A Risk-Based Approach to Evaluate the Potential Impactof Synthetic Pyrethroid Insecticides on Aquatic Organisms of the San Francisco Bay Delta

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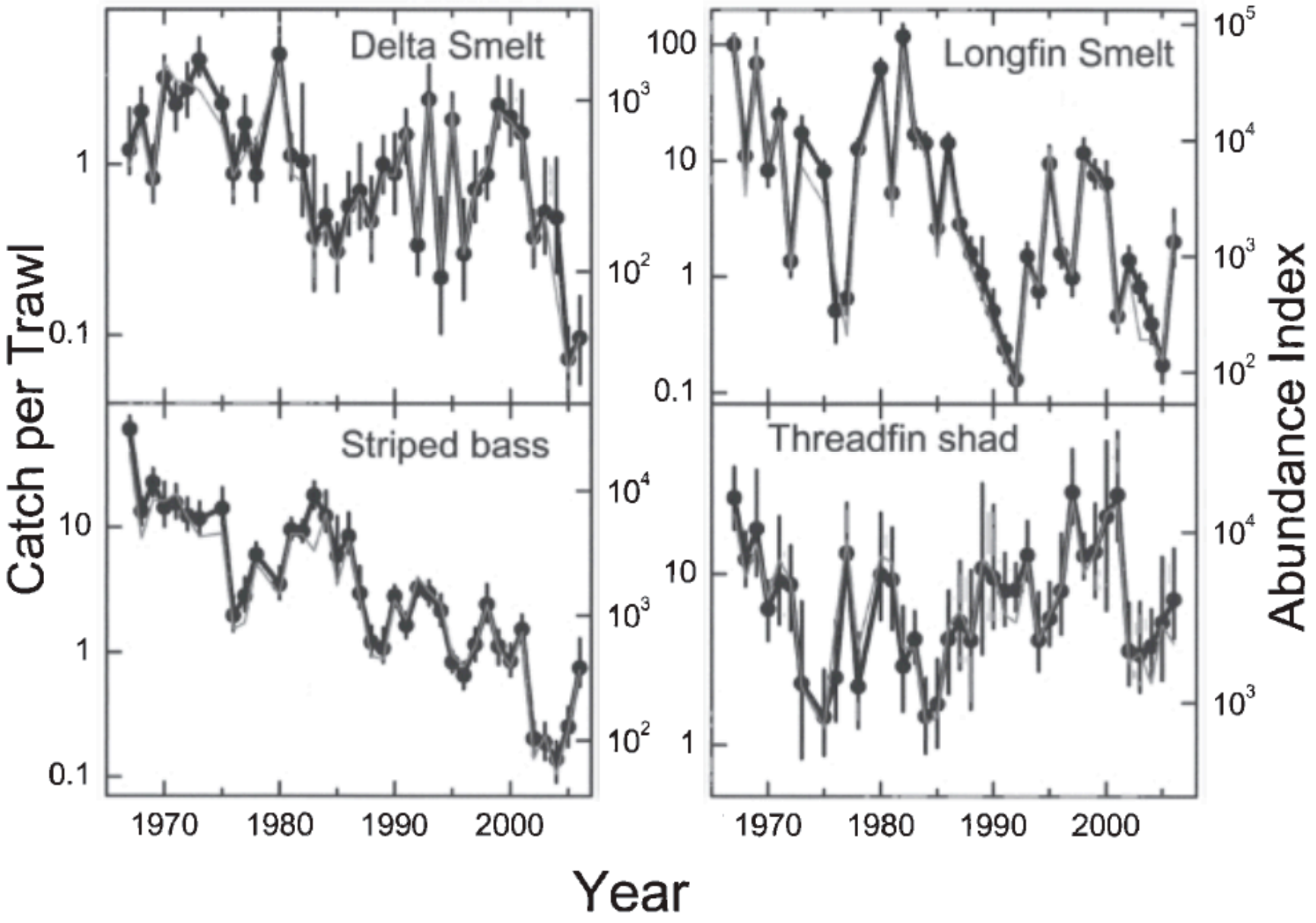

Delta Smelt
Longfin Smelt
Striped bass
Threadfin shad
Catch per Trawl
Abundance Index
Year
1970
1980
1990
2000
0.1
1
10
100
10^2
10^3
10^4
10^5

Table 2. Sales of Study-List Pesticides in California, 1999-2005 (Pounds of Pesticide Active Ingredient)

Pesticide	1999	2000	2001	2002	2003	2004	2005
Pyrethroids							
Bifenthrin	NR[a]	NR	32,000	32,000	71,000	110,000	44,000
Cyfluthrin	31,000	47,000	47,000	51,000	45,000	46,000	37,000
Beta-Cyfluthrin	NR	NR	NR	NR	4,300	16,000	5,500
Cypermethrin	44,000	50,000	50,000	65,000	82,000	78,000	91,000
Deltamethrin	2,100	8,300	3,200	4,400	4,900	3,900	4,000
Esfenvalerate	41,000	43,000	36,000	43,000	54,000	57,000	50,000
Lambda-Cyhalothrin	NR	NR	NR	24,000	28,000	26,000	38,000
Permethrin	290,000	440,000	280,000	430,000	480,000	470,000	480,000
Tralomethrin	1,900	1,900	34,000	?[b]	3,200	4,200	1,500
OPs							
Chlorpyrifos[c]	2,300,000	2,400,000	2,000,000	1,700,000	2,000,000	2,300,000	2,400,000
Diazinon[d]	1,500,000	1,400,000	1,400,000	920,000	750,000	810,000	500,000
Malathion	1,500,000	1,100,000	1,100,000	1,000,000	1,700,000	1,600,000	1,100,000
Other							
Carbaryl	640,000	560,000	410,000	420,000	330,000	390,000	410,000
Fipronil	NR	1,900	19,000	32,000	14,000	18,000	22,000
PHMB	NR	27,000	NR	NR	56,000	36,000	69,000

Source: DPR Sales data reports (DPR 2000a, 2001a, 2002a, 2003a, 2005a, 2006a, 2007b) Note that data in this table reflect corrected year 2003 and 2004 reports issued in 2007. Data are rounded to reflect their estimated accuracy (assumed to be two significant figures).

[a]NR = Not Reported. Sales of products with fewer than four registrants are not disclosed to the public.

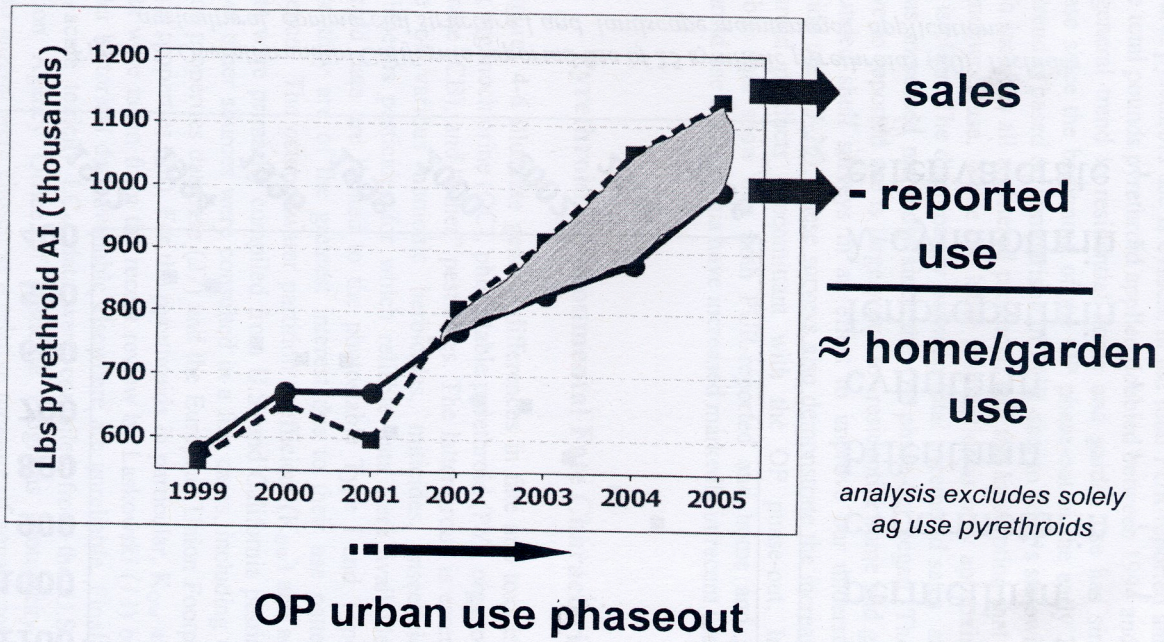


Figure 3. Approximate trend in residential home and garden pyrethroid use. Estimated by difference between sales(15) and reported use (16).

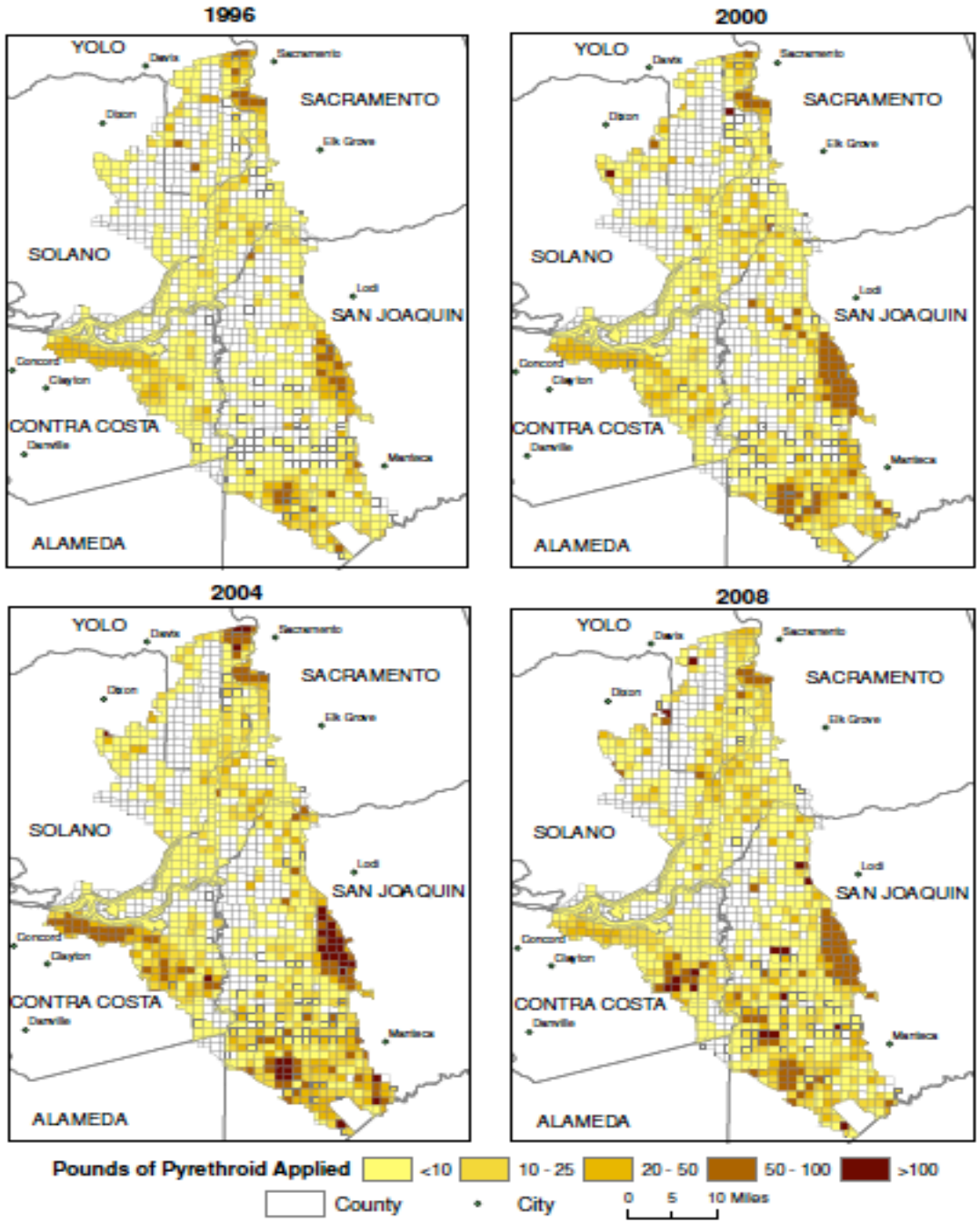

1996
2000
2004
2008
YOLO
SACRAMENTO
SOLANO
SAN JOAQUIN
CONTRA COSTA
ALAMEDA
Davis
Sacramento
Dixon
Elk Grove
Lodi
Concord
Clayton
Danville
Manteca
Pounds of Pyrethroid Applied
<10
10 - 25
20 - 50
50 - 100
>100
County
City
0
5
10 Miles

Table 1.
Growth in Delta-vicinity cities, 2000–2005. Courtesy Hans Johnson.

CITY	2000	2005	% CHANGE
Antioch	90 532	101 049	12%
Brentwood	23 302	40 912	76%
Pittsburg	56 769	62 605	10%
Elk Grove	70 000	121 609	74%
Galt	19 472	22 955	18%
Isleton	828	820	–1%
Sacramento	407 018	452 959	11%
Lathrop	10 445	12 565	20%
Lodi	57 011	62 467	10%
Manteca	49 255	61 927	26%
Stockton	243 771	279 513	15%
Tracy	56 929	78 307	38%
Dixon	16 103	17 179	7%
Fairfield	96 178	105 026	9%
Rio Vista	4 571	6 837	50%
Suisun City	26 118	27 716	6%
Vacaville	88 642	96 735	9%
West Sacramento	31 615	40 206	27%

Risk Based Approach

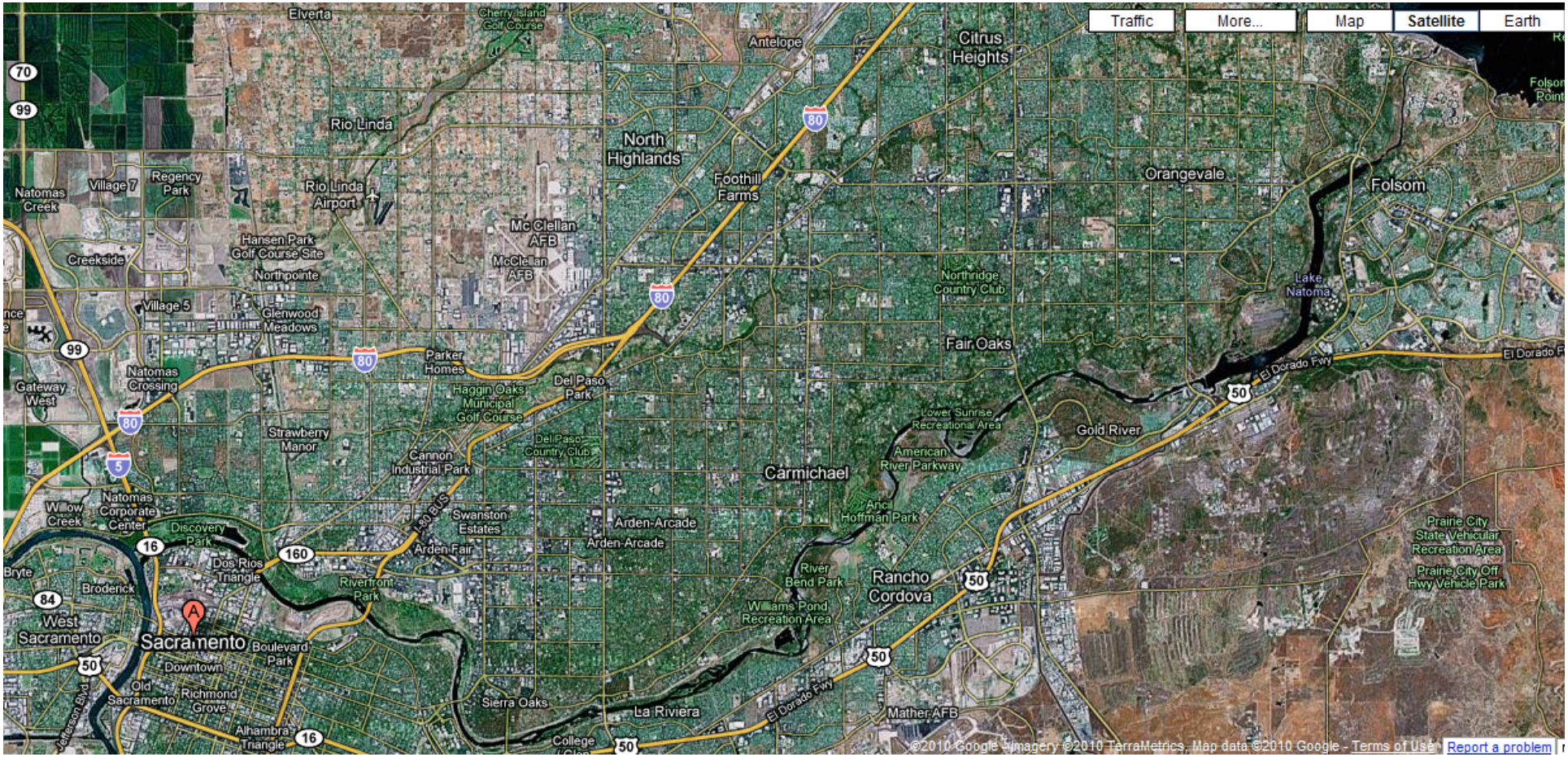
- Exposure Assessment
  - Estimate inputs from urban sources
- Effects Assessment
  - Estimate impacts to receptors of interest
    - Invertebrate prey items
    - Larval stages of fish

Approach Continued

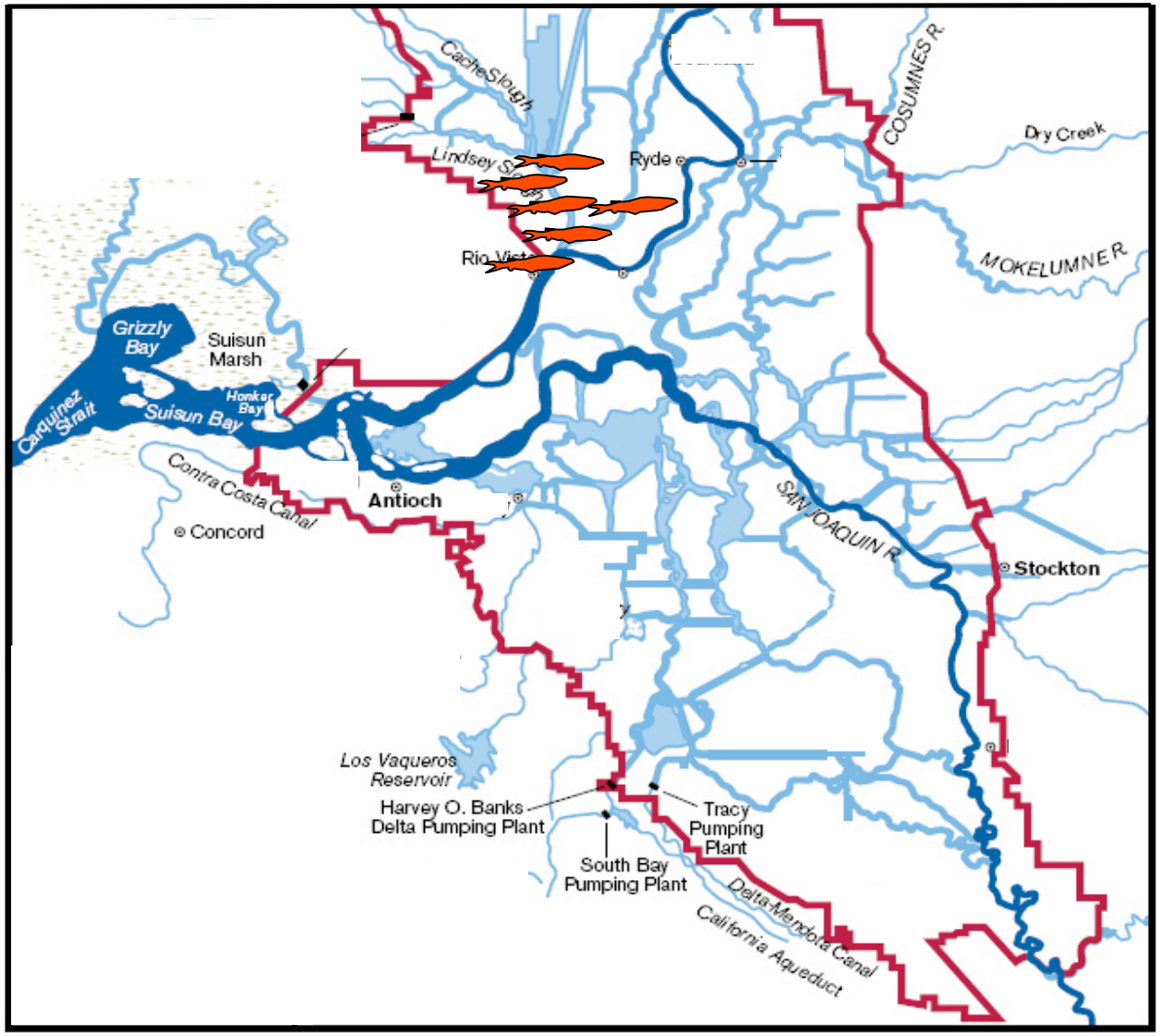
- Estimate Exposure in 2008
  - Modeled
    - Urban land use
    - Residential Pesticide use
    - Structural Pesticide use
    - Overall pesticide use
  - Validated with measured data

- Back estimate Exposure in 2005; 2000;1995

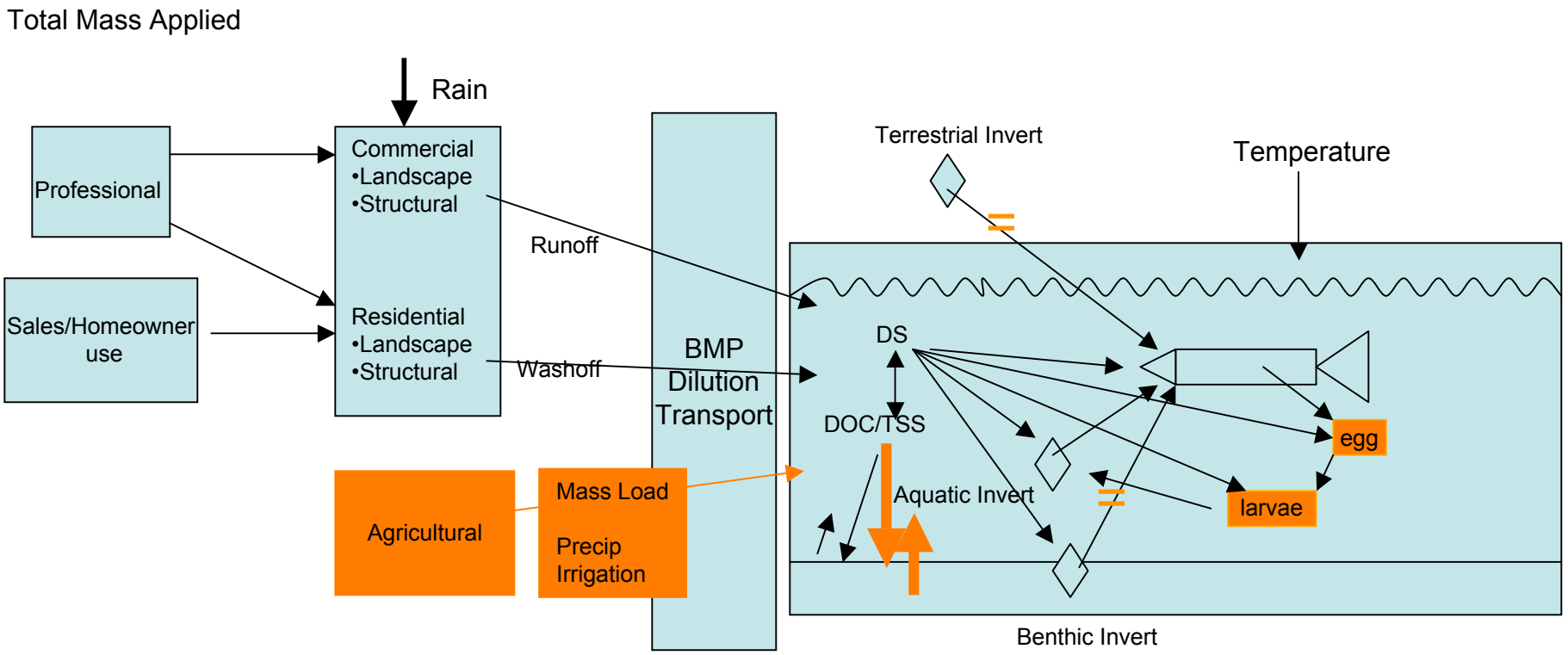
American River Aerial View



Delta Smelt in Cache Slough Area All Year



Conceptual Model for Pyrethroid inputs for American River and Cache Slough (Orange)



Exposure Assessment Objectives

- Determine the mass of each pyrethroid applied to each land use (e.g., agricultural, residential, commercial) and surface cover (e.g., pervious or impervious) within each study area as a function of time over the simulation period

Exposure Assessment Objectives

- Estimate the fraction of the applied mass that washes off in each storm event from the various surface types and land uses

Assumptions for Washoff Estimates

- Non-agricultural pyrethroid use occurs entirely in urban (incorporated) areas,
- Non-agricultural pyrethroid use in a given county is of the same intensity (mg/m^2) in each of the urban areas within the county,
- Pyrethroid application by commercial applicators in the "Structural pest control" category of the DPR database is exclusively above ground as an exterior perimeter barrier spray for general pest control for all pyrethroids except bifenthrin, cypermethrin and permethrin. The fraction of these compounds applied above grade was estimated based on information from pest control operators.

Assumptions Cont.

- The division of the pyrethroid mass applied for “Structural pest control”between pervious and impervious surfaces is proportional to the fraction of the two surface types around the perimeter of the average building within each land use category (residential, commercial, industrial).
- Pyrethroid application by licensed applicators in the “Landscape maintenance” category is entirely on pervious surfaces and occurs at the same rate (mg/m^2) in all incorporated areas of the county.
- Pyrethroid application within each class of applications occurs uniformly throughout the month at a rate of (monthly total application/days in month)

Washoff factor parameters for pyrethroid products applied to concrete

$$M_R = M_{avail}\beta_0 e^{\beta_1 \cdot \text{int} + \beta_2 \cdot dur} \quad (2)$$

where *int* =storm intensity in mm/hr and *dur*=storm duration in minutes and β_0, β_1 and β_2 are empirical parameters obtained from washoff data,

Product	k_{deg}	β_0	β_1	β_2	R^2	N_{obs}
β-cyfluthrin	1.23E-1	2.80E-2	3.68E-2	9.39E-3	0.789	24
esfenvalerate	5.27E-2	2.60E-3	7.96E-3	2.56E-2	0.924	24
Average	8.79E-2	1.53E-2	2.24E-2	1.75E-2		

Washoff factors from turf for various pyrethroid products

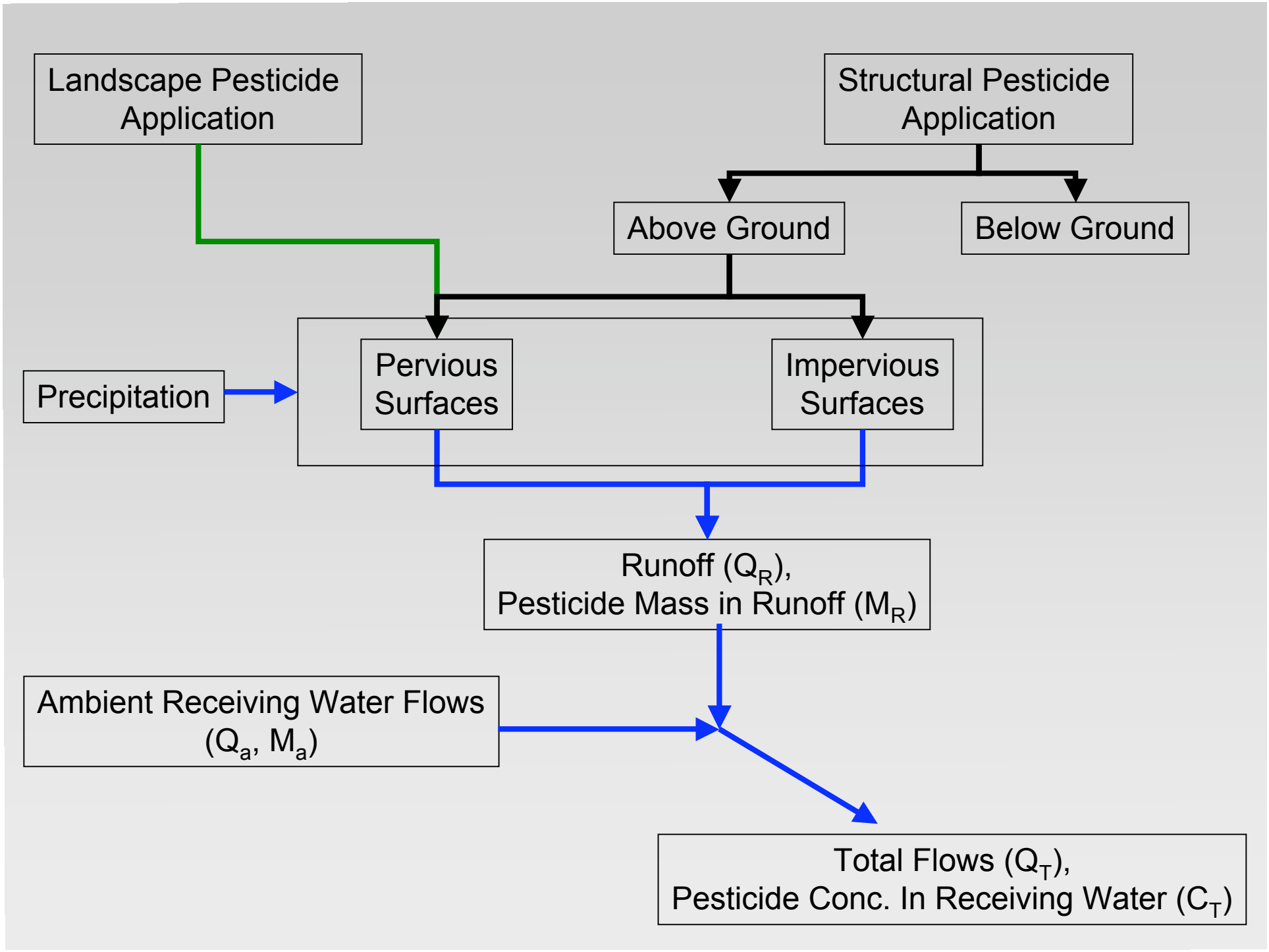
Product	Slope	R^2	k_{deg} (d^{-1})	β_0
Bifenthrin EC 1D	1.35E-04	0.963	0.210	1.66E-4
Bifenthrin EC 7D	3.14E-05	0.933		
Bifenthrin EC 7D 2nd	4.69E-05	0.966		
β-cyfluthrin SC 1D	8.62E-04	0.889	0.184	1.04E-3
β-cyfluthrin SC 7D	4.13E-04	0.912		
β-cyfluthrin SC 7D 2nd	1.97E-04	0.887		
β-cyfluthrin gran 1D	4.98E-05	0.851	0.119	5.61E-5
β-cyfluthrin gran 7D	2.24E-05	0.735		
β-cyfluthrin gran 7D 2nd	2.64E-05	0.337		
λ-cyhalothrin gran 1D	2.66E-05	0.937	0.162	3.13E-5
λ-cyhalothrin gran 7D	1.07E-05	0.834		
λ-cyhalothrin gran 7D 2nd	9.43E-06	0.812		
Average			0.169	3.23E-4

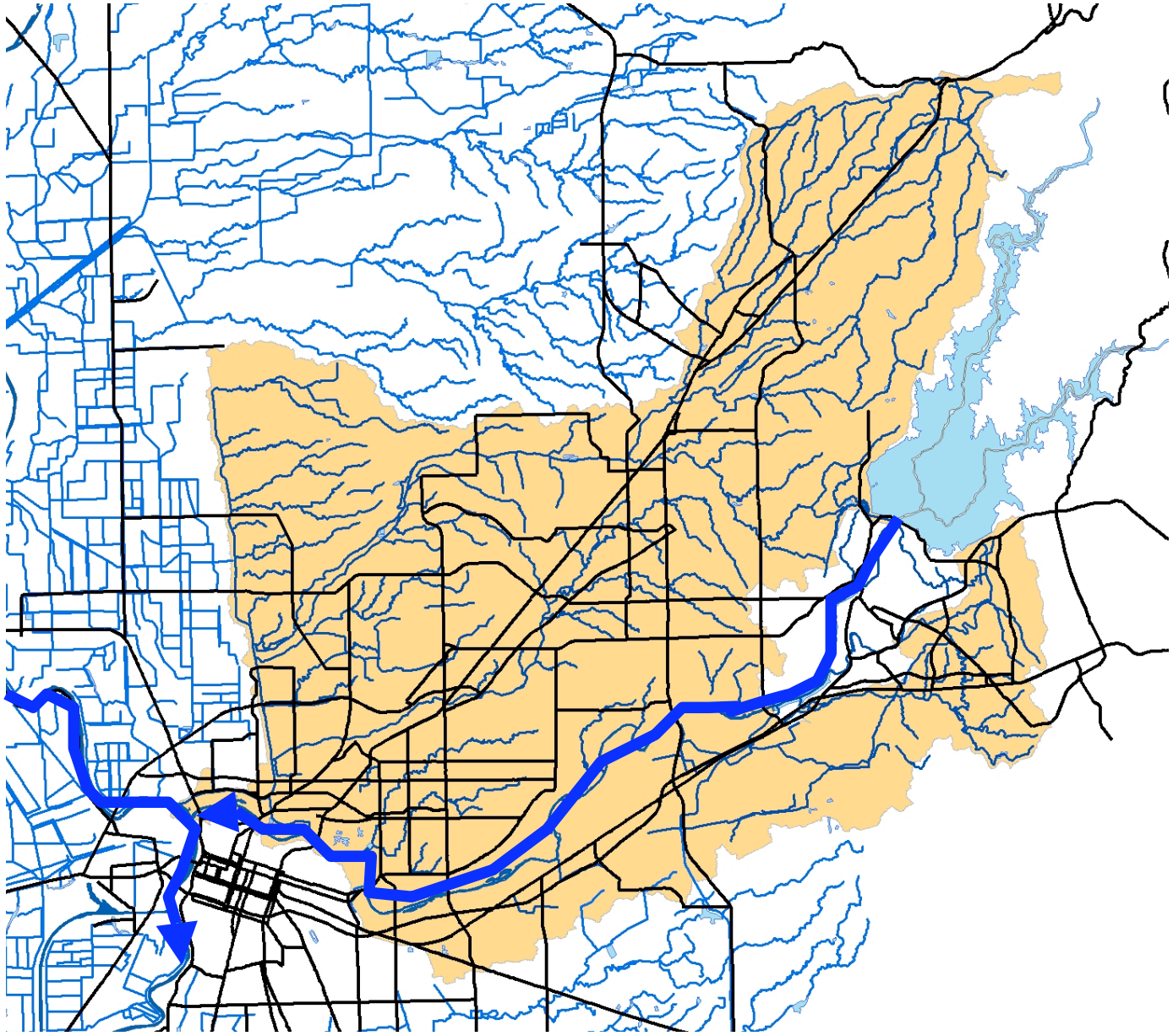
Agricultural Runoff

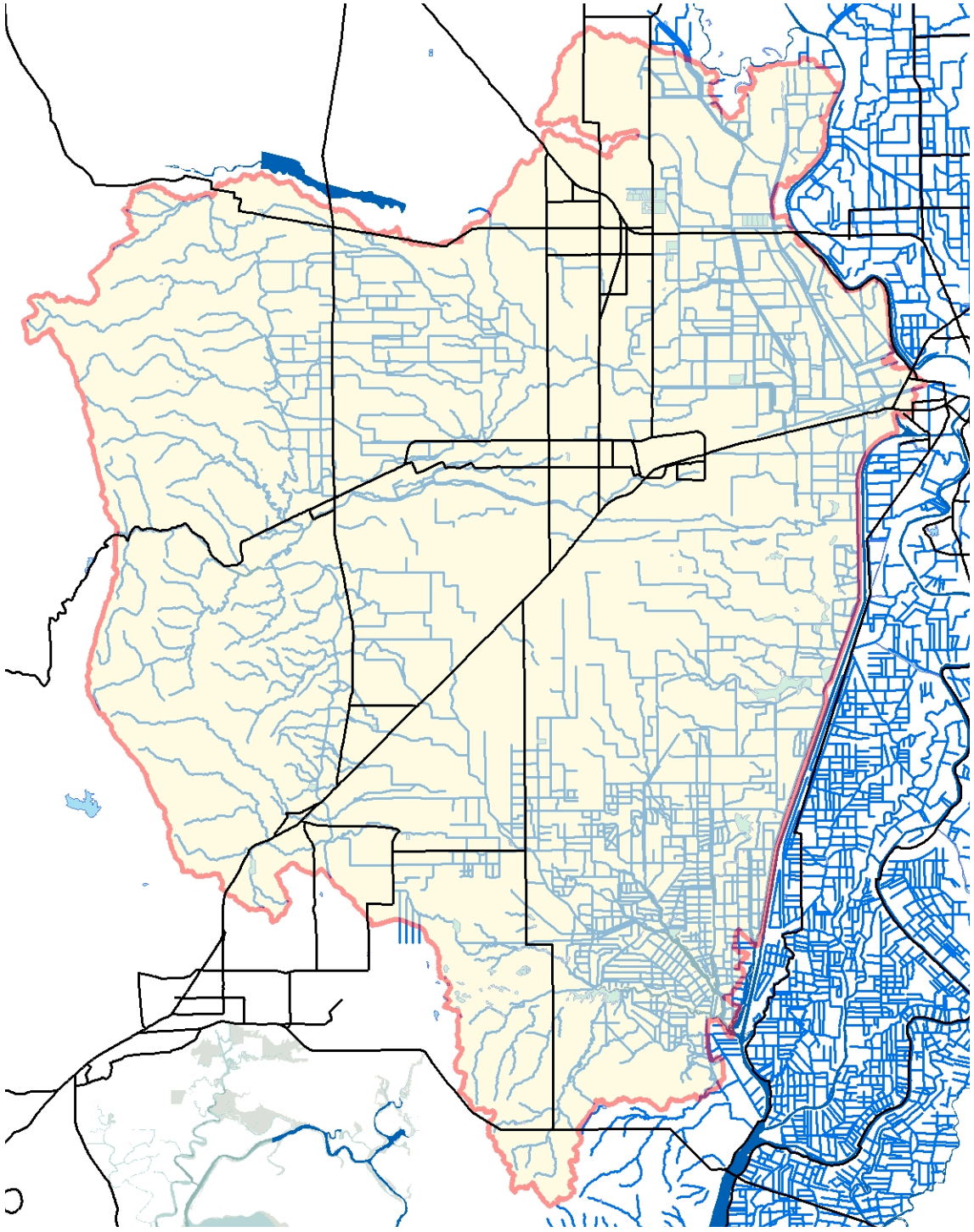
- Based on field trials (0.1%)
- Weston (unpublished)
  - Lettuce field treated with permethrin, (0.07%)
  - Dry bean field treated with zeta-cypermethrin (0.14%)
  - Tomato field treated with lambda-cyhalothrin (0.54%)

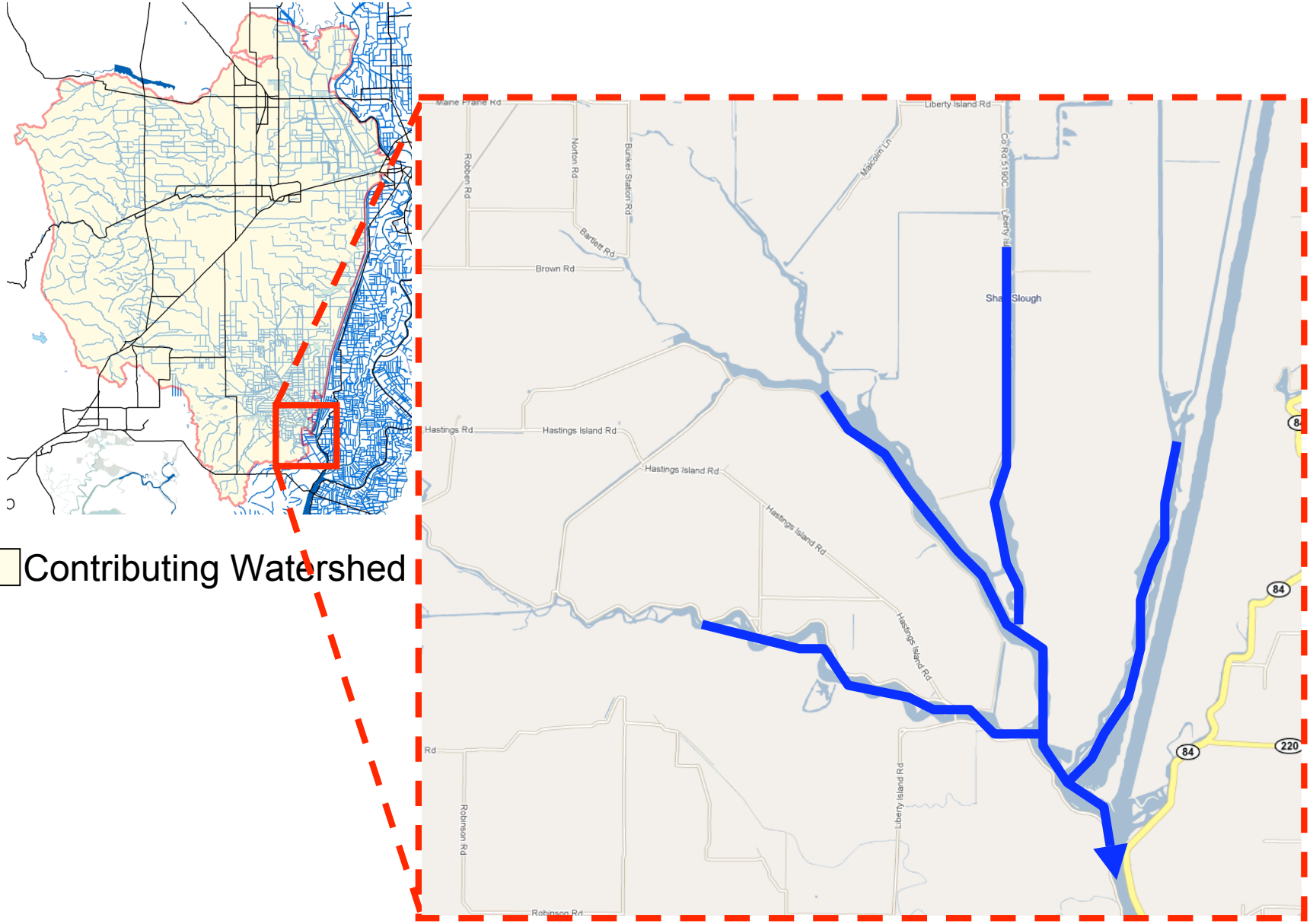
Exposure Assessment Objectives

- Predict pyrethroid concentrations over time at the selected locations within each watershed using available historical precipitation and hydrodynamic data and the mass loading estimates produced from the first two steps


Landscape Pesticide Application
Structural Pesticide Application
Above Ground
Below Ground
Precipitation
Pervious Surfaces
Impervious Surfaces
Runoff (Q_R), Pesticide Mass in Runoff (M_R)
Ambient Receiving Water Flows (Q_a, M_a)
Total Flows (Q_T), Pesticide Conc. In Receiving Water (C_T)


Contributing Watershed


Contributing Watershed


Contributing Watershed
Maine Prairie Rd
Liberty Island Rd
Robben Rd
Norton Rd
Bunker Station Rd
Malcolm Ln
Co Rd 5190C
Bartlett Rd
Brown Rd
Slough
Hastings Rd
Hastings Island Rd
Hastings Island Rd
Hastings Island Rd
Hastings Island Rd
Rd
Robinson Rd
Liberty Island Rd
Robinson Rd
84
84
220

Toxicity Assessment

- Acute
  - Combination of Solomon et al. 2001; Giddings et al. Unpublished; Palumbo et al. 2010.
- Acute-Chronic Ratio
  - 23 data points comparing NOEC with LC50
  - Applied to 5th Percentile of Acute LC50 data 0.8-136; median 12.7

Pyrethroid acute toxicity thresholds derived from species sensitivity distribution

		Solomons	Giddings[1]	Palumbo
Bifenthrin				
	All aquatic species	<1.9	54	3.7
	Arthropods		55	
	Fish		--	
Cyfluthrin				
	All aquatic species	<2	46	0.2
	Arthropods		--	
	Fish		--	
Cypermethrin				
	All aquatic species	2	3.5	
	Arthropods	1.5	2.7	
	Fish	<115	308	
Deltamethrin				
	All aquatic species	1.5	8.2	
	Arthropods		5.1	
	Fish		123	
Esfenvalerate				
	All aquatic species	8.5	115	
	Arthropods	1.5	53	
	Fish	40	119	
Fenpropathrin				
	All aquatic species	57	168	
	Arthropods		--	
	Fish		--	
Lambda-cyhal				
	All aquatic species	<2	1.4	1
	Arthropods		1.3	
	Fish		56	
Permethrin				
	All aquatic species	34	40	
	Arthropods	18	17	
	Fish	425	790	

Toxicity Threshold

Pyrethroid	Acute toxicity threshold (ng/L)	Chronic toxicity threshold (ng/L)
Bifenthrin	<1.9	<0.29
Cyfluthrin	0.2	0.03
Cypermethrin	1.5	0.24
Deltamethrin	1.5	0.24
Esfenvalerate	1.5	0.24
Fenpropathrin	57	9.0
Lambda-cyhalothrin	1	0.2
Permethrin	17	2.7

Target species

- *O. mykiss*
  - Bifenthrin (100 ng/L); Permethrin (4744 ng/L)
- Delta Smelt (larval-39-51 dph)
  - Bifenthrin (143 ng/L); Cyfluthrin (420 ng/L)
- *Eurytemora affinis*
  - Bifentrin (11 ng/L)*
  - Cyfluthrin (13 ng/L)*
  - Permethrin (158 ng/L)*

* Nominal Values Teh et al. (unpublished)

Where are we now?

- Toxicity assessment complete
- Runoff models are complete
- Needed
  - Hydrologic and Receiving Water Calculations
  - Temporal Comparisons pre and post inflection point
  - Food web model……

Thanks

- National Center for Ecological Analysis and Synthesis (UC Santa Barbara)
- IEP POD Steering Committee
- Pyrethroid Working Group