Appendix H: Delta Drinking Water Quality and Treatment Costs

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Outline

- Introduction
- Water Quality in and near Delta
- Disinfection byproducts (DBP)
- Treatment processes for disinfection and DBP removal for Delta waters
- Cost analysis for water qualities and Delta locations
- Residual health risk
- Conclusions

Introduction

- The Delta is the largest single drinking water source for California.
- Treatment costs and public health risks of drinking water drawn from the Delta are expected to increase in the future.
- This appendix explored the current and long-term effects of Delta export water quality on drinking water treatment cost and public health risks from DBP formation.

Source: www.amenfoto.com

Delta Drinking Water Intakes

Current primary intakes for urban uses

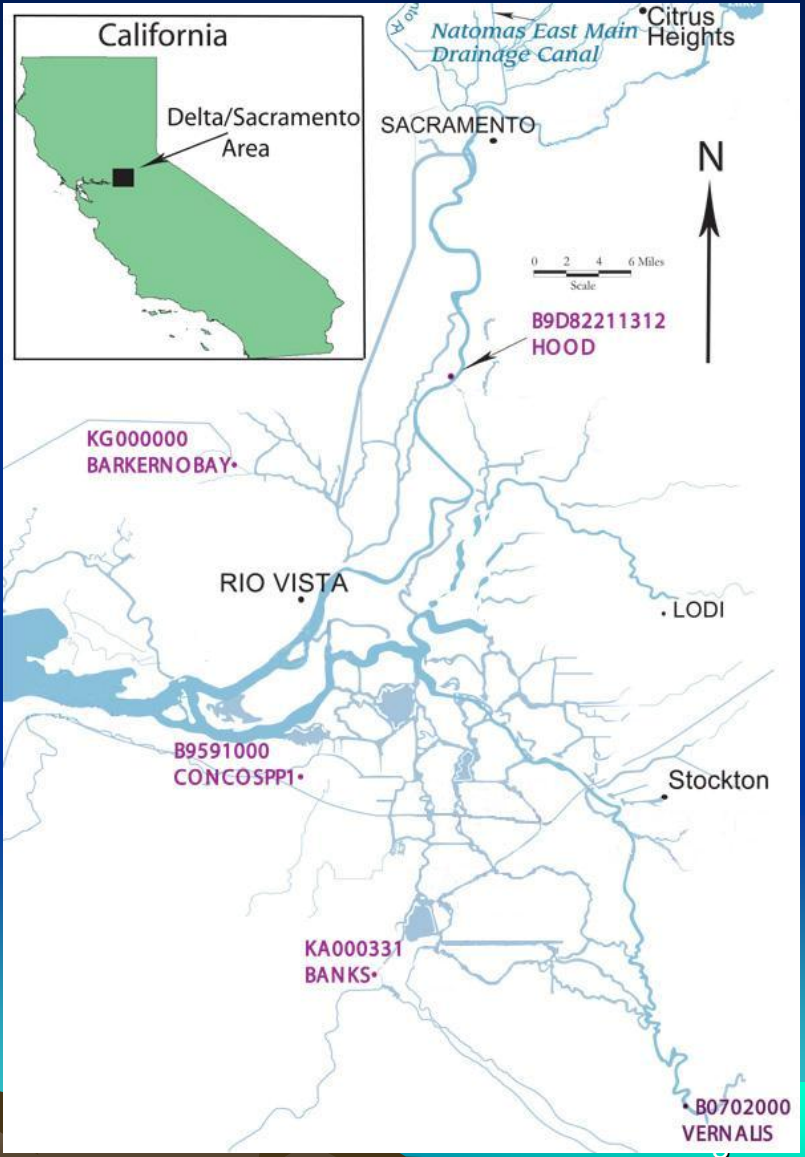
- South Delta intakes
  - Rock Slough and Old River serving Contra Costa Water District
  - The State Water Project (SWP) and main federal Central Valley Project (CVP) Banks and Jones pumping plants
- North Delta intake
  - Barker Slough feeding the SWP's North Bay Aqueduct (NBA)

Delta Source	Water Agency	Treatment Plant	Capacity (mgd)
Contra Costa Canal/ Los Vaqueros	Contra Costa Water District	Randall-Bold	40
		Bollman	75
North Bay Aqueduct (Barker Slough)	Fairfield/ Vacaville	North Bay Regional	40
	Benicia	Benicia	10
	Vallejo	Fleming Hill	42
		Travis Air Force Base	7
South Bay Aqueduct (South Delta pumps)	Zone 7	Patterson Pass	20
		Del Valle	36
	Alameda County Water District	Mission San Jose	10
		Treatment Plant 2	21
	Santa Clara Valley Water District	Penitencia	42
California Aqueduct (South Delta pumps)	Santa Clara Valley Water District (from San Luis Reservoir)	Rinconada	80
		Santa Teresa	100
	Metropolitan Water District of Southern California	Robert B Diemer	520
		Joseph Jensen	750
		Henry J. Mills	326
		Robert A. Skinner	630
		F.E. Weymouth	520

SOURCE: CALFED (2005) and MWDSC website: http://www.mwdh2o.com/index.htm.

Water Quality in and near Delta

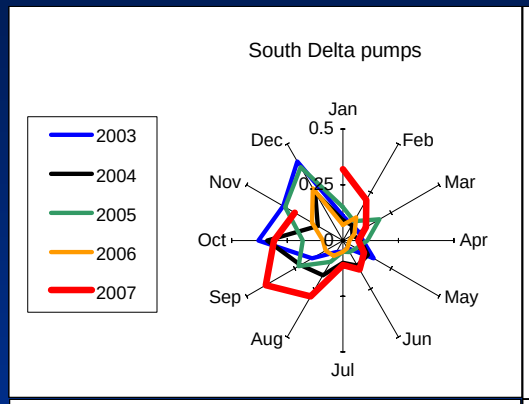
Drinking water constituent	Concern
Electrical Conductivity	Salinity
Bromide	DBP precursor, salinity
Chloride	Salinity
Total Organic Carbon	DBP precursor
Dissolved Organic Carbon	DBP precursor
Total Nitrogen	Algal growth, taste, odor, reduction of dissolved oxygen
Total Phosphorus	Algal growth, taste, odor, reduction of dissolved oxygen
Pesticide/ Herbicide	DBP potential precursor, risks to environmental and public health

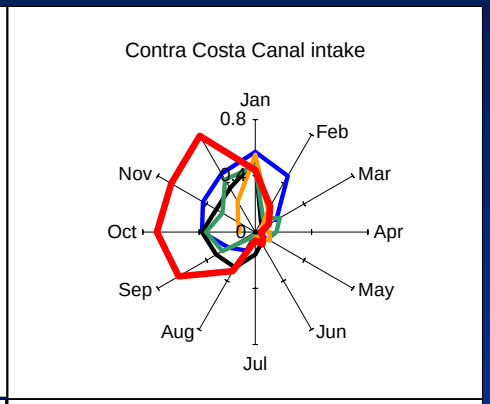


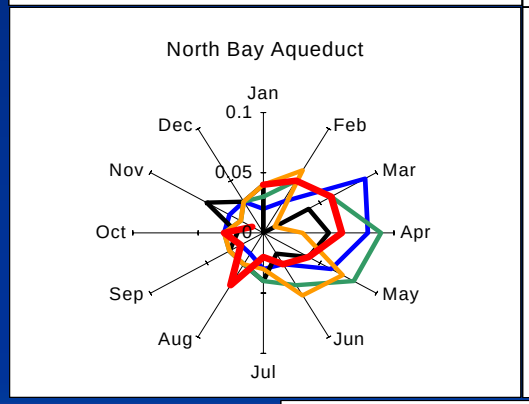
Current Water Quality in and near Delta

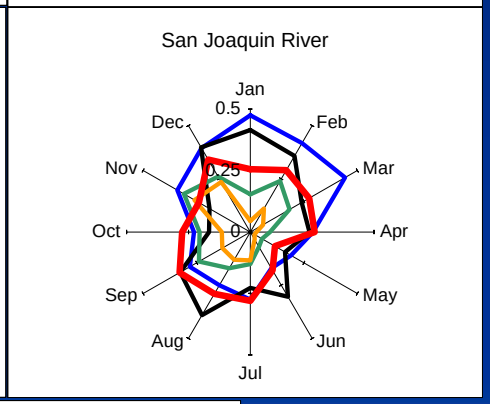
Salinity and Bromide

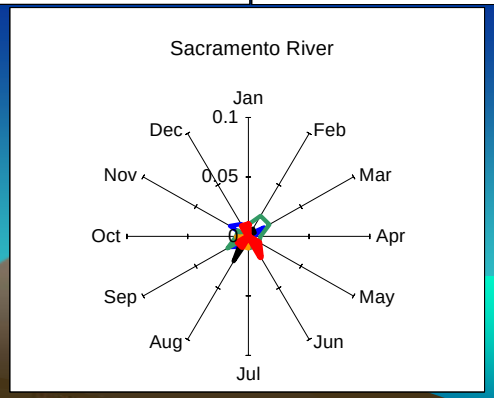
- Similar seasonal patterns for EC, bromide, and chloride concentrations in the Delta.
- Bromide greatest concern for DBP formation.
- CALFED record of decision (ROD) bromide target concentration of 50 μg/l for public health.
- EC, bromide, and chloride show serious salinity problems in the South Delta and San Joaquin River.







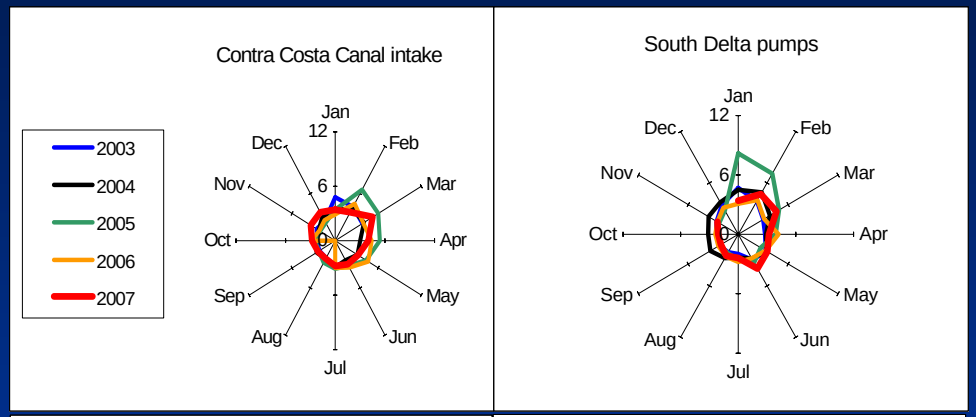


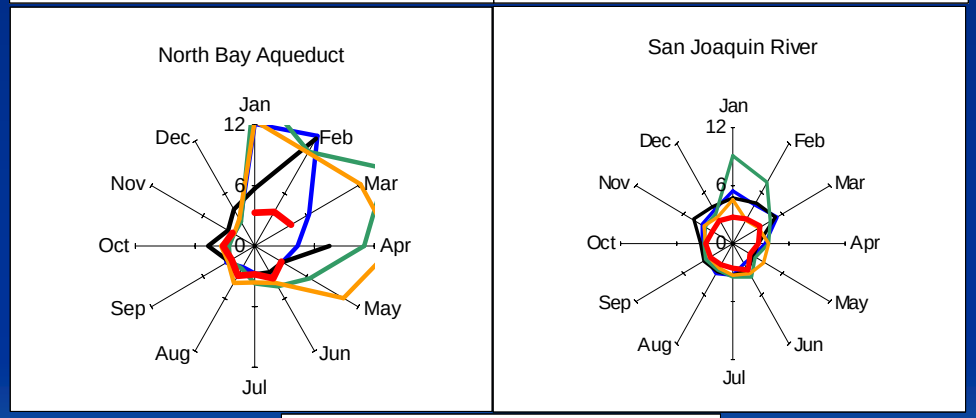


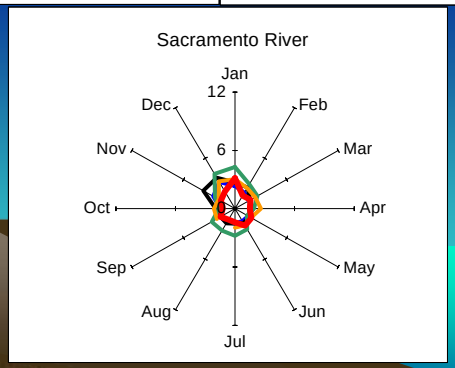
Current Water Quality in and near Delta

TOC and DOC

- Has potential to react with chlorine and ozone to form DBPs.
- High level of organic carbon increases amount of disinfectants required.
- NBA at Barker Slough has a higher TOC/DOC concentration than other selected Delta locations.
- Usually have less annual variability than does salinity.







Current Water Quality in and near Delta

Nutrients

- Nutrients are represented as total nitrogen and total phosphorous concentrations.

- San Joaquin River has the highest nutrient concentrations of these monitoring locations, with peak concentration from winter to late spring and a second peak in the summer from agricultural drainage.

Pesticides and Herbicides

- Several pesticides and herbicides were detected by DWR and DPR at the NBA at Barker Slough, South Delta pumps at Banks, and Sacramento and San Joaquin River.

Future Water Quality in and near Delta

- Likely future water quality in the Delta predicted with respect to EC using hydrodynamic modeling from Appendix C.
- Three long-term conditions: 1 and 3 feet of sea level rise, and the failure of the Delta's western islands
- Likely future EC concentrations used to estimate bromide and chloride concentrations by using MWDSC regression model.

Assumptions:

- CCWD takes water exclusively from Rock Slough
- No changes in upstream or in-Delta operations to meet water quality with sea level rise or island failure.

Current and future water quality conditions at Delta intakes

		Concentration of constituents (Low, **Average**, High)						
Location	Time	Conductance (EC, µS/cm)	Bromide (mg/l)	Chloride (mg/l)	TOC (mg/l C)	DOC (mg/l C)	Nitrogen (mg/l N)	Phosphorous (mg/l)
Sacramento River	Current (2003-2007)	73, **155**, 232	0, **0.01**, 0.02	2, **6**, 10	1.4, **2.4**, 7.0	1.3, **2.0**, 4.3	0.08, **0.68**, 1.40	0.04, **0.09**, 0.17
San Joaquin River	Current (2003-2007)	109, **636**, 1143	0.02, **0.25**, 0.48	8, **71**, 160	2.7, **4.8**, 10.7	2.1, **3.7**, 9.0	0.38, **2.02**, 3.93	0.08, **0.18**, 0.45
North Bay Aqueduct	Current (2003-2007)	136, **299**, 572	N.D., **0.04**, 0.09	6, **20**, 50	2.7, **7.9**, 52.5	2.4, **5.5**, 15.9	0.44, **0.96**, 2.21	0.08, **0.22**, 0.63
South Delta pumps at Banks	Current (2003-2007)	125, **355**, 671,	0.03, **0.15**, 0.41	11, **52**, 130	1.9, **3.8**, 5.7	2.0, **3.2**, 8.2	0.28, **0.89**, 2.50	0.06, **0.10**, 0.28
	1 ft SLR	126, **455**, 1166	0.03, **0.16**, 0.85	11, **80**, 259	N.A.	N.A.	N.A.	N.A.
	3 ft SLR	126, **741**, 2120	0.03, **0.50**, 1.64	11, **152**, 500	N.A.	N.A.	N.A.	N.A.
	W Is. Fail	210, **439**, 729	0.06, **0.25**, 0.49	18, **76**, 149	N.A.	N.A.	N.A.	N.A.
Contra Costa Water District	Current (2003-2007)	151, **497**, 1212	0.03, **0.25**, 0.79	10, **84**, 217	2.2, **3.5**, 6.3	2.1, **3.3**, 6.5	0.24, **0.74**, 3.10	0.03, **0.06**, 0.11
	1 ft SLR	151, **679**, 2010	0.03, **0.45**, 1.55	10, **137**, 472	N.A.	N.A.	N.A.	N.A.
	3 ft SLR	151, **1153**, 3360	0.03, **0.84**, 2.67	10, **256**, 812	N.A.	N.A.	N.A.	N.A.
	W Is. Fail	183, **607**, 1064	0.04, **0.39**, 0.77	12, **118**, 234	N.A.	N.A.	N.A.	N.A.
Record of Decision (ROD) target concentration		-	0.05	-	3	-		

Disinfection byproducts

- DBPs from Bromide and TOC greatest concern.
- Hundreds of DBPs from disinfectants reacting with water quality constituents.
- DBPs include:
  - Halomethanes, haloacids, and total organic halides (most regulated and studied)
  - Aldehydes, bromate, and halonitromethanes (formed with use of ozonation and Ultraviolet irradiation (UV))
  - Bromate and brominated DBPs (formed with bromide)

Treatment Processes for disinfection and DBP precursor removal

- Technologies selected to treat constituents (primarily TOC (& DOC) and bromide) to prevent DBP formation

Alternative disinfection

- Ozonation (widely used for Delta water)
- UV irradiation

Treatment processes for DBP precursor removal

- Enhanced coagulation (removes TOC)
- Adsorption (GAC is common)
- Membrane filtration (MF/UF, NF, and RO)
- Magnetic ion exchange (can remove NOM and bromide)

Current treatment processes in the Delta

	South Bay Aqueduct							Contra Costa Canal/ Los Vaqueros		North Bay Aqueduct				Southern California				
	Zone 7		ACWD		Santa Clara Water District			Contra Costa Water District		Fairfield Vacaville	Benicia	Vallejo		Metropolitan Water District of Southern California (MWDSC)				
Treatment Process	PP	DV	MSJ	TP2	Penitencia	Rinc-onada	Santa Teresa	Randall-Bold	Bollman	NBR	Benicia	Fleming Hill	Travis AFB	Robert B. Diemer	Joseph Jensen	Henry J. Mills	Robert A. Skinner	F.E. Weymouth
Water delivered (mgd)	20	36	10	21	42	80	100	40	75	40	10	42	7	520	750	326	630	520
Filtration/ Separation																		
Anthracite/Sand	X	X		X							X			X	X	X	X	X
GAC/Sand					X	X	X	X	X	X		X	X					
Membranes	X		X															
Disinfection																		
Chlorine	X	X	X		X	X	X			X	X	X	X	X	X	X	X	X
Chloramines	X	X	X	X	X	X	X	X	X					X	X	X	X	X
Ozonation				a	b	(b)	b	b	b	a, c		a, b	a	(a)	a	a	(a)	(a)
Ultraviolet																		

a – Pre, b – Intermediate, c – Post – ozonation use, ()- Under construction

SOURCE: CALFED (2005) and MWDSC (http://www.mwdh2o.com/index.htm)

Treatment Cost Estimation

- Costs of each treatment process investigated in terms of capital and O&M costs, and as a function of source water quality (TOC and bromide).
- System sizes considered from 1 to 520 mgd.
- UV irradiation is potentially cost-effective for replacing current disinfection and oxidation processes (but requires more electricity, lamp cleaning).
- Technologies for additional DBP precursor removal with lowest costs are GAC, followed by MF/UF, and then NF.

Limits of Technologies

- Treatments for Delta water quality conditions to minimize cost within technology limits.
- Results developed using state and local studies, and may differ slightly because of site-specific conditions or different safety factors.
- Ozonation assumed as base treatment technology for disinfection and oxidation.

TOC (mg/l)		
3 - 5	Ozone/GAC or Enhanced Coagulation/ Ozone	UV/GAC with/without MIEX/UF
	Ozone	Ozone/MIEX/UF or UV
	0.3 – 0.5	
	Bromide (mg/l)	

Costs for Treatment Alternatives in Delta

- O&M costs only considered for enhanced coagulation and ozonation since already used in most Delta treatment plants.
- Ozonation costs increase with bromide concentration.
- UV disinfection with other treatments eventually appears cost competitive.

		Estimated costs ($/AF)			
Plant /Intake location	**Treatment**	**Base cost**	**Combined with GAC**	**Combined with MF/UF**	**Combined with NF**
Sacramento River (Hood; medium plant)	Enhanced coagulation /Chlorine	19 – 25	-	-	-
	Enhanced coagulation /Ozone	37 – 62	100 - 343	251 - 363	402 - 525
	Enhanced coagulation/UV	28 - 45	90 - 327	241 - 346	392 - 509
Sacramento River (Hood; large plant)	Enhanced coagulation /Chlorine	18 - 22	-	-	-
	Enhanced coagulation /Ozone	35 - 40	74 - 187	193 - 254	329 – 405
	Enhanced coagulation/UV	24 – 33	63 - 179	182 - 247	318 - 397
North Bay Aqueduct	Enhanced coagulation /Ozone	54 – 81	117 - 363	268 - 382	419 - 545
	Enhanced coagulation/UV	44 – 65	107 - 346	258 - 366	409 - 528
CCWD	Enhanced coagulation /Ozone	66 – 91	128 - 373	280 - 392	431 – 555
	Enhanced coagulation/UV	32 – 50	94 - 332	246 - 351	396 - 514
South Bay (South Delta export)	Enhanced coagulation /Ozone	53 – 78	115 - 359	266 - 379	417 - 541
	Enhanced coagulation/UV	33 – 51	100 - 333	246 - 352	397 - 515
Southern California (South Delta export)	Enhanced coagulation /Ozone	46 – 53	85 - 199	204 - 266	340 - 417
	Enhanced coagulation/UV	25 - 35	64 – 181	183 – 249	318 - 400

Treatment Costs for Future Conditions

- Sea level rise and western island failure increases total costs to treat Delta water.
- Most likely treatment processes and costs highlighted in bold.
- Some treatment technologies might not be practical. UV or additional treatment technologies might be needed.

			Estimated costs ($/AF)				
Plant /Intake Location	Condition	Bromide (mg/l)	Enhanced coagulation /Ozone	In combination with GAC	In combination with MF/UF	In combination with MIEX/MF /UF	In combination with NF
Sacramento River (Medium plant)	All	0.01	**37 - 62**	100 - 343	251 - 363	301 - 463	402 - 525
Sacramento River (Large plant)	All	0.01	**35 - 40**	74 - 187	193 - 254	243 - 354	329 - 405
CCWD	Current (2003-2007)	0.25	**66 - 91**	128 - 373	280 - 392	330 - 492	431 - 555
	1 ft SLR	0.45	91 – 127	**153 - 409**	305 - 428	355 - 528	455 - 591
	3 ft SLR	0.84	147 – 183	209 - 465	360 - 484	**410-584**	511 - 647
	W is. Fail	0.39	82 - 119	**145 - 400**	296 - 420	346 - 530	446 - 582
South Bay (South Delta export)	Current (2003-2007)	0.15	**53 - 78**	115 - 359	266 - 379	316 - 479	417 - 541
	1 ft SLR	0.26	63 – 100	**126 - 381**	277 - 401	327 - 501	428 - 563
	3 ft SLR	0.50	98 - 134	**160 - 416**	311 - 435	361 - 535	462 - 598
	W is. Fail	0.25	62 - 98	**124 - 380**	276 - 399	326 – 499	426 - 562
Southern California (South Delta export)	Current (2003-2007)	0.15	**46 - 53**	85 – 199	204 – 266	254 – 366	340 - 417
	1 ft SLR	0.26	61 - 78	**124–360**	275 – 379	325 – 479	426 - 542
	3 ft SLR	0.50	96 – 113	**158–394**	309 – 414	359 – 514	460 - 576
	W is. Fail	0.25	60 – 77	**122–359**	274 – 378	324 – 478	425 - 541

Residual health risks

Ozonation

- Avoids chlorinated DBPs (THMs and HAAs), but forms ozonation DBPs.
- Of ozonation DBPs, bromate is greatest concern.

UV irradiation

- Has fewer DBP issues.
- Not effective for water with high turbidity or suspended solids.
- Formation of some DBPs enhanced by UV.

- Ozone and UV require chlorination or chloramination for residual disinfection.
- More brominated DBPs could form if bromide not removed and high bromide-to-TOC ratio occurs with chlorination or chloramination.

Conclusions

- Salinity poses water treatment constraints for South Delta intakes.
- High TOC/DOC concentrations occur at NBA and South Delta intakes.
- Although Sacramento River has lower salinity and TOC/DOC concentrations, has occasional pesticide and herbicide contamination.
- Delta drinking water quality problems from DBPs produced by reactions between Delta water and disinfectants used.
- Ozone likely will continue as primary disinfectant for agencies using Delta water.

Conclusions

- Contra Costa Canal intake has highest treatment cost increases.
- Treatment cost difference between South Delta and Sacramento River will increase from $20 - $60/af to $100 - $500/af.
- With 1.5 million af/yr use, treatment cost difference increases from $30 - $90 million/yr currently to $200 - $1000 million/yr in the future.
- Residual health risks may significantly affect selection and operation of water treatment.

	Annualized treatment cost ($/af)			
Plant/Intake location	Current (2003 – 2007)	1 ft SLR	3 ft SLR	W Is. Fail
Sacramento River (Medium plant)	37 – 62			
Sacramento River (Large plant)	35 – 40			
CCWD (Contra Costa Canal intake)	66 - 91	153 – 409	410 – 584	145 - 400
South Bay (South Delta pumps)	53 – 78	126 – 381	160 – 416	124 – 380
Southern California (South Delta pumps)	46 – 53	124 – 360	158 – 394	122 - 359

Acknowledgements

- Thanks to many people who helped us understand the drinking water quality and treatment problems of Delta, and prepare the report.

Source: California Department of Water Resources

Questions?

Source: California Department of Water Resources