Long-term water quality forecasts using allocation studies

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Outline

- Objectives
- Background
- Methodology
- Hydrodynamics and water quality simulations (with emphasis on Delta)
- Example of long-term forecasting of Delta water quality
- Discussion
- Work in the future

Objectives

- Long-term forecast of water quality in the Delta using DSM2

- Long-term forecast of water quality in O'Neill Forebay, San Luis Reservoir, and the California Aqueduct using the DSM2 California Aqueduct Extension Model

* long-term --- up to 1 year

Background

- O&M has a well-established procedure for short-term (1-2 weeks) forecasts of Delta hydrology, operations and water quality

- Developing long-term forecasting tools is one of the goals of MWQI's Real Time Data and Forecasting (RTDF) Project

- In 2003 the proof of concept of long-term forecasting of Delta and California Aqueduct water quality was advanced
  - ✓ Jim Wilde presented Delta modeling results
  - ✓ Tony Liudzius at MWD presented California Aqueduct water quality modeling results

- In 2005, CH2MHILL developed DSM2 extension for California Aqueduct, South Bay Aqueduct and Delta-Mentota Canal

Method

- Establish initial conditions
  - ✓ Update historical simulation
- Simulate projected conditions through end of year
  - ✓ Allocation studies
  - ✓ Projected astronomical tide
  - ✓ Flow/salinity relation established for planning studies
  - ✓ Gate operations

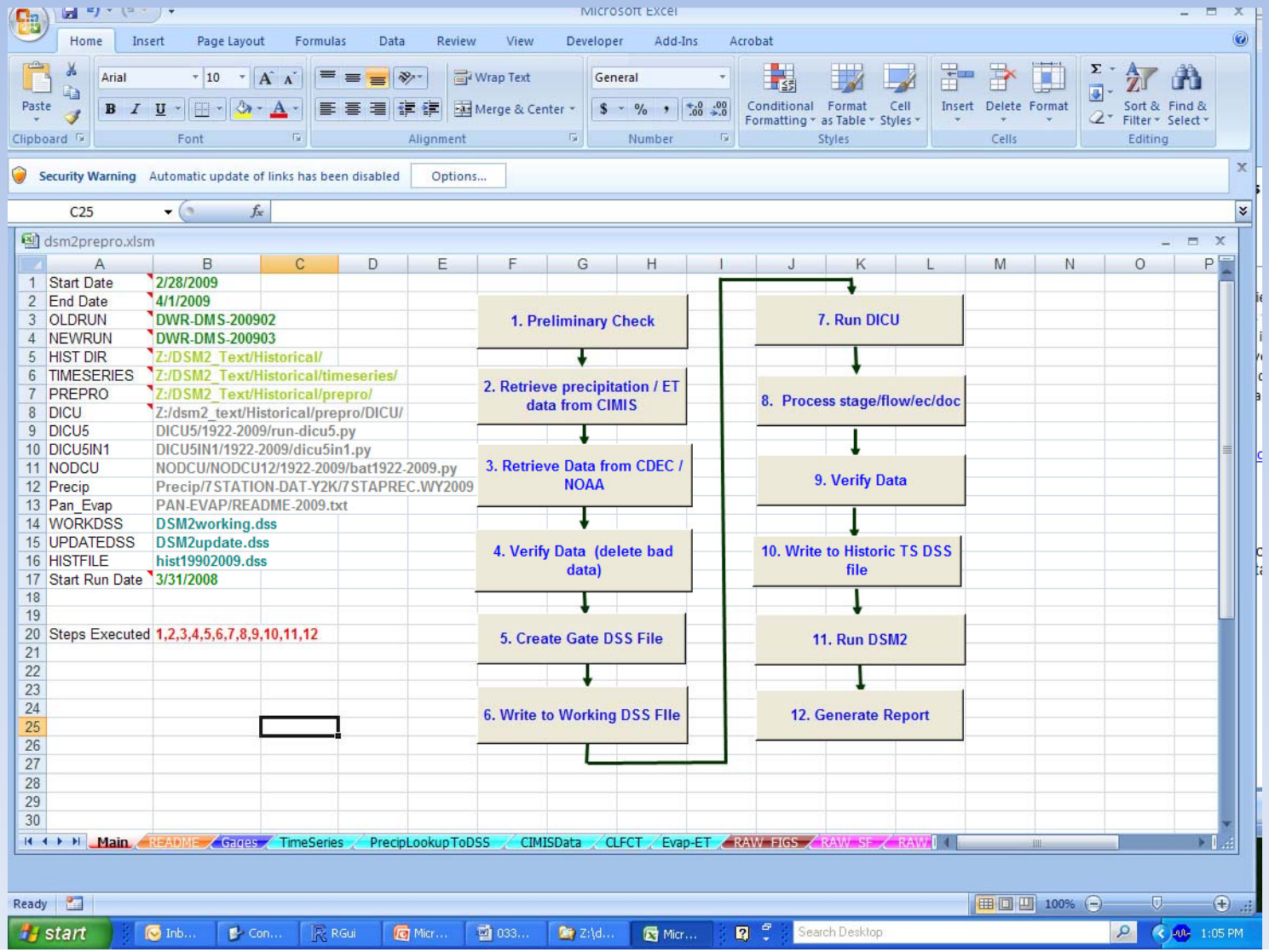
Long-term Forecasting of Delta Water Quality

Initial Conditions

- DSM2 historical monthly update
  - ✓ Download ET, precipitation from CIMIS
  - ✓ Download stages, inflows, outflows, EC, DOC from NOAA, CDEC, and IEP
  - ✓ Download gate operations data from IEP
  - ✓ DICU
  - ✓ Fill missing data
  - ✓ Run DSM2
  - ✓ Generating report

Initial Condition, Cont

- Interface of VBA Tool for DSM2 historical monthly update



Projected Conditions

- Boundary inflows --- forecasted by O&M's Delta Coordinated Operations (DCO) Model
  - ✓ Sacramento River
  - ✓ San Joaquin River
  - ✓ East-side flow (Consumnes, Mokelumne, Calaveras)
- Outflows --- forecasted by DCO model
  - ✓ Delta Consumptive Use
  - ✓ Net Delta Outflow
  - ✓ Pumping (Banks, Jones, North Bay, Contra-Costa)

Projected Conditions, Cont

- Downstream Tide at Martinez
  - ✓ Projected astronomical tide
- *Operation of Delta Structures*
  - ✓ Temporary barriers (HOR, MR, OR, GL) dependent upon time of year and San Joaquin River flow
  - ✓ Delta Cross Channel operation is given as the percentage of time open each month
  - ✓ CLFCT gate is kept open for the whole forecasting period

Projected Conditions, Cont

- Delta Island Consumptive Use (DICU)

  DICU is used to distribute agricultural diversions and drainage via the Adjusted Delta Island Consumptive Use Model (ADICU).

- Forecasted EC at Martinez is calculated by using astronomical tide and a program for filling missing EC

- EC in the Sacramento River and Eastside rivers is assumed to be a constant value of 150

EXCEL Spreadsheet for Proof-of-Concept Using 1999 Allocation Study from DCO Model

d98w0309.xls [Compatibility Mode] - Microsoft Excel

M20 | 105

1998 Delta Coordinated Operation Forecast [taf] For: **Water Budget**

Prob of Exceedence (J-S,O-I) **99%**, 90%
SRI [maf] 23.4
SVI [403030], WY type 10.4, W
SJI [602020], WY type 3.8, AN

DWR forecast date: 3/9
Hydrology f'cast date: 3/1
Projection begins: MAR
Delta Restrictions: D-1485 6/95 rev, 1995 ESA BO's
Roe triggered FEB,MAR, APR,MAY,JUN

Case: 99%,SWP outage 3/5; No AFRP
SWP Deliveries: 100% 2820 taf
CVP Deliv's (est): 85% 2781 taf

1998 Delta Coordinated Operation Forecast [taf] **For: Water Budget**

Name Convention "DyyCmmdd": yy=study year, C=case (w=watbud, ..), mmdd= date
Note: Calculated cells locked, no password needed to unprotect. Input desired data/operation in blue cells.
See instructions below
Suggested Adjustments:

	Lake Shasta Inflow	Keswick Rel plan	Keswick Rel (min)	Eom Storage calc	Eom Storage (max)	Folsom Lake Inflow	Nimbus Rel plan	Nimbus Rel (min)	Eom Storage calc	Eom Storage (max)	Lake Oroville Inflow wKR	FeathRiv Rel plan	FeathRiv Rel (min)	Eom Storage calc	Eom Storage (max)
Jan	1590	1037	331	3390	3830	466	351	136	542	575	839	392	105	2655	2786
Feb	2139	2206	316	3567	4250	730	710	115	559	575	1035	980	96	2714	2786
Mar	890	750	336	3777	4550	462	340	169	672	680	696	400	105	2999	3150
Apr	770	437	312	4199	4550	431	290	149	798	800	638	120	60	3454	3450
May	540	540	246	4304	4550	432	280	184	933	975	548	400	61	3428	3536
Jun	310	780	292	4017	4550	306	285	149	934	975	313	430	60	3146	3536
Jul	236	892	364	3519	4550	161	280	92	792	975	197	430	61	2727	3536
Aug	200	750	321	3130	4550	132	155	92	750	975	166	368	61	2360	3536
Sep	192	440	266	2987	4550	124	130	104	729	975	156	140	60	2301	3350
Oct	220	369	261	2882	3830	50	170	123	601	680	80	180	105	2147	3125
Nov	250	321	193	2823	3250	50	170	119	471	500	108	105	101	2129	2975
Dec	310	310	200	2841	3300	70	160	123	367	400	148	105	105	2161	2850
Year	7647	8832	3563	-	-	3414	3321	1556	-	-	4924	4050	980	-	-
Sept Targets:				1900					200					1570	

	Change Releases due to: DOI Total	Exp/Inf Total	COA CA	RVista Total	Flood Reservation Shas	Fols	Orov	Max or Min Release Kesw	Nimb	Feath	Hyatt off-pk	Maximum Releases Kesw	Nimb	Feath
Jan	-4485	-6238	ok	-3983	ok	ok	ok	-668	-44	ok	0	369	307	736
Feb	-18041	-19465	ok	-9326	ok	ok	ok	-1861	-422	-290	-563	345	286	690
Mar	-2062	-3666	ok	-2293	ok	ok	ok	-381	-33	ok	0	369	307	736
Apr	-463	-1348	ok	-658	ok	ok	+4	-20	ok	ok	0	417	286	714
May	-28	-593	-71	-617	ok	ok	ok	ok	ok	ok	-130	615	307	736
Jun	-1	-173	+4	-618	ok	ok	ok	ok	ok	ok	-74	833	286	714
Jul	-1	-540	+107	-564	ok	ok	ok	-31	ok	ok	-77	861	307	736
Aug	-1	-283	+97	-532	ok	ok	ok	ok	ok	ok	0	861	307	736
Sep	-2	-59	+186	-151	ok	ok	ok	ok	ok	ok	0	476	179	714
Oct	-1	-53	+84	-139	ok	ok	ok	ok	ok	ok	0	430	184	246
Nov	-30	-17	+146	-251	ok	ok	ok	ok	ok	ok	0	357	286	149
Dec	-213	-162	ok	-381	ok	ok	ok	ok	ok	ok	0	369	307	736
Year				553										
				323										

	Delta Inflow & Use: Sacram River Accr	F'port	East Side	SJoaq Vernal	DCU net	Delta Export Pumping: Tracy PP US	(max)	Contra Costa	US Total	Banks PP US	CA	Other	Clifton Court Total	(max)	Grand Total
Jan	3020	4800	160	345	-90	243	246	6	249	0	196	0	196	526	445
Feb	7092	####	523	1557	-386	164	330	6	170	0	5	0	5	903	175
Mar	1485	2975	159	827	30	100	246	8	108	0	6	0	8	549	114
Apr	328	1175	87	614	86	180	152	8	188	0	8	0	12	326	196
May	-2	1218	33	346	139	185	165	9	194	0	170	0	176	340	364
Jun	-139	1356	13	174	220	263	266	11	274	0	220	0	228	397	494
Jul	-246	1356	4	201	267	280	283	13	293	0	390	0	398	411	683
Aug	-143	1130	3	183	232	283	283	13	296	0	395	0	401	411	691
Sep	172	882	3	149	151	250	256	12	262	0	390	0	394	397	652
Oct	140	859	40	110	84	260	259	12	312	40	328	0	370	411	640
Nov	225	821	53	115	34	244	244	11	295	40	354	0	394	397	649
Dec	400	975	77	125	12	246	246	11	297	40	380	0	420	432	677
Year	####	28535	1156	4746	780	2698	2676	120	2938	120	2842	0	3002	5300	5780
													Jan-Jun		1788

	Change Exports due to: DOI Total	Exp/Inf Total	COA CA	Plant Max Tracy	ClifCt	On-pk Banks	S.Luis Stor. US	CA	Total Export limitations: E/I threshold Allow	Differ	Maximum for: plant	NDOI	E/I
Jan	+4485	+4054	ok	+3	+330	0	ok	-6	n/a	n/a	778	4930	4499
Feb	+18041	+6813	ok	+66	+898	0	ok	ok	n/a	n/a	1139	18216	6988
Mar	+2062	+1283	ok	+146	+541	0	-2	ok	n/a	n/a	801	2174	1395
Apr	+463	+472	ok	-28	+214	0	-2	ok	n/a	n/a	382	655	664
May	+28	+207	+71	-20	+64	0	ok	ok	668	+304	408	386	565
Jun	+1	+61	-4	+5	+169	0	ok	ok	586	+92	668	487	547
Jul	+1	+351	-107	+3	+13	-144	ok	ok	1683	+1000	699	676	1026
Aug	+1	+184	-97	-0	+10	-149	ok	ok	1215	+524	701	686	869
Sep	+2	+39	-186	+6	+3	-152	ok	ok	758	+106	661	650	687
Oct	+1	+34	-84	-2	+41	-82	ok	ok	736	+96	679	639	672
Nov	+30	+11	-146	-0	+3	-116	ok	ok	626	-23	652	679	660
Dec	+213	+106	ok	-0	+12	-134	ok	ok	584	-93	689	890	783
Year			-553			(CA)							

	Delta Requirements: Total Inflow	XChan Gates	NDOI Calc	(min)	Export/Inflow Calc	(max)	Control Stnd	COA Account: On?	US Account month	cumul	San Luis Reservoir estimate: gross demand US	CA	Eom Storage US	CA	Total
Jan	6913	0%	6556	2071	6%	65%	excess	Y	0	13	98	60	790	1068	1858
Feb	####	0%	####	2116	1%	35%	excess	Y	0	13	44	97	963	1062	2025
Mar	3969	0%	3822	1760	3%	35%	excess	Y	0	13	94	56	968	1011	1978
Apr	1885	0%	1600	1137	10%	35%	excess	Y	0	13	176	239	968	776	1744
May	1607	18%	1100	1072	22%	35%	excess	Y	-71	-58	300	304	848	636	1485
Jun	1553	53%	834	633	31%	35%	NDOI	Y	4	-54	438	467	668	384	1051
Jul	1571	100%	616	615	43%	65%	plant	Y	107	53	539	521	403	247	650
Aug	1326	100%	398	398	51%	65%	plant	Y	97	150	541	459	141	**179**	320
Sep	1044	100%	237	235	61%	65%	plant	Y	186	336	283	214	**106**	352	458
Oct	1019	100%	291	269	62%	65%	salin	Y	84	420	102	187	302	491	793
Nov	999	50%	312	262	64%	65%	plant	Y	146	566	99	139	487	705	1192
Dec	1187	48%	495	262	56%	65%	plant	Y	0	566	68	114	705	970	1675
Year	43021	-	36418	11090	13%	-	-	(Y/N)	(+) = US credit		2781	2857	-	-	-
									Deliv scaling:		85%	100%	incl loss & S.resv change		

	Close XCG ?	Change Deliv due to S Luis US	CA	Addt'l Delta standards: Rio Vista Calc	(min)	Qwest Calc	(min)
Jan	scour	ok	+6	4136	154	809	n/a
Feb	scour	ok	ok	9498	115	3666	n/a
Mar	scour	+2	ok	2539	246	1300	n/a
Apr	-	+2	ok	956	295	656	n/a
May	-	ok	ok	925	307	188	n/a
Jun	-	ok	ok	915	296	-63	n/a
Jul	-	ok	ok	748	154	-123	n/a
Aug	-	ok	ok	594	61	-193	n/a
Sep	-	ok	ok	448	295	-212	n/a
Oct	-	ok	ok	447	307	-161	n/a
Nov	-	ok	ok	549	295	-239	n/a
Dec	-	ok	ok	689	307	-187	n/a

Enter 12/31 starting and actual storages, leave future blank

Actual Eom Storages to Date	Shas	Fols	Orov	usSL	caSL	usCOA
Dec	2734	421	2224	649	994	13
Jan	3390	542	2655	790	1068	13
Feb	3567	559	2714	963	1062	13
Mar						
Apr						
May						
Jun						
Jul						
Aug						
Sep						
Oct						
Nov						
Dec						

Note: These actual storages override pg 1 calc storage

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99% | 99% (50%) | OR&SL | SumTable | SWP SL Plot | check | SWP DA. | Sheet1

Ready 75%

DCO Model Results Released to Contractors

2009 Delta Coord Operation Fcast [flow cfs, stor. taf] — **For: 2009 Water Planning (Low)**

Prob of Exceedence (J-S,O-D): 50%, 90% | DWR forecast date: 1/1 | Case: Jan EI=35%; V/E =1:1
SRI [maf] 13.5, | Hydrology f'cast date: 1/1 | SWP Deliveries: 24% 1229.3 taf
SVI [403030], WY type 5.9, D | Projection begins: Jan | CVP Deliv's (est): 15% 1374.3 taf
SJI [802020], WY type: 2.6, BN | Delta Restrictions: D-1641 3/15/01 rev; 10/04 BO Salmon; 2/05 BO Smelt
Apr-Jul Feather unimpaired runoff >1068 taf [Y/N]? Last year: N This year: Y

	Lake Shasta					Folsom Lake					Lake Oroville				
	Inflow	Keswick Rel plan	(min)	Eom Storage calc	(max)	Inflow	Nimbus Rel plan	(min)	Eom Storage calc	(max)	Inflow w/KR	FeathRiv Rel plan	(min)	Eom Storage calc	(max)
Jan	5115	3269	3500	1505	3600	1648	829	500	261	350	2802	960	950	1058	2788
Feb	11491	3493	3500	1992	3800	4916	3187	500	350	350	8420	954	950	1470	2788
Mar	10878	3497	3500	2477	4100	5448	1626	500	576	600	8297	813	800	1917	3000
Apr	8148	5495	4000	2646	4550	5025	2353	500	721	800	7180	1731	800	2170	3300
May	6110	4993	5000	2732	4550	5334	894	500	975	975	5695	813	800	2274	3522
Jun	4236	9008	9000	2474	4550	2958	2504	500	975	975	3609	975	800	2244	3522
Jul	3082	12002	12000	1988	4550	1870	2749	500	889	975	2836	4375	800	1940	3522
Aug	2849	10506	10500	1553	4550	1822	1724	500	868	975	2830	7693	800	1454	3522
Sep	2978	7495	7500	1323	4550	1630	1781	750	835	975	2188	5630	800	1164	3300
Oct	3253	6326	4000	1219	3890	813	2732	1000	700	700	1203	2147	1325	1008	3150
Nov	3865	4638	3250	1230	3250	840	3193	1000	550	550	1395	1328	1325	906	3000
Dec	4228	3253	3250	1299	3370	976	2488	1000	450	450	1789	1334	1325	863	2875
Avg.	5519	6165	5750	-	-	2773	2172	646	-	-	4020	2396	956	-	-

	Delta Inflow & Use					Delta Export Pumping									
	Sacram River Accr	F'port	East Side	SJoaq Vernal	DCU net	Tracy PP US	(max)	Contra Costa	US Total	Banks PP US	CA	Other	Clifton Court Total	(max)	Grand Total
Jan	4446	9504	1224	1239	-1424	1301	4200	228	1529	0	1854	0	1854	7093	3383
Feb	20707	28341	1739	3445	-1643	1379	4200	252	1631	0	1379	0	1379	7828	3010
Mar	16751	22688	1664	3485	-616	1675	4200	207	1882	0	1659	0	1691	7261	3541
Apr	7394	16974	1049	3252	849	1597	4200	213	1810	0	1546	0	1613	6680	3356
May	2440	9140	764	5258	2035	748	4200	207	955	0	651	0	748	6680	1605
Jun	-1176	11310	554	1609	3644	1113	4200	165	1278	0	975	0	1109	6680	2253
Jul	-4066	15060	228	1240	4334	4196	4200	181	4376	0	2846	0	2976	6680	7223
Aug	-1952	17971	232	1221	3764	4196	4200	207	4403	0	6587	0	6684	6680	10988
Sep	1344	16251	336	1097	2401	4201	4200	235	4437	0	6605	0	6672	6680	11041
Oct	-407	10799	210	1138	1449	4196	4200	273	4469	0	2196	0	2228	6680	6665
Nov	1479	10638	260	1344	753	4201	4200	309	4511	0	2638	0	2638	6680	7149
Dec	2228	9303	160	1464	492	1252	4200	298	1550	0	1252	0	1252	6924	2802
Avg.	4099	14832	702	2149	1336	2505	4200	231	2736	0	2516	0	2571	6879	5251

	Delta Requirements							COA Account			San Luis Reservoir estimate				
	Total Inflow	XChan Gates	NDOI Calc	(min)	Export/Inflow Calc	(max)	Control Stnd	On?	US Account month	cumul	gross demand US	CA	Eom Storage US	CA	Total
Jan	12195	90%	10235	6236	26%	65%	excess	Y	0	0	799	815	252	321	574
Feb	33764	0%	32395	11400	8%	35%	excess	Y	0	0	1555	1127	242	334	576
Mar	28062	0%	25135	22310	12%	35%	excess	Y	0	0	1065	1412	278	348	626
Apr	21475	0%	17269	17249	15%	35%	X2	Y	-2	-2	1501	1851	280	326	606
May	15359	18%	11712	10272	9%	35%	excess	n	0	-2	2325	2590	178	202	380
Jun	13666	53%	7693	7673	15%	35%	X2	n	0	-2	3278	3560	44	42	86
Jul	16727	100%	5070	5063	42%	65%	salin	Y	-3	-5	3644	2583	73	52	125
Aug	19628	100%	4784	4757	55%	65%	plant	Y	7	3	3148	2326	134	310	444
Sep	17890	100%	4382	4359	60%	65%	plant	n	0	3	2352	1516	241	610	851
Oct	12349	100%	4192	4150	52%	65%	salin	Y	8	11	1550	1209	402	668	1070
Nov	12450	50%	4522	4500	55%	65%	NDOI	Y	1	12	701	1162	609	755	1364
Dec	11143	48%	7827	5000	22%	65%	excess	Y	0	11	835	1161	634	760	1395
Avg.	17892	55%	11268	8583	28%	-	-	-	(+) =US credit		1896	1776	-	-	-

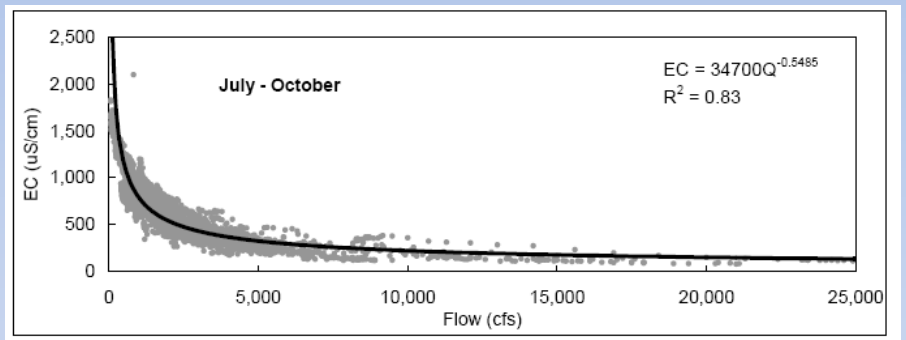
Add buffer

Projected Conditions, Cont

- Forecasted EC in the San Joaquin River at Vernalis is based upon flow-EC relationships

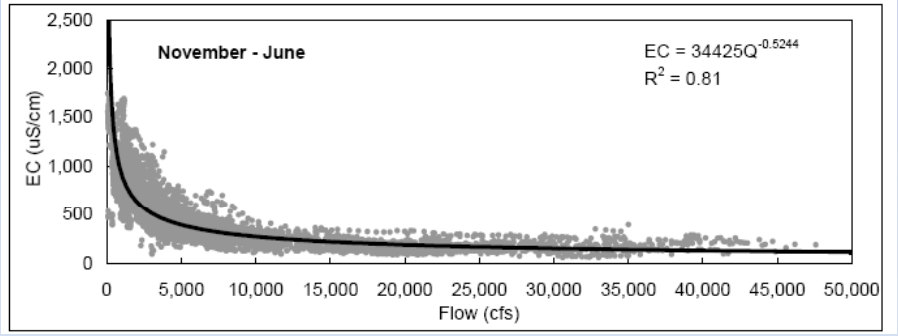
July – October:

$$EC = 34700\ Q^{-0.5485}$$



November - June:

$$EC = 34425\ Q^{-0.5244}$$



- DOC and Bromide have not been incorporated in the Delta forecast model yet

Long-term Forecasting of CA Aqueduct
(Capability currently being developed)

Initial Conditions

- SWP monthly operations data

http://swpoco.water.ca.gov/monthly/monthly.menu.html

- CVO monthly report,

http://www.usbr.gov/mp/cvo/

- Tool for update of CA Aqueduct model

Projected Conditions

- Boundary inflows
  - ✓ Exports at Banks PP
  - ✓ Exports at Jones PP
- O'Neill P/G flows
- Reservoir Storage changes (Del Valle, San Luis, Pyramid, Castaic, Silverwood, Perris)

Projected Conditions, Cont

- CVP Delta Mendota Canal Demands
- CVP Dos Amigos Demands
- Outflows
  - ✓ CVP deliveries including CVP San Felipe Demands
  - ✓ SWP deliveries including South Bay, North Bay, and Coastal Aqueduct
  - ✓ Evaporation & seepage loss

Projected Conditions, Cont

- EC at Banks PP and Jones PP is from the Delta Forecast Model
- Bromide at Banks PP and Jones PP is calculated from an expression consists of
  - ✓ Volumetric fingerprint of Martinez at Banks PP and Jones PP
  - ✓ EC at Banks PP and Jones PP

Projected Conditions, Cont

- Forecasted TDS at Banks PP and Jones PP is based upon EC-TDS relationships

SWP Intake:

$$TDS = 0.545(EC) + 11.0$$

DMC Intake:

$$TDS = 0.558(EC) + 5.0$$

Example of Long-Term Forecasting of Delta Water Quality

Allocation Studies

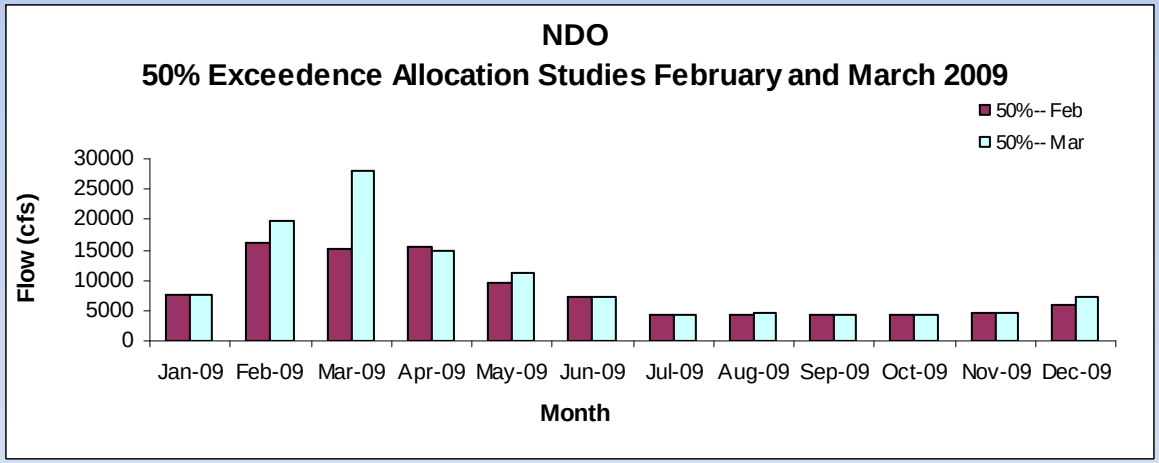
- O&M conducts monthly hydrological forecast using DCO model for different exceedance levels

- We are more interested in the 50% and 90% exceedance levels

- February and March allocation studies based on 50% and 90% exceedance level were conducted

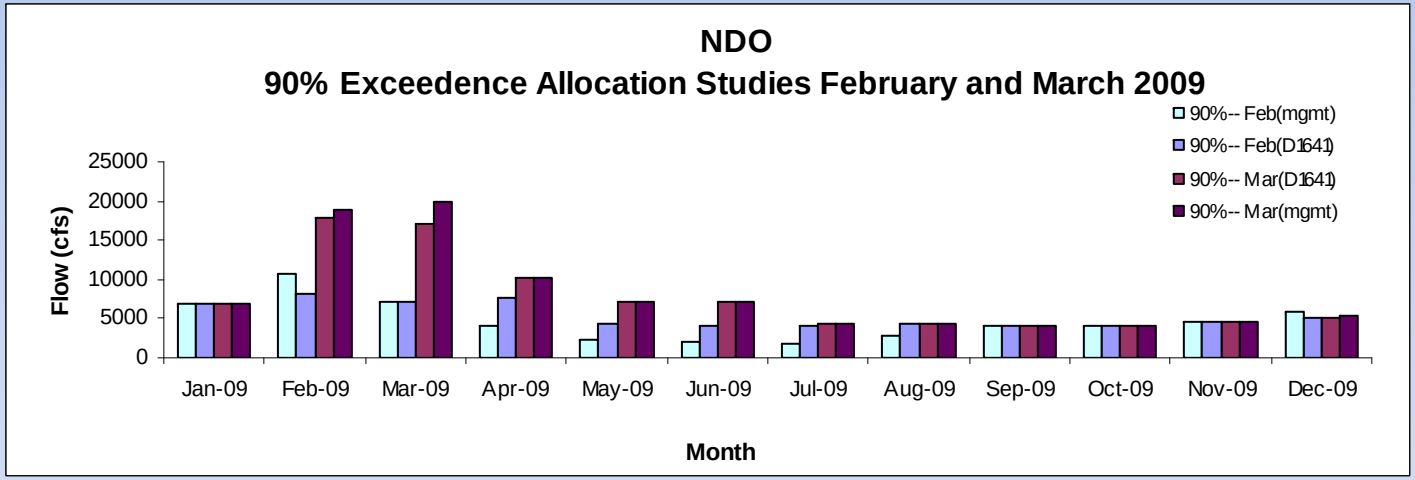
Allocation Studies, Cont

- Comparison of February and March NDO for 50% exceedance level



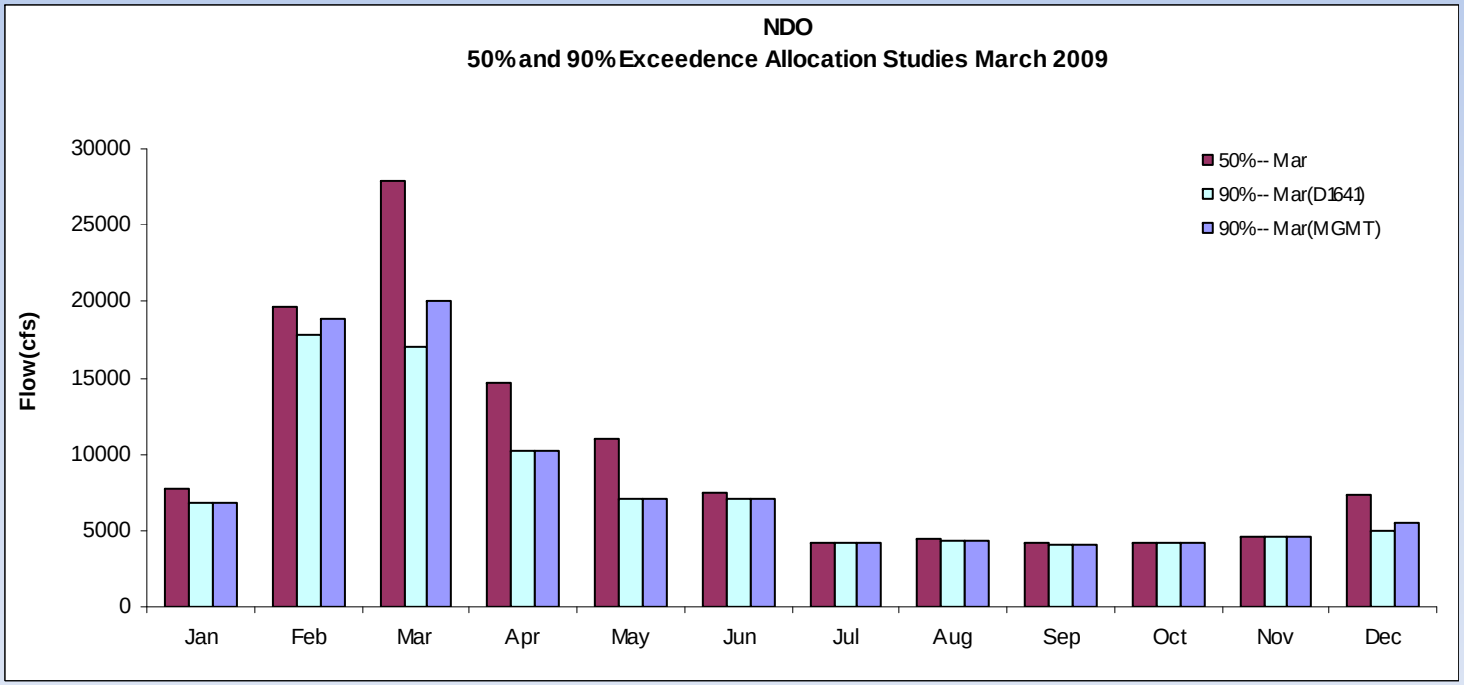
Allocation Studies, Cont

- Comparison of February and March NDO for 90% exceedance level



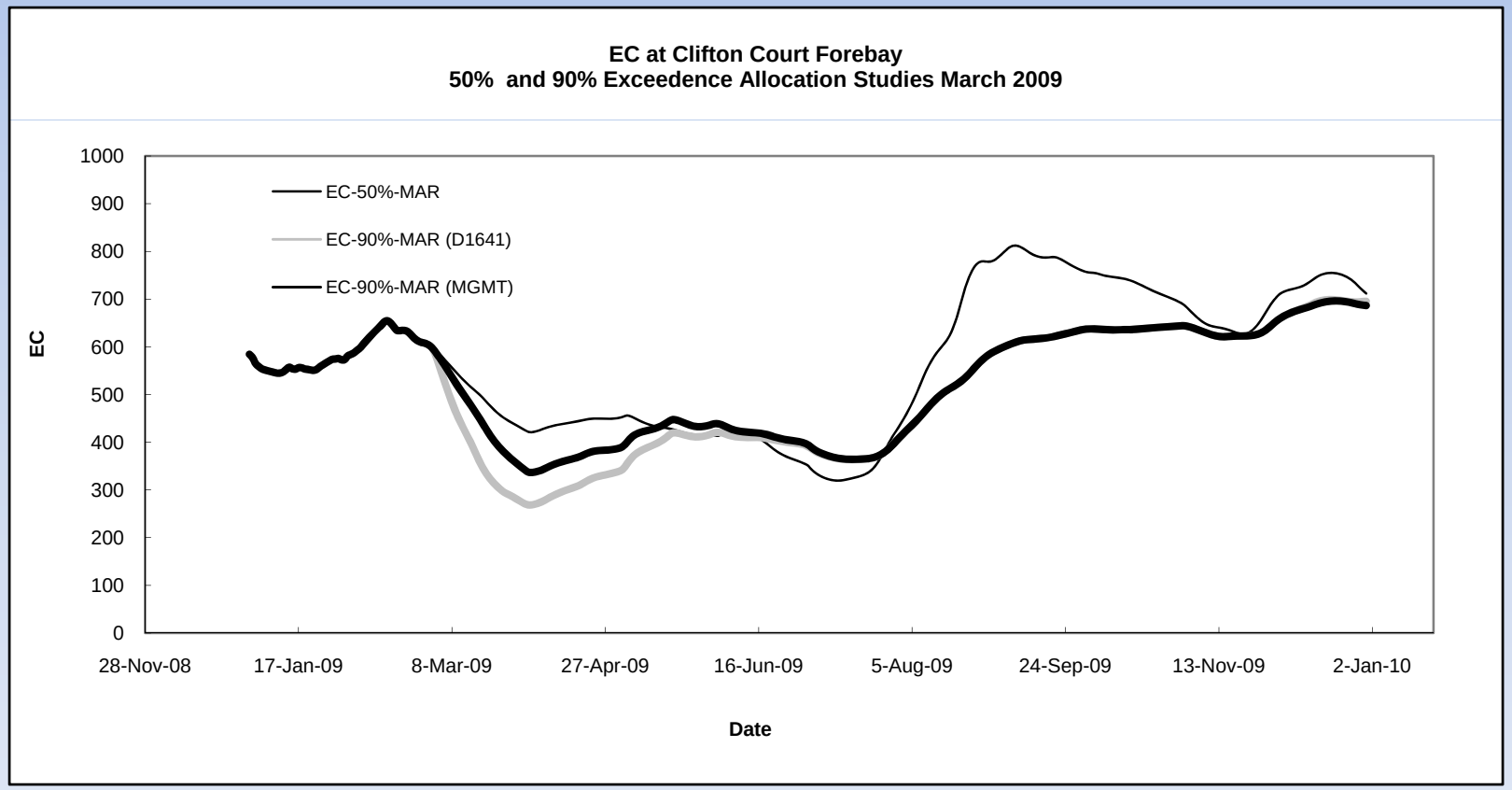
Allocation Studies, Cont

- Comparison of March NDO for 50% and 90% exceedance level



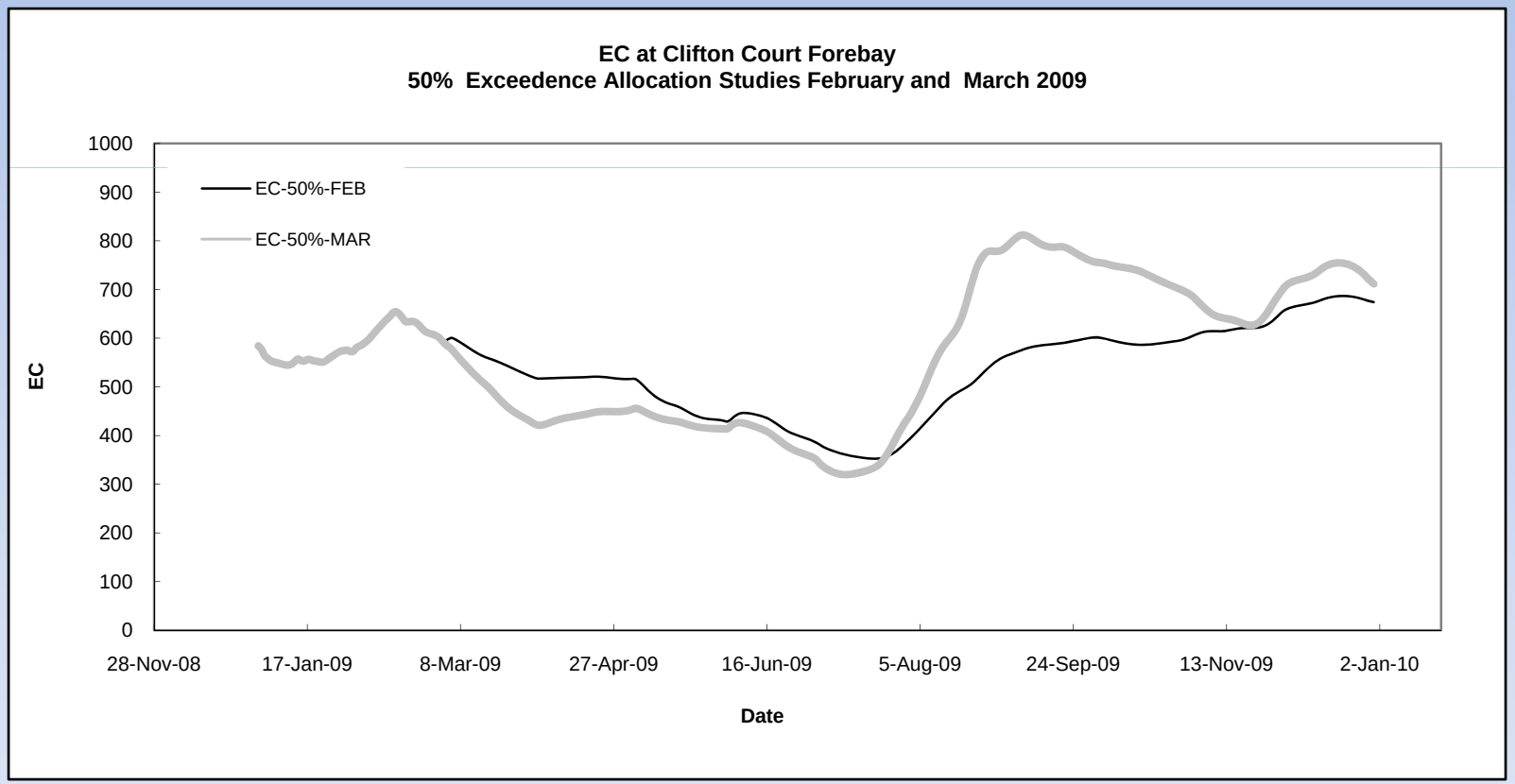
Example of Results

- March 50% and 90% exceedance allocation study



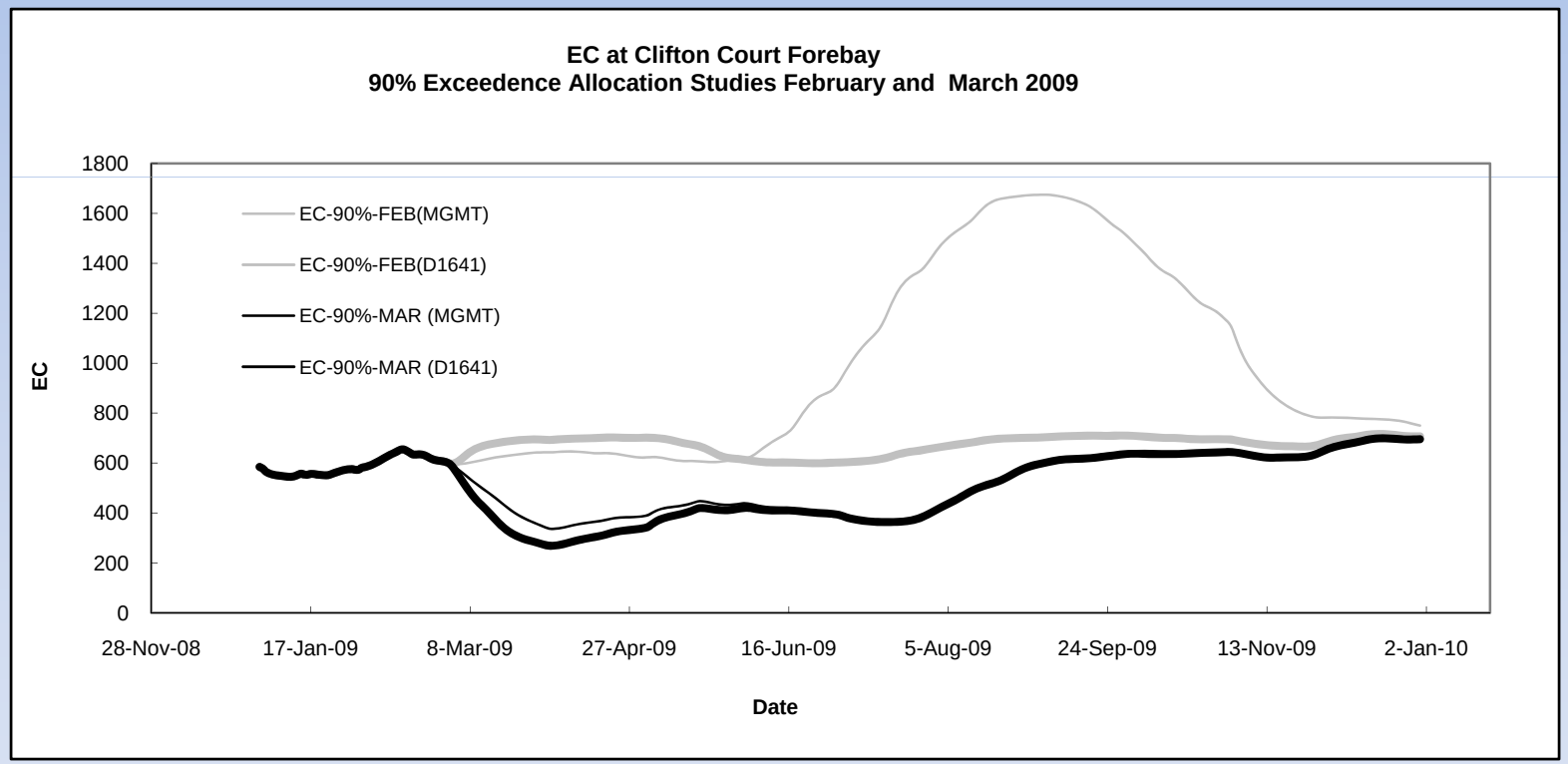
Example of Results, Cont

- 50% exceedence allocation studies (Feb. & Mar)



Example of Results, Cont

- 90% exceedence allocation studies (Feb. & Mar)



Discussion

- The procedure for short-term (1-2 weeks) forecasts of Delta hydrology, operations and water quality can be adapted to a longer-term seasonal forecast

- Water quality forecasts are dependent on the integrity of hydrology and operations forecasts, including tidal conditions, river inflows, DCU, gate and barrier operations, and pumping and delivery schedules.

Discussion, Cont

- Delta DOC forecast has not been incorporated yet because of the difficulty in providing boundary DOC. Implementation depends on the progress of Watershed Analysis Risk Management Framework (WARMF) by Systech .

- CA Aqueduct Water quality forecasts are dependent on Delta hydrology and water quality forecasts, groundwater, storm water forecasts, as well as forecasts of delivery schedules.

Work in the Future

- Delta boundary DOC
- Complete the CA Aqueduct forecast model by using information from OCO's allocation model
- Update historic CA Aqueduct model to current

Questions?