OP & Pyrethroid Pesticide-Caused Aquatic Life Toxicity: Inadequate Regulation of Urban Use

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Topics

- Review Study of Aquatic Life Toxicity of Stormwater Runoff from Upper Newport Bay/Orange County, CA Watershed
- Need & Proposed Approach for More Appropriate Regulation of Urban Use of Pesticides to Reduce Aquatic Life Toxicity
  - Proactive Approach for Screening New/Expanded-Use Pesticides for Aquatic Life Toxicity

Presented at CA Department of Pesticide Regulation informal pesticide seminar, organized by Dr. Kean Goh, DPR Surface Water Program Manager (916-324-4072), Sacramento, CA, March 9 (2010).

Background to Studies

- Development of Eastern Transportation Corridor (ETC) in Orange County, CA
  - 22-mi Toll Road North of Irvine to Riverside – State Route 261
  - Impact of Heavy Metals in Highway Stormwater Runoff of Concern
    - Cu, Zn, CD above US EPA Water Quality Criteria -- Potential for Aquatic Life Toxicity
    - Need for BMPs to Control Pollution in ETC Runoff
  - Initially Proposed BMP: “Compost Filter”
    - Bags of Compost in Septic Tank-Type Structure
    - Not Technically Valid
  - Conventional Approach: Detention Basins

Unconventional Development of Appropriate BMPs

- GFL & AJL Asked to Assist Engineering Firms in Developing BMPs
  - Conventional Monitoring Approach:
    - Measure Total Levels of Heavy Metals in Runoff
    - Compare Concentrations with Water Quality Standards/Criteria
    - Try to Extrapolate to Aquatic Life Toxicity
  - Conventional Approach Problematic
    - Many Factors Affect Availability/Toxicity of Total Heavy Metals
      - e.g., Particulate Forms of Heavy Metals Not Toxic
      - e.g., Concentration/Duration of Exposure Relationships Given Periodic, Short-Term Exposure with Rainfall Event
  - Rather Than Mechanically Follow Conventional Approach, Convinced WQCB to Follow “Evaluation Monitoring” Approach
  - Leave Land Where Other BMPs Could Be Constructed If Needed

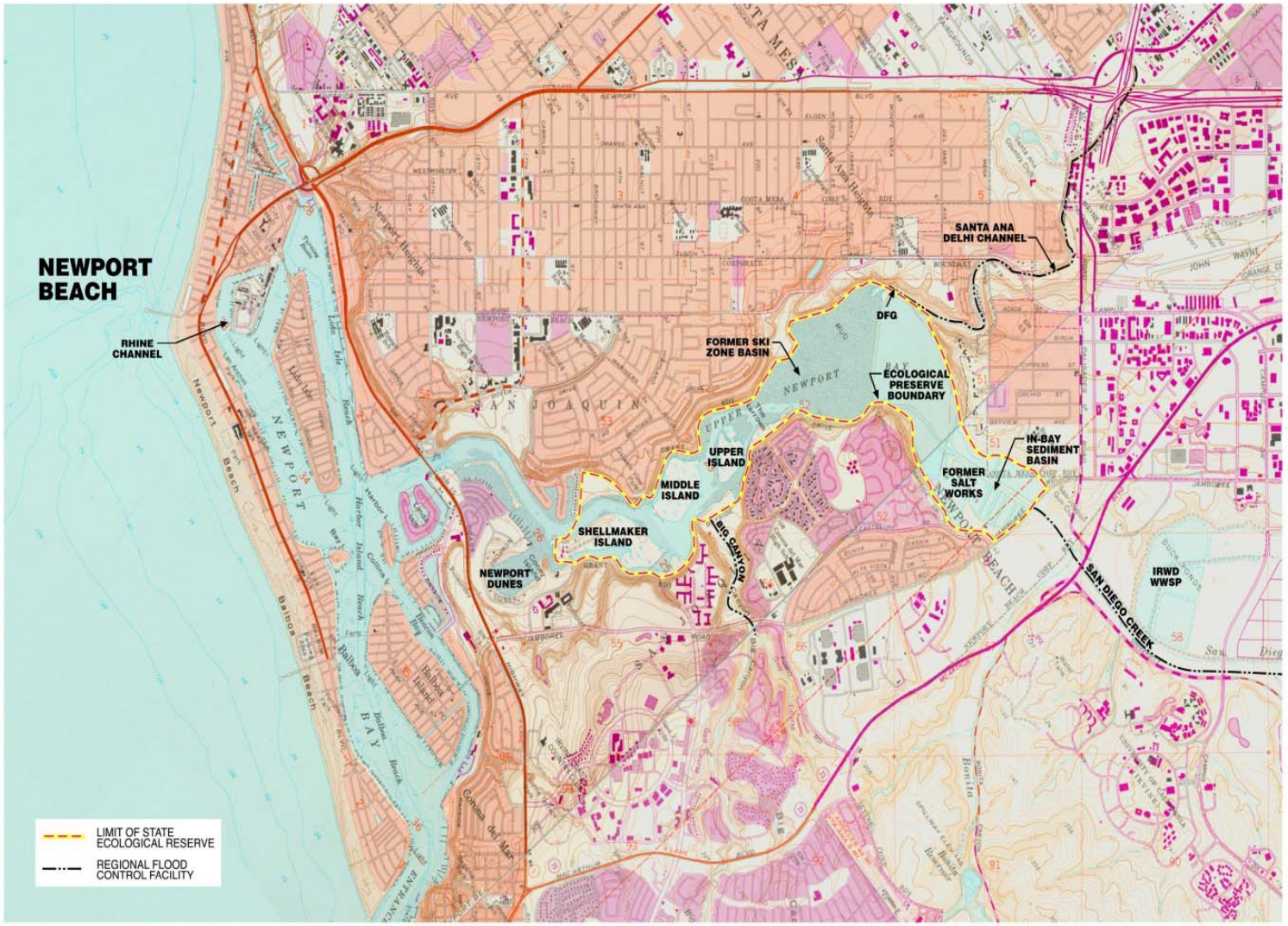
Evaluation Monitoring Approach

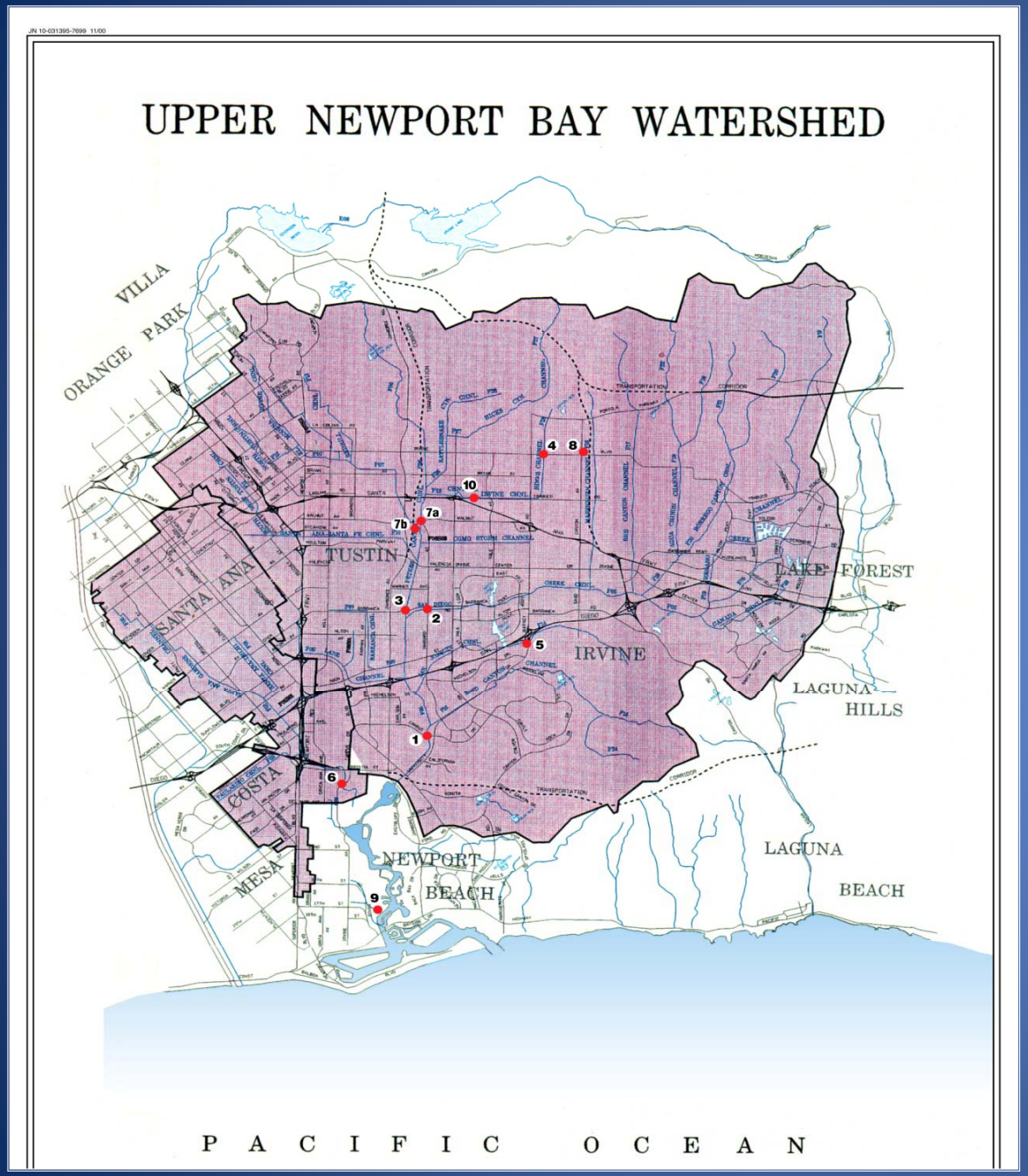
- Since Elevated Concentrations of Heavy Metals Noted, First Focus on Potential Impact of Heavy Metals
  - Measure Toxicity
  - If Toxicity Found
    - Define Cause(s) of Toxicity
      - Due to Heavy Metals?
      - If Not, Define Cause of Toxicity
    - Significance of Toxicity to Beneficial Uses of Receiving Waters

Organization of Study

- ~ $0.5-million, 3-yr Study of Aquatic Life Toxicity in Streams That Receive Urban & Ag Stormwater Runoff in Upper Newport Bay Watershed (Orange Co., CA), 375 toxicity tests over 3 years
- Key Professionals Involved in Study:
  - Scott Taylor, RBF, Inc, Irvine, CA
  - Dr. G. Fred Lee, G. Fred Lee & Associates, El Macero, CA
  - Dr. Jeff Miller, AquaScience, Davis, CA
  - Linda Deanovic, University of California, Davis Aquatic Toxicology Laboratory
  - Dr. Scott Ogle Pacific Eco-Risk Fairfield, CA
- Conducted in Cooperation with
  - Santa Ana Regional Water Quality Control Board
  - Orange County Public Facilities & Resources Department (Orange County Stormwater Management Agency)
- Supported by US EPA Region IX Funds

Newport Bay, CA Area

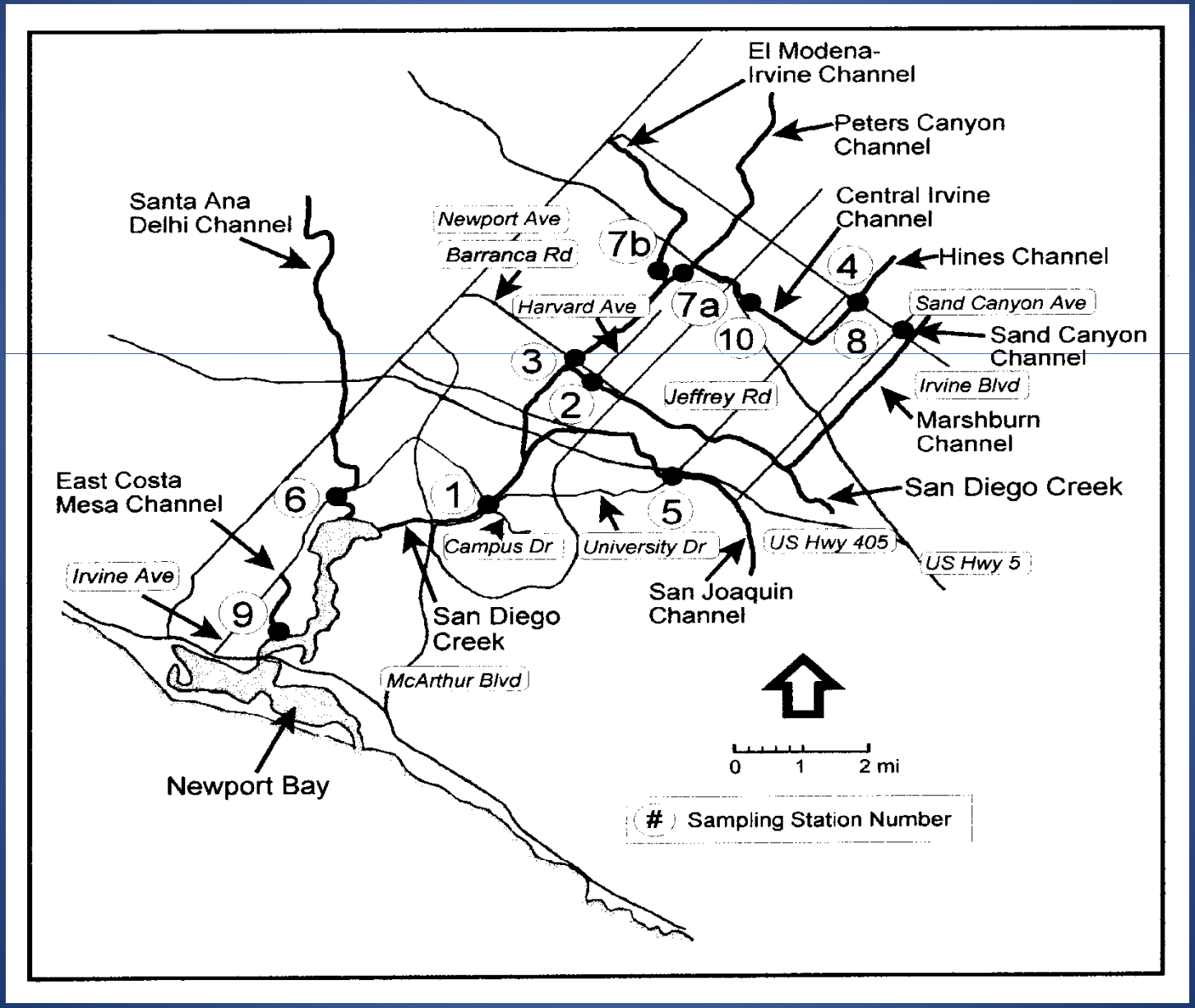




Sampling Stations

1 San Diego Creek @ Campus Drive
2 San Diego Creek @ Harvard Avenue
3 Peters Canyon Channel @ Barranca Parkway
4 Hines Channel @ Irvine Boulevard
5 San Joaquin Channel @ University Drive
6 Santa Ana Delhi Channel @ Mesa Drive
7a Peters Canyon Channel @ Walnut Avenue
7b El Modena-Irvine Channel upstream of Peters Canyon Channel confluence
8 Sand Canyon Avenue – NE corner Irvine Blvd
9 East Costa Mesa Channel @ Highland Drive
10 Central Irvine Channel @ Monroe

Newport Bay Watershed Sampling Sites



Land Use—San Diego Creek - (1990 Data)[1]

Land Use	Percent of Watershed	Area (mi^2)
Residential	15.0	17.9
Commercial	8.0	9.5
Industrial	6.3	7.5
Open space/vacant	23.1	27.5
Agriculture/ranching	10.0	11.9
Public	0.3	0.4
Recreation	0.3	0.4
Transportation and communication/utility	1.2	1.4
Roads	35.8	42.6
Sum	100	119.1

[1] Data are based on projections for ultimate buildout.
Source: OCEMA (1990) & California RWQCB (2000)

Toxicity of Diazinon and Chlorpyrifos to *Ceriodaphnia* and *Mysidopsis bahia*

Constituent	*Ceriodaphnia* LC_{50} (ng/L)	*Mysidopsis bahia* LC_{50} (ng/L)
Diazinon	450	4,500
Chlorpyrifos	80	35
Methomyl	5,560	-
Carbaryl	3,500 – 5,200	-
Malathion	1,400	-

- No information available.

Summary of Results for Selected Analytes September 29, 1999, Event

Station	Analyte (ng/L) [LC_{50}]								
	Diazinon [960]	Chlorpyrifos [100]	Malathion [1,000]	Prowl [280,000]	Benomyl [80,000]	Carbaryl [13,000]	Diuron [21,000]	Methomyl [8,800]	Other-Dimetho-ate
3	820	<50	<100	<100	<400	<70	<400	<70	-
4	220	310	<100	170	300J	70	<400	<70	250

Summary of *Ceriodaphnia* 96-hr PBO TIE Conducted on Samples San Diego Creek at Campus Drive January 25, 2000[1,2]

Treatment	Mortality for each day of the test[3]				Conclusions	Final pH at 24 hr
	1	2	3	4		
Laboratory Control	0	0	0	0	Control met all EPA criteria for test acceptability.	8.1
Laboratory Control + PBO	0	0	0	0	No artifactual toxicity present in control blanks.	8.1
12.5% Campus/SD Creek	0	0	0	50	These results suggests that the ambient sample has 8 toxic units	8.1
25% Campus/SD Creek	0	95	100	100	Toxicity detected.	8.1
50% Campus/ SD Creek	100	100	100	100	Toxicity detected.	8.0
50% Campus/ SD Creek + 50 ppb PBO	0	0	100	100	Delay in mortality suggests that the toxicity was at least in part due to a metabolically activated pesticide.	8.0
100% Campus/SD Creek	100	100	100	100	Toxicity detected.	8.1
100% Campus/SD Creek + 50 ppb PBO	100	100	100	100	Toxicity detected.	8.1

1. Four replicates with 18 mls of sample and 5 *Ceriodaphnia* each.
2. Daphnids were fed the standard EPA amount of food for only 4 hr/day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Pesticide Use in Orange County

(Based on DPR Database)

Pesticide	Pounds (ai) of Pesticide Used				
	1995	1996	1997	1998	1999
Diazinon	21,543	16,438	21,655	25,766	24,452
Chlorpyrifos	41,782	75,396	73,662	91,707	79,990
Carbaryl	5,648	3,199	5,636	6,506	2,835
Methomyl	4,174	3,163	3,059	2,413	3,181
Malathion	9,192	4,724	4,341	5,858	5,953
Permethrin	18,644	10,299	11,218	19,011	10,480
Bifenthrin	18	39	130	493	5,257
Cypermethrin	2,483	6,377	4,106	5,925	5,871
Esfenvalerate	396	436	278	227	113
Fenvalerate	4,129	8,125	8,492	428	18
Cyfluthrin	-	-	1,478	1,567	793
Deltamethrin	-	-	0.08	25	86
Piperonyl Butoxide, Technical, Other Related	-	-	461	547	387
Total Copper used as pesticide	-	-	15,635	23,883	16,389

-- data not available

Sources of Pesticides in Watershed

- Usage of Pyrethroid-Based Pesticides in Orange Co., CA during Late 1990s (according to CA DPR Use Reports)
  - ~ 25,000 lbs (ai)/yr
- Nurseries in Upper Newport Bay Watershed
  - At Times, Responsible for up to 50 TUa Diazinon Toxicity in Streams Just Downstream from Nurseries

CDFA Used a Pyrethroid-Based Pesticide to Address Fire Ant Infestation

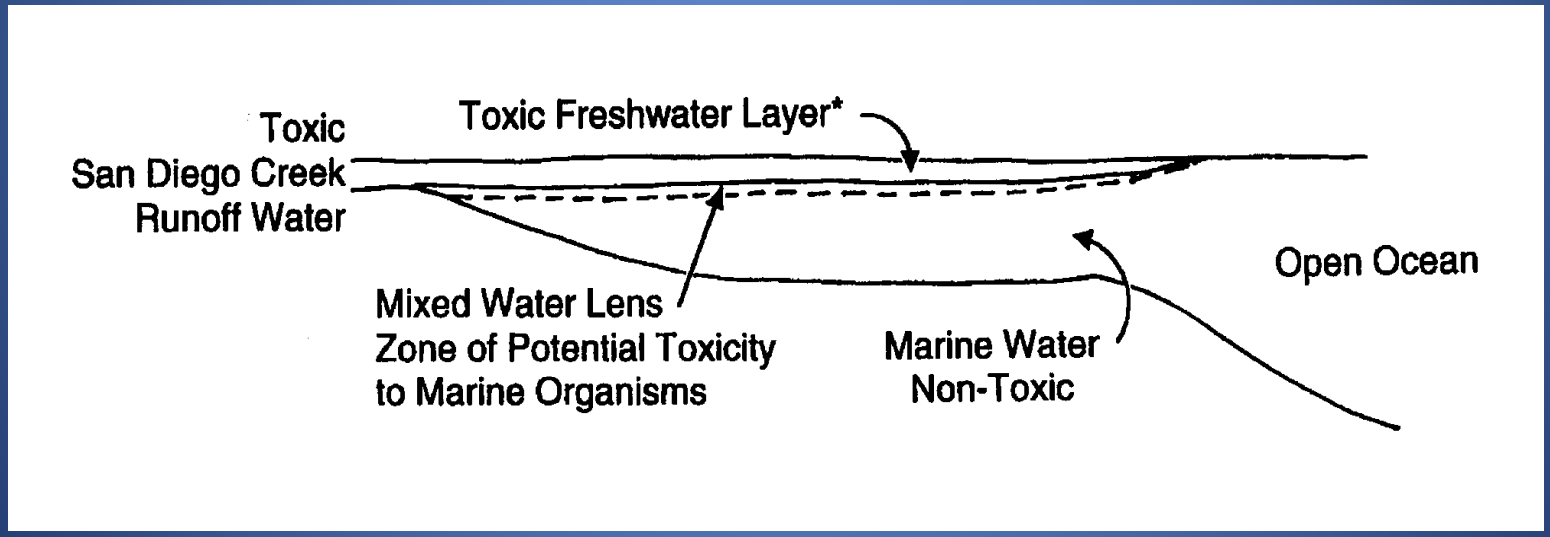
- That Use Was Not Included in DPR Pesticide Use Report

Summary of Key Results

- *Ceriodaphnia dubia* & *Mysidopsis bahia* Toxicity Tests on Stormwater Runoff to Tributaries of Upper Newport Bay
  - Standard US EPA Procedures - 375 Toxicity Tests
  - Result: 1 – 10 TUa
- Dual Column GC & ELISA Analysis & TIEs
  - Result: About Half Toxicity Due to
    - OP Pesticides
      - Diazinon and Chlorpyrifos
- TIEs Involving Serial Dilutions & PBO Additions
  - Result: Substantial Part of Remaining Toxicity Potentially Attributable to Pyrethroid-Type Pesticides
- TIEs Showed That Heavy Metals in Runoff Not Toxic
  - Despite Exceeding Criteria Concentrations

Water Quality Significance of OP Pesticide Toxicity

- Several-Day Travel Time from Headwaters to Upper Newport Bay



Evaluation Monitoring on Trial

- Employee of Transportation Corridor Agency (TCA) Made Public Claims That TCA Was Not Protecting Environment When It Adopted Evaluation Monitoring Approach Rather Than Her Recommended Compost Filters for ETC BMP
  - Employee Was Terminated for Claims
- Employee Filed Suit for Wrongful Termination & Damage to Professional Reputation
- GFL Testified in the Jury Trial Regarding Why Her Approach of Compost Filters Was Not Valid BMPs & Why Evaluation Monitoring Was Valid Approach
- Jury Did Not Support Her Argument; Supported EM Approach

Illustration of Need for Different Regulatory Approach

- Early 2000s Pyrethroid-Based Pesticides Appeared in Urban Pesticides as Replacement for OP Pesticides
  - Available to Public for Urban Residential Use
  - Predicted Watercolumn Aquatic Life Toxicity in Receiving Waters for Urban Stormwater Runoff

    Lee, G. F., "The Urban Pesticide Problem: How Do We Know the Substitutes Aren't Worse Than the Ones They're Replacing?" Feature Article, Journal Stormwater 2(1):68-71, Forrester Press, January/February (2001).

    http://www.gfredlee.com/Runoff/UrbanPestStormwater1.pdf
- Continued to Advocate for Monitoring of Urban Stormwater Runoff & Receiving Waters for Pyrethroid Toxicity
- Summer 2009, Dr. D. Weston (UC Berkeley) Presented Results of His Studies
  - Showed Pyrethroid-Based Pesticides Used in Urban Areas Causing Toxicity to Aquatic Life in Watercolumn of Waters Receiving Urban Stormwater Runoff

Inadequate Regulatory Approach

- Current Reactive Approach Failed to Detect Aquatic Life Toxicity of OP Pesticides for More Than a Decade after Damage to Ecosystems Began to Occur
- Consequence of Phase-Out & Phase-Down of OP Pesticides Diazinon & Chlorpyrifos in Urban Areas:
  - Large-Scale Use of Other Pesticides
  - Need to Evaluate Pesticide Impact Beyond Registration
- Should Focus Initial Development & Application of Pro-active Approach in Urban Areas

Need Pro-active Approach for Managing Aquatic Life Toxicity Caused by Pesticides

- Aquatic Life Toxicity due to OP Pesticides Known
  - in Central Valley Rivers Since Late 1990s
  - in Urban Stormwater Runoff from Stockton, CA Since Mid-1990s
    - Due to OP pesticides
- US EPA Clean Water Act Requires Control of Aquatic Life Toxicity
- US EPA Office of Pesticide Programs Allows “Insignificant” Aquatic Life Toxicity
- Current “Reactive” Approach for Regulating Aquatic Life Toxicity of Pesticides Not Protective of Environment
- Need “Pro-active” Approach to Properly Screen Pesticides for Potential Water Quality/Ecological Impacts

Need Pro-active Approach

- US EPA OPP & CA DPR Registration of Pesticides Significantly Deficient in Evaluating Potential for Registered Uses to Result in Aquatic Life Toxicity
  - Allow Toxicity in Stormwater Runoff & Irrigation Water Releases
    - Do Not Require Fate/Transport Information or Aquatic Life Impact Information for Stormwater Runoff & Irrigation Water Releases
      - Information Essential for Evaluating Potential Aquatic Life Impacts of All Pesticides That Could Be Mobilized by
        - Rainfall Runoff
        - Fugitive Irrigation Water
        - Irrigation Tailwater (Runoff/Release Waters)

Pro-active Approach

- Need to Properly Screen Pesticides for Potential Water Quality / Ecological Impacts Under Conditions of Actual Use
  - Monitoring Stormwater Runoff & Irrigation Water Releases Should Be Required Part of Registration for All Pesticides That Present Potential Threat to Water Quality
  - Monitor For:
    - Presence of the Pesticide in Runoff/Release Water
    - Persistence / Transformation of the Pesticide in Aquatic Systems That Receive Runoff/Release Water
    - Toxicity of Runoff/Release Water to Several Forms of Watercolumn & Benthic Life

Aquatic Life Toxicity Studies on Stormwater Runoff

Issues That Need Consideration

- Could There Be Toxicity in Stormwater Runoff?
- Is There Toxicity in Receiving Water during Water Runoff Event?
- Is There Toxicity in Receiving Water between Runoff Events?
- Concentration / Duration of Exposure Profile of Pesticide Being Evaluated, during Runoff Event
- If Pesticide Toxic or Potentially Toxic
  - Evaluate Period of Time during Which Planktonic & Benthic Organisms in Urban Stream or Receiving Water Could Be Exposed to Toxic Conditions

Pro-active Approach

- Where Toxicity Found or Concentrations of Pesticides at Potentially Toxic Levels (> Worst-Case Water Quality Criteria)
  - Require Comprehensive Field Study to Evaluate
    - Whether Measured or Potential Toxicity Adversely Impacts Numbers, Types, or Character of Aquatic Life in Receiving Water
  - If Potential Adverse Impacts Found on Organism Assemblages in Receiving Water:
    - Determine Significance of Impacts to Water Quality / Beneficial Uses of Waterbody
- Err on Side of Water Quality / Beneficial Use Protection When Inadequate or Inconclusive Data Exist
- Funding for Required Studies:
  - Provided by Pesticide Manufacturer, Users, Others Who Profit from Use of the Pesticide

Issues That Need Consideration -Significance of Toxicity

- Fate of Toxic Urban Stream Water in Receiving Water
  - Rate of Dilution/Dissipation of Toxicity in Receiving Water
  - Toxicity in Receiving Water Upstream of Entrance of Urban Stream during Stormwater Runoff Event
- If Desirable Forms of Aquatic Life Could Receive Toxic Exposure That Could Adversely Affect Beneficial Uses of Urban Stream or Receiving Water:
  - Conduct Special-Purpose Study of Planktonic and/or Benthic Organism Assemblages
    - Evaluate Whether Toxicity Causes Significant Alteration of Numbers & Types of Desirable Aquatic Life
- Use Best Professional Judgment, Weight-of-Evidence Triad Approach in Interactive, Peer-Review Process to Determine if Adverse Impacts to Beneficial Uses of Urban Stream Are Potentially Significant

Aquatic Chemistry – Toxicology – Fate Modeling

- Determine Expected Transport – Fate – Impact Model for Pesticide
  - Predict Areas of Receiving Water Where Aquatic Life Toxicity Could Be Expected to Occur with Stormwater Runoff Event or Irrigation Water Discharge
  - Compare Predictions with Field Assessments
    - Work with County Ag Commissioners to Determine Where & When to Set up Pro-Active Field Monitoring Program
  - Initial Predictions Not Likely Highly Reliable
  - Reliability of Predictions Will Improve with Experience & Appropriate Monitoring
  - Eventually Will Be Able to Greatly Reduce Field Studies as Modeling Capability Improves

For Currently Regulated Pesticides

- Define Pesticides Used in an Area
  - Which Pesticides Used
  - Application Practices
    - How Applied, How Much, When, Where
- Conduct Field Monitoring Program for Low-LC50 for Daphnia & Fathead Minnow Larvae That Could Be Present in Stormwater Runoff & Irrigation Water Releases to Determine:
  - Concentrations of Each Pesticide in Runoff & Release Water
  - Fate & Persistence of Each Pesticide in Receiving Water
  - Aquatic Life Toxicity to Suite of Watercolumn & Benthic Organisms

For Currently Regulated Pesticides

- Field Monitoring Program Also to Assess
  - Whether Organism Assemblages in Receiving Water in Keeping with Habitat Characteristics
    - Examine Worst-Case Situations near Points of Use/Runoff
    - Follow Runoff/Discharge Plumes Using Toxicity & Pesticide Concentrations
  - Establish Toxicity—Duration of Exposure Relationship for Planktonic & Benthic Organisms
- To Assess Meteorological Influences, Studies Need to Be Conducted over Several-Year Period for Given
  - Pesticide Formulation & Application Method
- Studies Need to Be Repeated if Formulation or Application Practices Change

Adequacy of Analytical Methods

- Sampling & Analytical Methods Must Be Evaluation to Ensure
  - Potential Toxicant Can Be Determined Reliably at Potentially Toxic Levels
- If Analytical Methods Not Available to Quantify Pesticide at 0.1 LC50 for Most Sensitive Form of Aquatic Life:
  - Require Manufacturer to Develop Reliable Analytical Method before Pesticide Is Registered
- If Analytical Method Inadequate, Contact:
  - US EPA Office of Water & Pesticide Programs
  - CA Dept. Pesticide Regulations
  - State Water Resources Control Board
  - Request That Pesticide Manufacturer Be Required to Immediately Develop & Properly Evaluate Analytical Methods for Pesticide

Suggested Approach

- Appoint & Fund Pro-Active Approach Advisory Committee Consisting of Representatives of
  - CVRWQCB
  - US EPA
  - DPR
  - Pesticide Manufacturers
  - Ag Interests
  - Aquatic Toxicologist
  - Hydrologist
  - Others?
  - SWRCB
  - OEHHA
  - SRWP
  - County Ag Commissioners
  - CALFED
  - Aquatic Chemist
  - Invertebrate Biologist
- Geographical Scope: Include Sacramento & San Joaquin River Watersheds & Delta

Suggested Approach

- Develop Draft Guidance on Implementation of Pro-Active Approach
  - Review Pesticide Use in Central Valley
  - Select for Initial Review Those Pesticides That Are:
    - Used in Large Amounts
    - Have Low LC50s for Daphnia & Fathead Minnow Larvae
    - Expected in Stormwater Runoff and/or Irrigation Water Releases
    - Reliably Measurable at Concentrations of 0.1 LC50

Key Issue

- Is It Possible to Develop a Pesticide That
  - Is Effective against Target Pest
  - Is Cost-Effective
  - Will Not Also Kill Some Zooplankton?
- Insects Are Physiologically Similar to Some Zooplankton & Benthic Invertebrates

Additional Information

Lee, G. F., and Jones-Lee, A., “OP & Pyrethroid Pesticide-Caused Aquatic Life Toxicity: Inadequate Regulation of Urban Use,” Abstract of presentation at DPR informal pesticide seminar, organized by Dr. Kean Goh, DPR Surface Water Program Manager, Sacramento, CA, March 9 (2010).
http://www.gfredlee.com/SurfaceWQ/DPR_WS_PestToxicityAbs.pdf

Further Information

Consult Website of
Drs. G. Fred Lee and Anne Jones-Lee

http://www.gfredlee.com