prediction
Alkalinity (mg/L as CaCO3)
100
10
100
1,000
10,000
Specific Conductance (uS/cm)


Data
Predicted
Sodium (mg/L)
10,000
1,000
100
10
100
1,000
10,000
Specific Conductance (uS/cm)


Data
Prediction
Magnesium (mg/L)
1,000
100
10
100
1,000
10,000
Specific Conductance (uS/cm)


Data
High Salinity Data
Prediction
Total Dissolved Solids (mg/L)
10,000
1,000
100
100
1,000
10,000
Specific Conductance (uS/cm)


Simplified Approach for Estimating Salinity Constituent Concentrations in the San Francisco Estuary & Sacramento-San Joaquin River Delta

A User Guide

February 2022

Final

IF THIS TOPIC IS OF INTEREST TO YOU:

WEDNESDAY AFTERNOON
SESSION 24
GRAB BAG
1:15-3:00PM