Evaluation of the Impacts of California's Mandatory Minimum Penalty Enforcement Program on Effluent Quality and Surface Water Quality in the Sacramento-San Joaquin Delta

VICTOR VASQUEZ, D.Env.

UCLA Environmental Science and Engineering Program

Advisor/Co-author
Dr. Michael Stenstrom,
UCLA Dept. of Civil and Environmental Engineering

OVERVIEW

- Dischargers subject to NPDES permits
- Violations of NPDES permits result in enforcement actions
- New type of enforcement action – mandatory minimum penalty. Does it work?
- Do mandatory minimum penalties result in improved water quality?

CLEAN WATER ACT (1972)
"to restore and maintain the chemical, physical, and biological integrity of the Nation's waters"

Clean Water Act
40th Anniversay

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

NPDES Permits

- For municipal and industrial dischargers
- Effluent limitations
  - Technology-based
  - Water Quality-based
- Monitoring and Reporting Requirements

Violation: Reported value > Effluent limitation

Enforcement in California

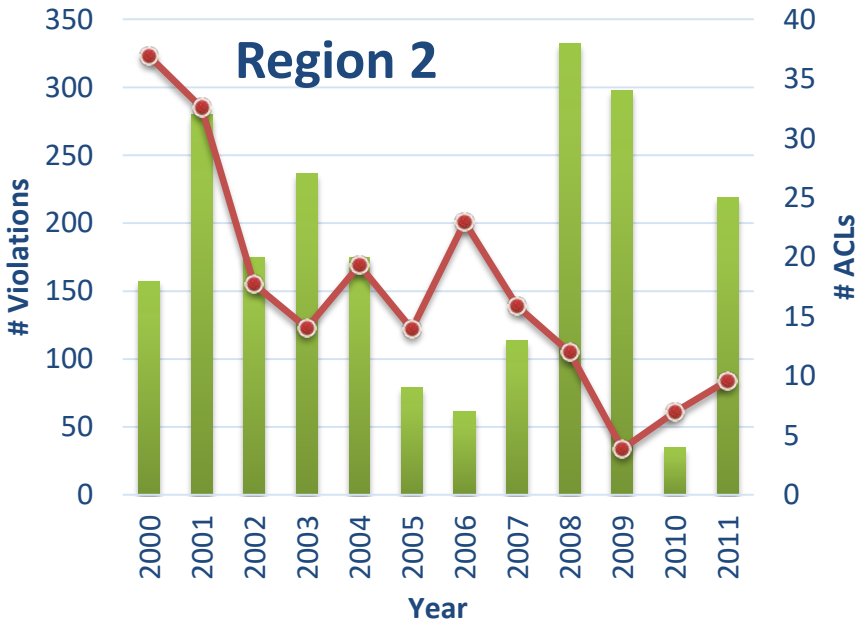
- Administrative Civil Liability (ACL)
  - Monetary penalties
  - Before 2000: Only discretionary ACLs
  - 2000: Mandatory Minimum Penalties (MMP)
    - Clean Water Enforcement and Pollution Prevention Act

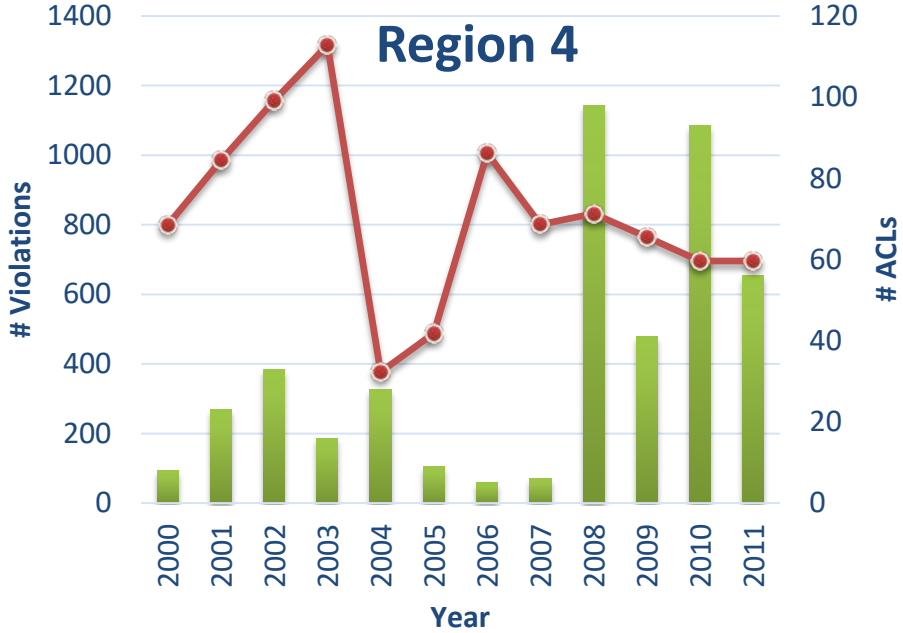
- Cease and Desist Order (CDO)
  - Corrective actions completed within 1 to 5 years

MMP Enforcement Program

- $3,000 MMP for each serious violation
  - *40% above conventional pollutant effluent limit*
  - *20% above non-conventional pollutant effluent limit*
  - *each 30-day period a monitoring report is late*

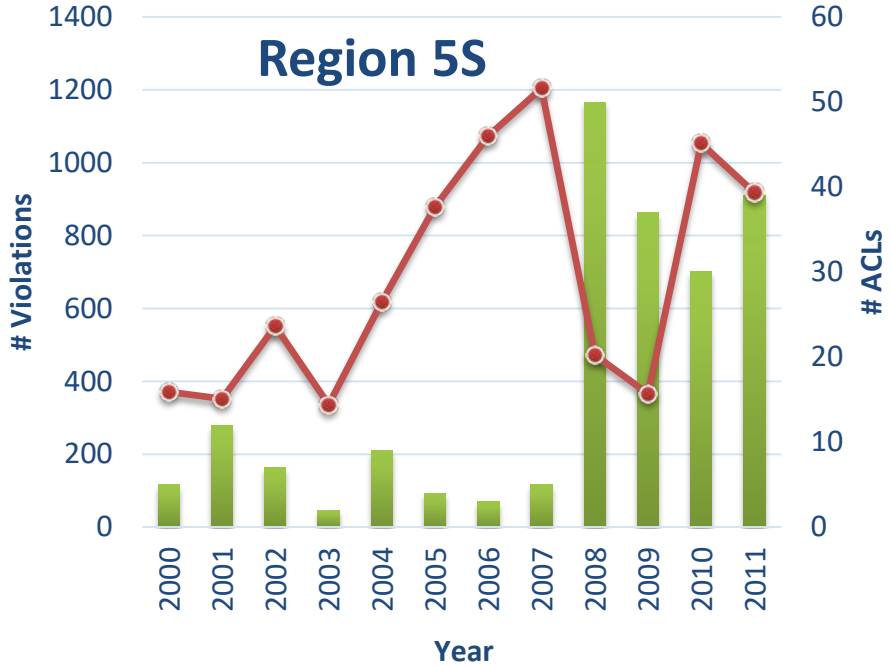
- $3,000 MMP for each chronic violation after third serious or chronic violation in a six-month period.
  - *Any non-serious effluent limit violation*





Number of ACLs

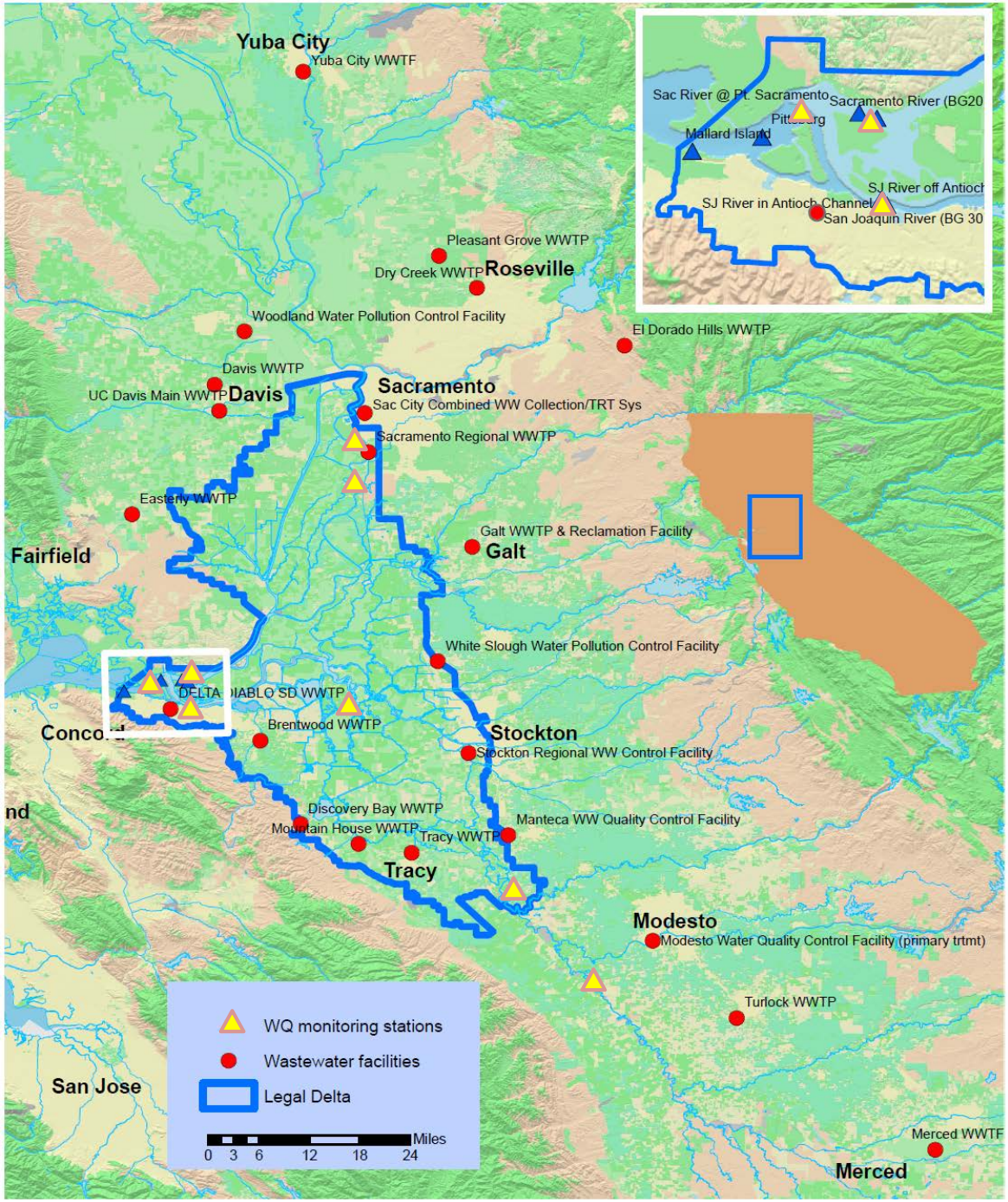
Total MMP Violations



Impact of MMPs on Effluent Quality?

- Correlate Effluent quality with MMP factors

- 22 major wastewater treatment plants



Data Source

California Integrated Water Quality System (CIWQS)

- Facility Characteristics
- Facility effluent data
- Enforcement actions

USEPA Envirofacts

- Facility effluent data

California Dept. of Water Resources Dayflow Model

- Delta flow rates

California Environmental Data Exchange Network (CEDEN)

- Delta water quality monitoring data

Effluent Constituents

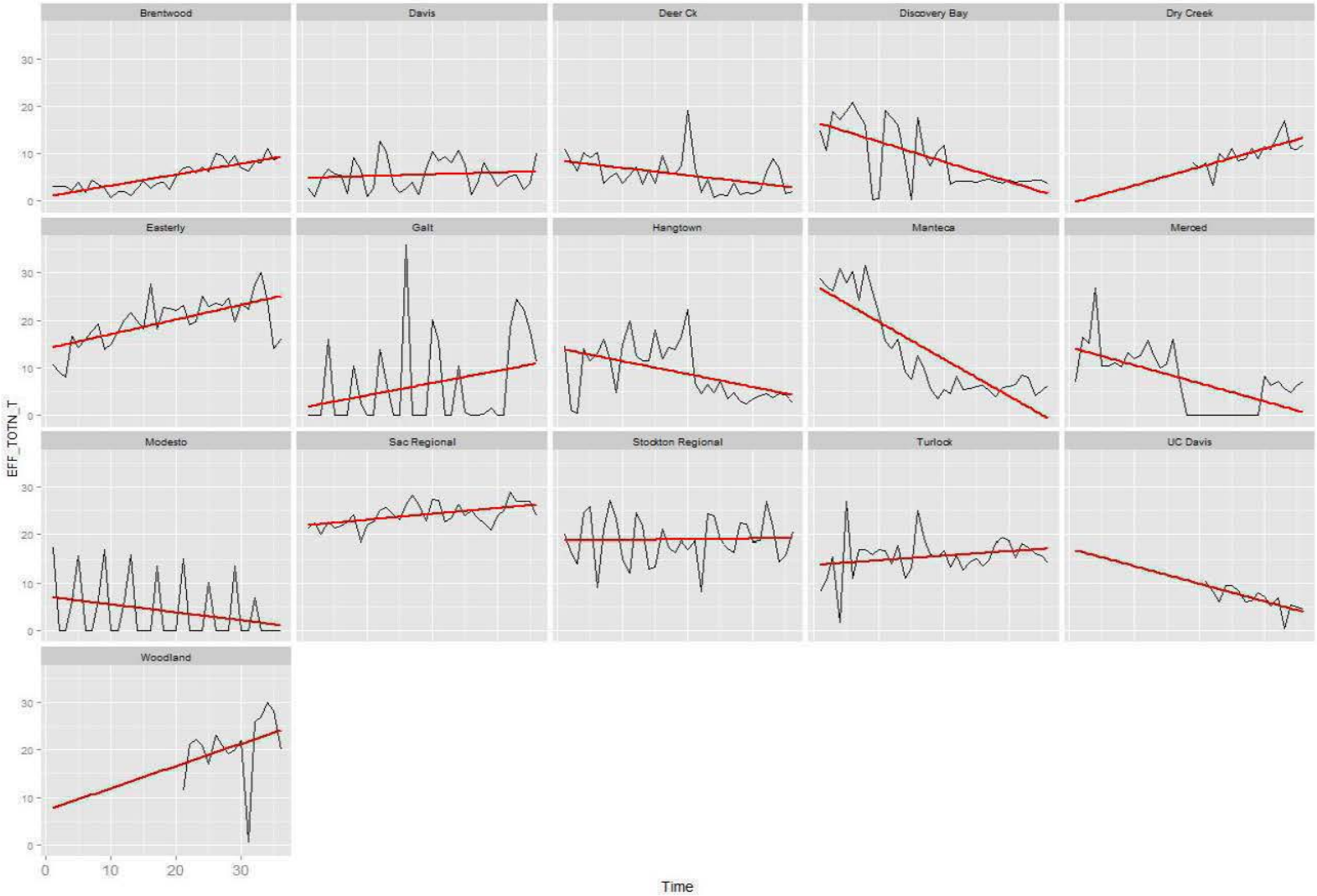
Total Nitrogen

- *Delta waterways listed for nutrients*

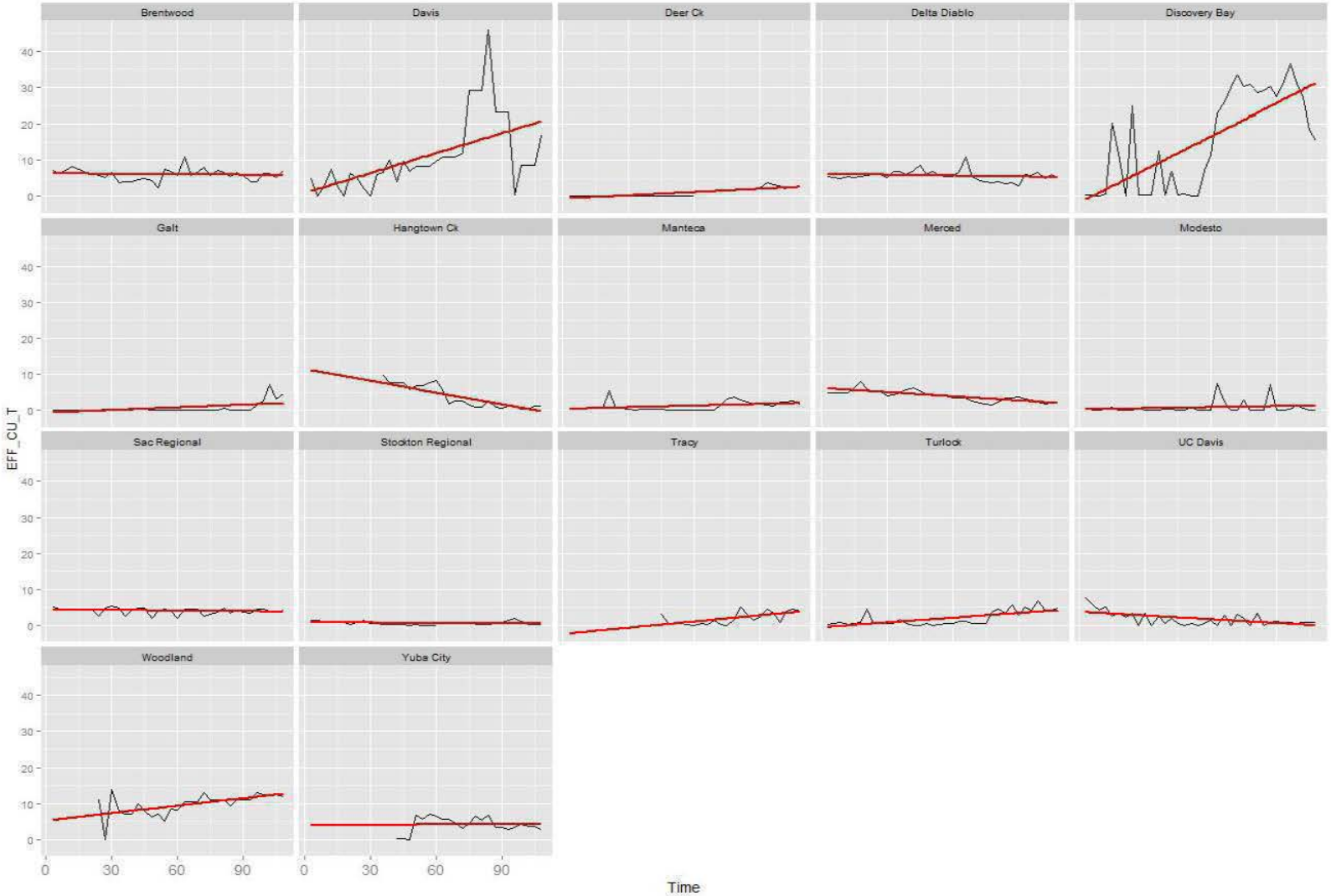
Total Copper

- *Delta waterways listed for metals*

Total Nitrogen Quarterly Average Effluent Concentrations



Total Copper Quarterly Average Effluent Concentrations



Linear Regression Modeling

$$y = \alpha + \beta_i X_i + \varepsilon$$

- dependent variable, *y*
- model intercept, α
- independent variable X_i
- regression coefficient, β_i
- ε is the error term.

p-value, type I and II errors

Null Hypothesis, H_o: $\beta i = 0$

Alternate Hypotheis, H_a: $\beta i \neq 0$

p-value = 0.1 for statistical significance

- *Type I error: rejecting H_o when H_o is true*
- *Type II error: failure to reject H_o when H_o is false*

Model Variables

Dependent Variable

- Quarterly average water quality concentration (22 facilities, quarterly 2004 – 2012, N = 792)

Explanatory Variables

- ACL issued to each facility
- CDO issued to each facility
- ACL Lagged effects
- ACL constituent-specific?
- Monthly average BOD effluent concentration
- Month
- Facility size - daily discharged volume (MGD)

Linear Regression Model

$$\log(EFF_{it}) = \alpha + \beta_1 TIME_t + \beta_2 FACILITY_i +$$

$$\beta_3 \log[EFF_{i(t-1)}] + \beta_4 \log[EFF_{i(t-4)}] + \beta_5 CDOTSO_{it} +$$

$$\sum_{q=1}^{20} \theta_q ACLQ_{itq} + \quad \sum_{y=1}^{5} \gamma_y ACLY_{ity} + \varepsilon$$

where EFF_{it} is the effluent concentration for total nitrogen or total copper.

Model Results: *Total Nitrogen*

Model Variable	Model 1		Model 2	
	Estimate	Signif. Code	Estimate	Signif. Code
$EFF_{i\,(t\,-\,1\ month)}$	0.572	a	0.563	a
$EFF_{i\,(t\,-\,12\ month)}$	0.062		0.066	d
$CDOTSO_{i\,t}$	0.218		0.215	d
$ACLQ_{i\,t\,7}$	-0.313	c		
$ACLY_{i\,t\,1}$			-0.174	d
$ACLY_{i\,t\,2}$			-0.255	c
$ACLY_{i\,t\,5}$			-0.275	c

Signif. codes: 0 ‘a’ 0.001 ‘b’ 0.01 ‘c’ 0.05 ‘d’ 0.1 ‘ ’ 1

Model Results: *Total Copper*

Model Variable	Model 1		Model 2	
	Estimate	Signif. Code	Estimate	Signif. Code
$EFF_{i\ (t\ -\ 1\ month)}$	0.512	a	0.531	a
$EFF_{i\ (t\ -\ 12\ month)}$	0.071		0.058	
$CDOTSO_{i\ t}$	0.377	b	0.354	b
$ACLQ_{i\ t\ 12}$	-0.281	c		
$ACLY_{i\ t\ 3}$			-0.233	c

Signif. codes: 0 ‘a’ 0.001 ‘b’ 0.01 ‘c’ 0.05 ‘d’ 0.1 ‘ ’ 1

Pollution Reduction and Water Quality Improvement?

- Calculated mass of pollutant not discharged
- Simple Delta mixing model

Pollution Reduction Estimates

Effluent pollutant concentration reduction

- $\Delta c_{it} = EFF^*_{i\,t} - EFF_{i\,t}$

For total nitrogen

- $\Delta c_{it} = exp[log(EFF_{i\,t}) - \theta_{12} ACLQ_{i\,t\,12}] - EFF_{i\,t}$

For total copper

- $\Delta c_{it} = exp[log(EFF_{i\,t}) - \theta_{7} ACLQ_{i\,t\,7}] - EFF_{i\,t}$

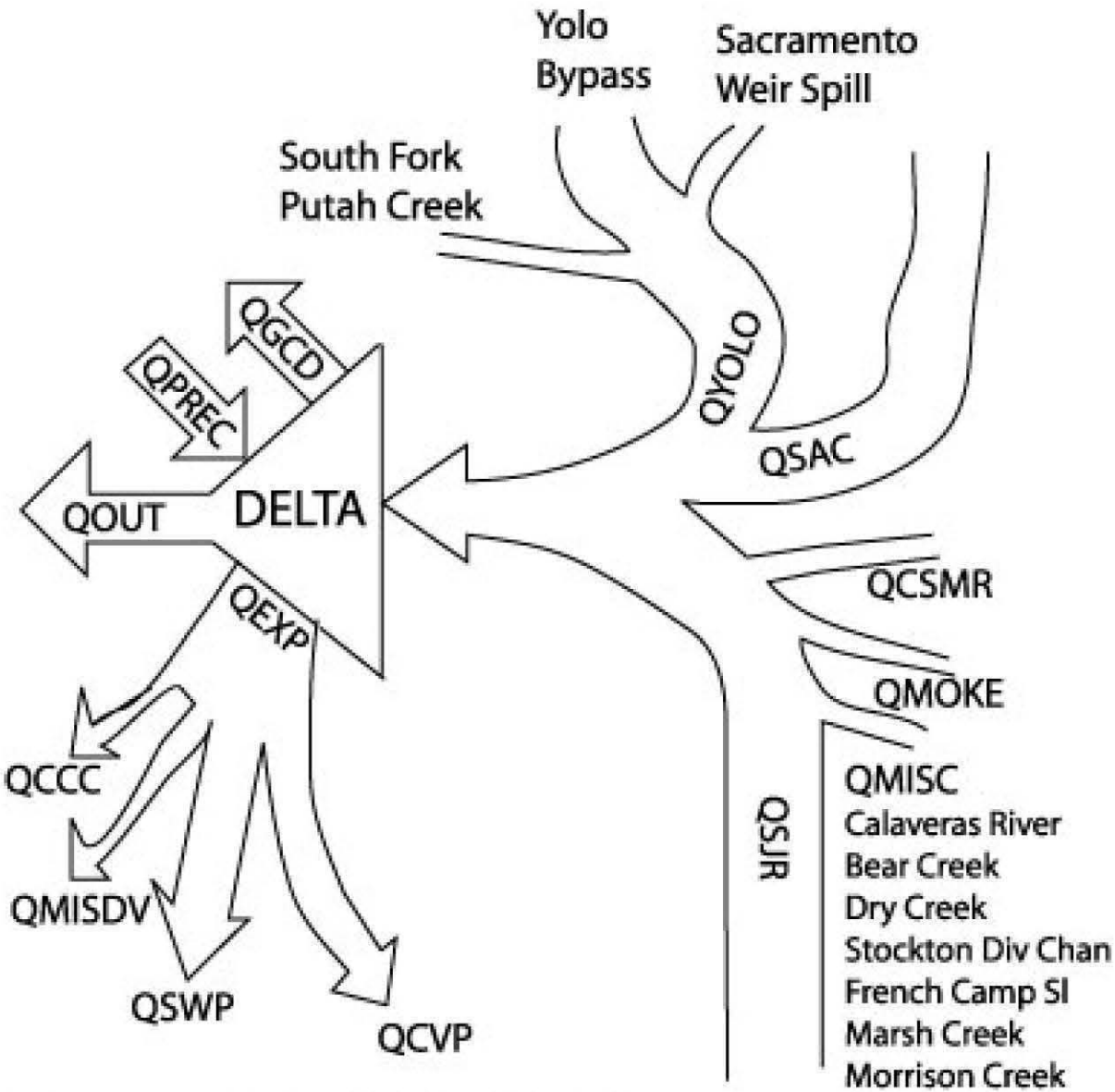


Figure 2: Delta Hydraulic Scheme used in Dayflow

Source: CA Dept. of Water Resources

Total Nitrogen Effluent Concentration Reductions, mg/L

	Yolo Bypass				Sacramento River			Delta		San Joaquin River					East tributaries	
Quarter	Davis	Wood-land	UC Davis	Easterly	Sacra-mento Regio-nal	Dry Creek	Hang-town	Brent-wood	Disco-very Bay	Stock-ton Regio-nal	Man-teca	Mer-ced	Mo-desto	Tur-lock	Deer Ck	Galt
2008-Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
2008-Q4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q1	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0
2010-Q1	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0
2010-Q2	0.0	0.0	3.1	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
2010-Q3	1.4	7.7	0.0	0.0	8.7	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-Q4	0.0	0.0	2.3	0.0	0.0	0.0	1.1	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011-Q1	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0
2011-Q2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011-Q3	1.7	0.0	1.9	0.0	0.0	0.0	1.5	0.0	1.5	0.0	2.4	0.0	0.0	0.0	0.0	0.0
2011-Q4	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012-Q1	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012-Q2	0.0	0.0	0.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012-Q3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012-Q4	0.0	7.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	7.6	2.3	0.0	0.0	5.2	0.0	0.0

Total Nitrogen mass discharged reductions

thousand lbs/quarter

	Yolo Bypass				Sacramento River			Delta	
	Davis	Wood-land	UC Davis	Easterly	Sacra-mento Regional	Dry Crk	Hang-town	Brent-wood	Disco-very Bay
Average	2.9	5.0	1.4	8.7	66.7	6.4	0.4	0.00	0.4

	San Joaquin River					East tributaries	
	Stockton Regional	Man-teca	Merced	Modesto	Turlock	Deer Ck	Galt
Average	50.7	2.4	0.02	0.00	8.7	0.03	0.00

Total Copper Effluent Concentration Reductions, ug/L

	Yolo Bypass			Sacramento River			Delta			San Joaquin River						East Tributaries	
Quarter	Davis	UC Davis	Woodland	Sacramento Regional	Yuba City	Hangtown Ck	Brentwood	Discovery Bay	Delta Diablo	Manteca	Merced	Modesto	Stockton Regional	Turlock	Tracy	Deer Ck	Galt
2008-Q1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008-Q2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008-Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008-Q4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009-Q4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-Q1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-Q2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-Q4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011-Q1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.6	0.0
2011-Q2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011-Q3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.5	0.0	0.0
2011-Q4	0.2	0.0	4.3	1.5	1.1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.6	0.0	0.0	0.0	0.0
2012-Q1	0.0	0.2	0.0	0.0	0.0	0.1	0.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
2012-Q2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
2012-Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012-Q4	0.0	0.2	0.0	0.0	0.0	0.4	0.0	5.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

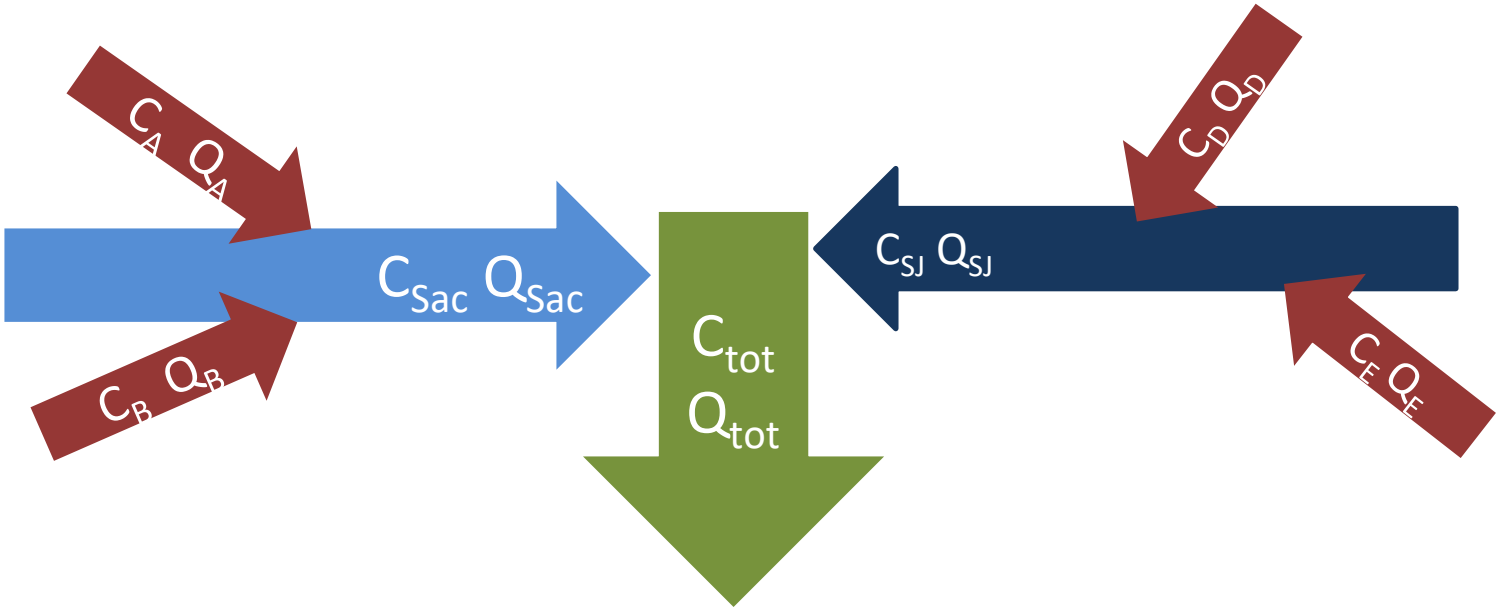
Total Copper mass discharged reductions

thousand lbs/quarter

	Yolo Bypass			Sacramento River			Delta		
	Davis	UC Davis	Wood-land	Sacra-mento Regio-nal	Yuba City	Hang-town Ck	Brent-wood	Disco-very Bay	Delta Diablo
Average	0.1	0.1	1.4	11.8	0.5	0.05	0.00	2.2	1.3

	San Joaquin River						East Tributaries	
	Man-teca	Mer-ced	Mo-desto	Stock-ton Regio-nal	Tur-lock	Tracy	Deer Ck	Galt
Average	0.5	0.8	7.0	1.6	1.4	1.2	0.06	0.00

Simple Delta Mass Balance



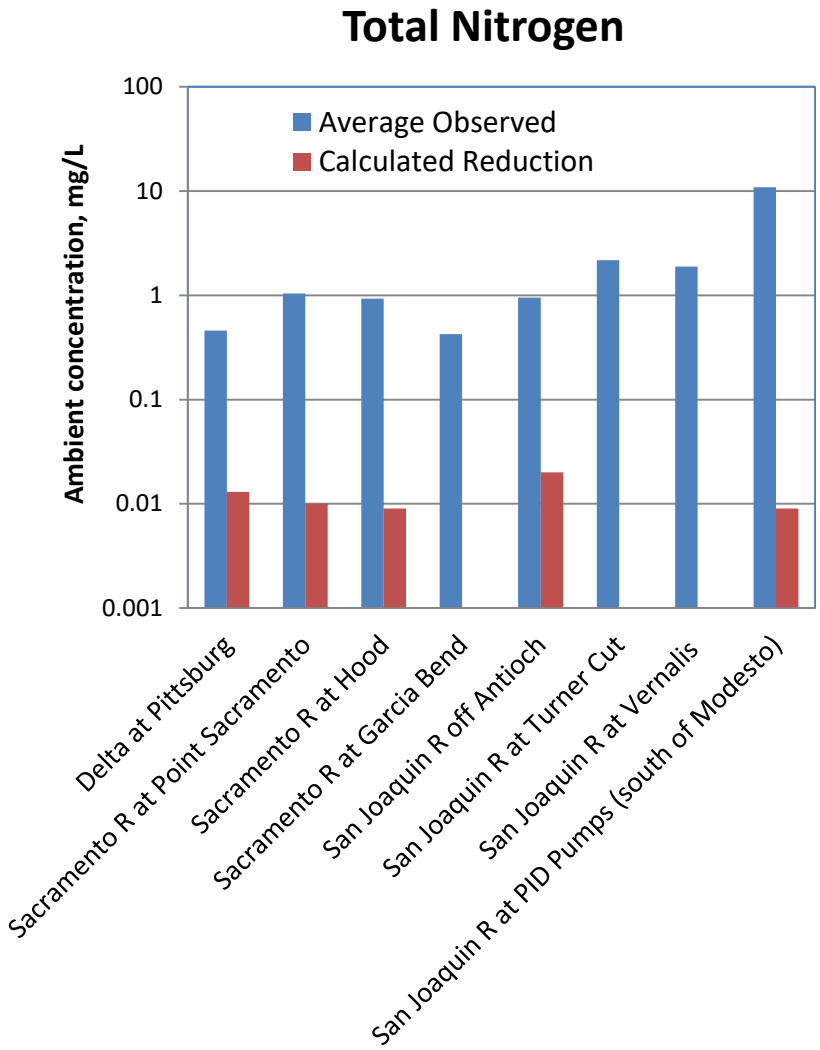
Total Nitrogen, Delta water quality concentration reduction, mg/L

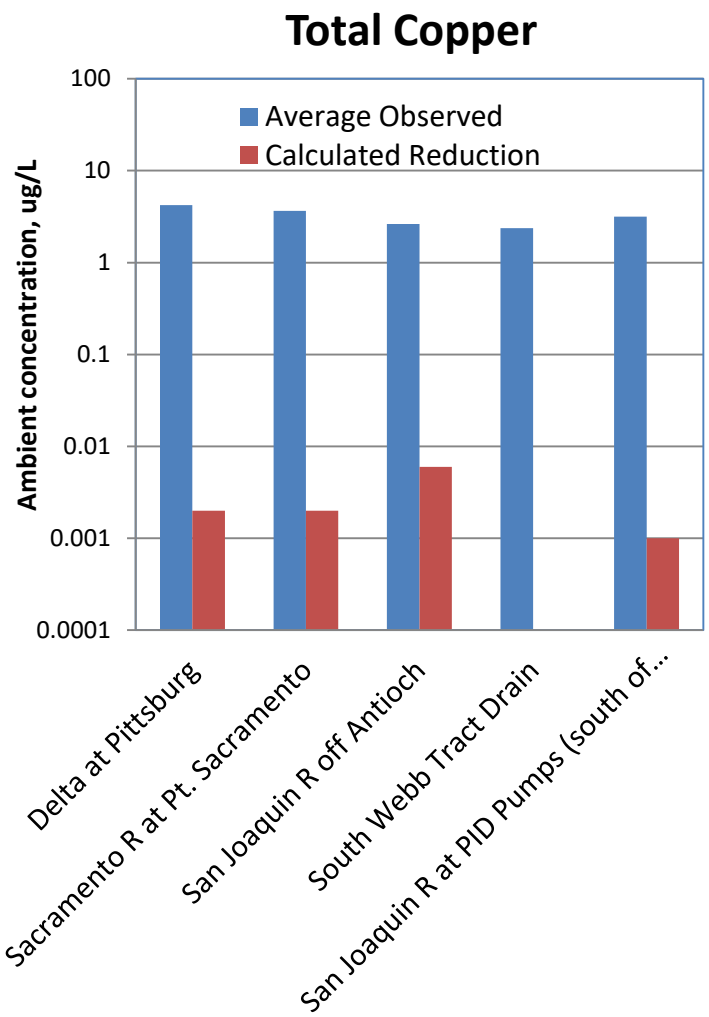
Quarter	Delta-wide at Pittsburg	Sacramento R. at Pt Sacramento	San Joaquin R. at Antioch	Sacramento R at Hood	San Joaquin R at PID pumps (south of Modesto)
2008-Q3	0.001	0	0.005	0	0.015
2008-Q4	0	0	0	0	0
2009-Q1	0.001	0.002	0	0	0
2009-Q2	0	0	0	0	0
2009-Q3	0	0	0	0	0
2009-Q4	0.0004	0	0.002	0	0
2010-Q1	0.005	0.006	0.004	0	0.009
2010-Q2	0.009	0.005	0.014	0.005	0.034
2010-Q3	0.150	0.142	0.118	0.141	0.0003
2010-Q4	0.001	0.001	0.0005	0.0002	0
2011-Q1	0.010	0.0004	0.025	0	0
2011-Q2	0	0	0	0	0
2011-Q3	0.002	0.002	0.002	0.0003	0.004
2011-Q4	0.007	0.009	0	0.009	0
2012-Q1	0.0002	0.0003	0	0.0003	0
2012-Q2	0.007	0.009	0	0	0
2012-Q3	0.001	0.001	0	0	0
2012-Q4	0.031	0.004	0.189	0	0.106
Average	**0.013**	**0.010**	**0.020**	**0.009**	**0.009**

Total Copper, Delta water quality concentration reduction, ug/L

Quarter	Delta-wide at Pittsburg	Sacramento R. at Pt Sacramento	San Joaquin R. at Antioch	Sacramento R at Hood	San Joaquin R at PID pumps (south of Modesto)
2008-Q1	0	0	0	0	0
2008-Q2	0	0	0	0	0
2008-Q3	0	0	0	0	0
2008-Q4	0	0	0	0	0
2009-Q1	0	0	0	0	0
2009-Q2	0.00003	0	0.0002	0	0.0003
2009-Q3	0.003	0	0.0359	0	0
2009-Q4	0.0004	0	0.0024	0	0.004
2010-Q1	0	0	0	0	0
2010-Q2	0	0	0	0	0
2010-Q3	0	0	0	0	0
2010-Q4	0	0	0	0	0
2011-Q1	0.004	0	0.0185	0	0
2011-Q2	0.0001	0	0.0003	0	0.0004
2011-Q3	0.003	0.000	0.0113	0	0.008
2011-Q4	0.029	0.033	0.0191	0.029	0.009
2012-Q1	0.002	0.000	0.0155	0.00003	0
2012-Q2	0.0002	0	0.0015	0	0
2012-Q3	0	0	0	0	0
2012-Q4	0.001	0.0001	0.0084	0.0001	0.003
Average	**0.002**	**0.002**	**0.006**	**0.001**	**0.001**

Delta Observed Quarterly Water Quality, 2008- 2012





Investigation Conclusions

- MMPs correlate with decreases in effluent concentrations
- Pollution reduced by several thousand lbs of total nitrogen and several hundred pounds for copper annually
- Improvements of water quality may be measurable but not significant

ACKNOWLEDGMENTS

- UCLA Environmental Science and Engineering Program
- UCLA Graduate Division
- Central Valley Regional Water Quality Control Board

Contact Information

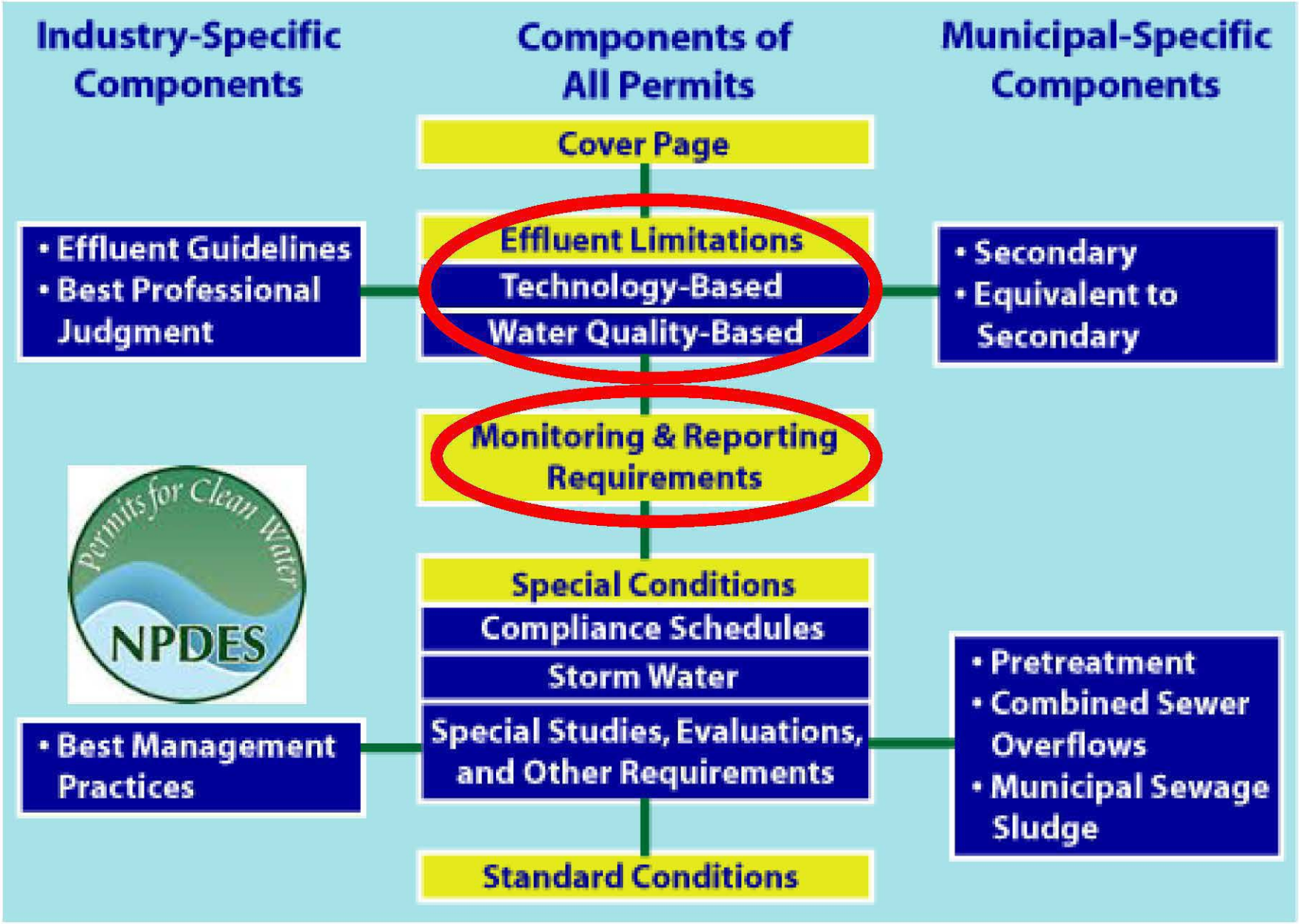
Victor Vasquez

vrvasquez@ucla.edu

- **EXTRA SLIDES**

Monitoring recommendation

- Need to evaluate effects of enforcement programs and other water quality programs using environmental endpoints.
- Develop a water quality index based on a core set of constituents.
- Require monitoring of core constituents in all discharges and receiving waters
- Require monitoring of core constituents across all programs



(Source: USEPA)

Enforcement Compliance Decision Equation

$$min_v TC = min_v \{C(v) + pV(v)\}$$

v = violation metric

TC = Total cost of compliance and violations

C(v) = Compliance costs, i.e., costs to prevent violations

$\downarrow C$ *as* $\uparrow v$

V(v) = Violation costs,

e.g., penalties, costs of corrective actions

$\uparrow V$ *as* $\uparrow v$

p = probability a violation will be detected and penalized

(Source: Rousseau, 2009)

Compliance Motivators

- Specific vs General deterrence
- Cost of penalties must be greater than cost to comply
- Public spotlight may be deterrent.
- Certainty, severity, swiftness, fairness, and perception affect compliance
- More actions, not amount, lead to specific deterrence.
- Mandatory vs discretionary penalties

Previous Examples

- Effectiveness of Coast Guard penalties in reducing oil spills
  (Weber and Crew, 2000)
- Effectiveness of inspections in promoting compliance at paper pulp mills

  (Magat and Viscusi, 1990; Laplante and Rilstone, 1996)
- Effectiveness of discretionary penalties in promoting compliance at major NPDES facilities

  (Earhart, 2004; Shimshack and Ward, 2005)

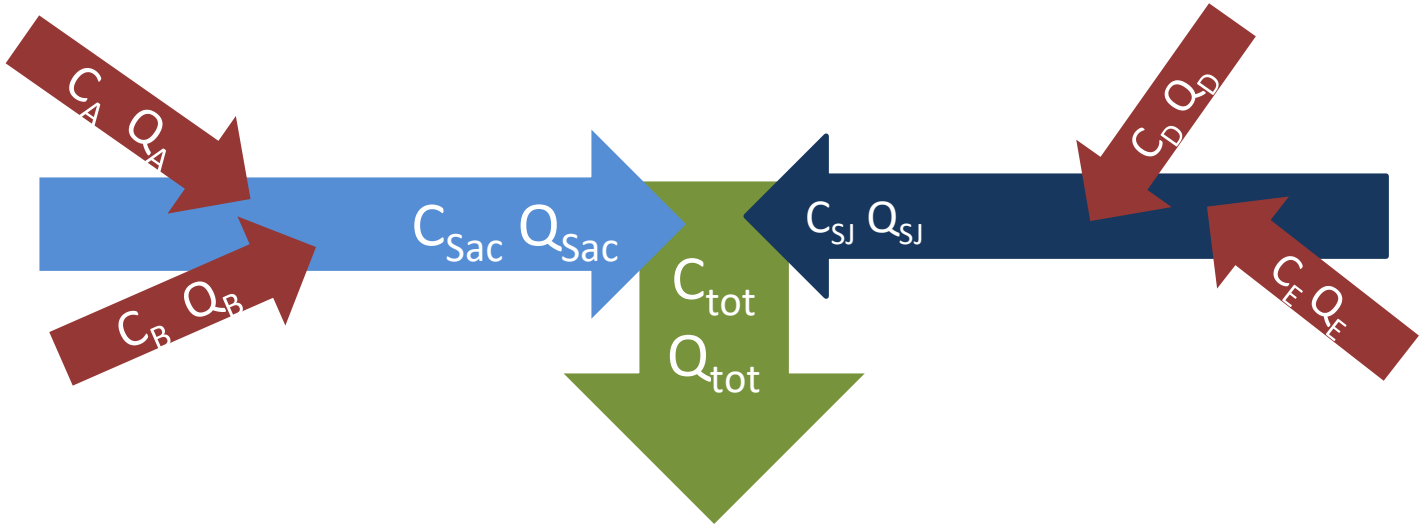
MMP Enforcement Program

- Assessed via ACL Complaint, ACL Order, or Expedited Letter
  - Not discretionary
- Violations exempt from MMP
  - single operational upset, act of war, natural disaster.
- Violations covered by Cease and Desist Order (CDO) or Time Schedule Order (TSO) not subject to MMP.

Simple Delta Mass Balance

$$\Delta c_{tot,t} Q_{tot,t} = \Delta c_{tot,t} \left(\sum_{r=1}^{k} Q_{rt} + Q_{precip} + \sum_{i=1}^{l} Q_i \right) = \sum_{i=1}^{l} \Delta c_{it} Q_i$$

k = # tributaries, l = # WWTP



Delta Observed Quarterly Water Quality, 2008- 2012

Total Nitrogen, mg/L

		Upstream →			Upstream →			
	Delta at Pittsburg	Sacramento R at Point Sacramento	Sacramento R at Hood	Sacramento R at Garcia Bend	San Joaquin R off Antioch	San Joaquin R at Turner Cut	San Joaquin R at Vernalis	San Joaquin R at PID Pumps (south of Modesto)
Max	0.605	1.405	1.030	0.705	1.153	3.420	2.435	29.710
Min	0.290	0.723	0.754	0.325	0.749	1.370	1.289	2.990
Average	0.458	1.042	0.931	0.425	0.952	2.181	1.891	10.875
Reduction	0.013	0.010	0.009		0.020			0.009

Total Copper, ug/L

		Upstream →		Upstream →		
	Delta at Pittsburg	Sacramento River (BG20)	Sacramento R at Point Sacramento	San Joaquin River (BG30) near Antioch	South Webb Tract Drain	San Joaquin River at PID Pumps
Max	5.120	3.020	4.570	3.140	5.100	5.133
Min	3.103	0.640	2.284	2.275	0.770	1.700
Average	4.226	2.147	3.641	2.625	2.361	3.171
Reduction	0.002		0.002	0.006		0.001

Future investigations

- Quantify effects of MMPs on water quality in context of other programs
- Determine optimal frequency and level of MMP
- Investigate how MMPs changed behavior of decision-makers

Contribution to literature

- Results indicate MMPs are effective in promoting compliance and achieving reductions in pollution emissions.
- The effects may be due to both facility-specific effects as well as enhancement of the regulatory agency's enforcement reputation.