Reductions in Organophosphate Pesticide Demonstrate Watershed-wide Improvements in Water Quality:
San Diego Creek Watershed (Orange County, CA)
Based on Multiple Lines of Evidence (SP 12 - Option 2b)

Executive Summary

Two Newport Bay watersheds show watershed-wide improvement in water quality for two organophosphate (OP) pesticides (diazinon and chlorpyrifos). Pesticide load reductions were achieved using a watershed approach and both regulatory and non-regulatory mechanisms. These mechanisms targeted the three primary sources of pesticides in the watersheds: residences, nurseries and municipalities. Water quality data show diazinon and chlorpyrifos concentrations have been reduced to levels that are no longer detrimental to beneficial uses and can therefore be removed from the Clean Water Act (CWA) 303(d) list of impaired waters. While continued efforts are needed to fully restore beneficial uses of the San Diego Creek watersheds, specifically to address multiple impairments, the success of the watershed approach to reduce OP pesticides and nutrients can be used as a model for future implementation (see http://www.epa.gov/region9/water/watershed/measurew/newport-bay/index.html).

Watershed Identification

a	Organization	Santa Ana Regional Water Quality Control Board - California
b	Point of Contact	Doug Shibberu, Environmental Scientist Santa Ana Regional Water Quality Control Board 3737 Main Street, Suite 500, Riverside, CA 92501 Tel: 951-782-7959; Dshibberu@waterboards.ca.gov
c	Project Title	Reducing toxicity due to organophosphate pesticides (diazinon and chlorpyrifos) in the Newport Bay Watersheds, Orange County, California
d	Watersheds Improved	Two Watersheds: Upper San Diego Creek (USDC) and Lower San Diego Creek (LSDC) *(note, EPA guidance does not allow one watershed to be counted more than once under SP12. In 2010, LSDC was counted under this measure for nutrient reductions, therefore only USDC will be counted under this measure in 2012.)*

Description of 2002 Baseline Condition

e	Watersheds	1. Upper San Diego Creek (180702040102); 2. Lower San Diego Creek (180702040103);
f	2002 Impairments	Upper San Diego Creek - Unknown toxicity, nutrients, metals, siltation
		Lower San Diego Creek - Pesticides (diazinon and chlorpyrifos), nutrients, excessive algae, metals, pathogens, siltation
g	Map (optional)	Attachment 1: Map of San Diego Creek showing monitoring sites, nurseries and educational outreach.

Evidence of Watershed Approach

h	Area of Effort	The San Diego Creek watershed is located in the central portion of Orange County on the Southern California coast. The watershed is defined by the foothills of the Santa Ana Mountains to the east and the San Joaquin Hills to the west and southwest. The watershed occupies an area of 120 square miles (77,000 acres), and constitutes 15% of the area of Orange County. The watershed is largely urbanized, but substantial open space areas and recreational parks constituting about 23% of the watershed, have been preserved. Only about 2% of the watershed is dedicated to agriculture (row crops, orchards, nurseries). Eight cities are located partially or fully within the watershed: Irvine, Lake Forest, Laguna Hills, Laguna Woods, Newport Beach, Orange, Santa Ana, and Tustin. The watershed also includes several unincorporated areas of Orange County. The total population within the watershed is about 600,000.

i	Key Stake-holders Involved and Their Roles	Santa Ana Regional Water Quality Control Board (Regional Board): California regional water quality agency responsible for implementing the federal Clean Water Act as well as the state water quality law (Porter-Cologne). The Regional Board adopted a diazinon and chlorpyrifos TMDL for the San Diego Creek and Newport Bay Watershed in 2003, which was approved by the U.S. Environmental Protection Agency (EPA) in 2004. The objective of the TMDL is the reduction of diazinon and chlorpyrifos concentrations in surface water to non-toxic levels. The TMDL established an implementation plan that includes both regulatory and non regulatory mechanisms requiring stakeholders to reduce pesticide discharges. County of Orange: The County of Orange acts as the lead for municipalities regulated under the area-wide National Pollutant Discharge Elimination System (NPDES) stormwater permit for Orange County. The stormwater permittees in the San Diego Creek Watershed (including the County, and the cities of Irvine, Laguna Hills, Laguna Woods, Lake Forest, Newport Beach, Orange, Santa Ana, and Tustin) are responsible for implementing a monitoring plan for pesticides in urban runoff. Permittees are also required to implement programs for reduction of pesticide runoff from urban areas to the maximum extent practicable. University of California Cooperative Extension (UCCE): The University of California Cooperative Extension (UCCE) operates a 250-acre research and extension station located within the watershed. UCCE staff and facilities provide training and expertise to improve agricultural runoff water quality and also to improve/reduce runoff from urban landscapes. Urban areas in the watershed were demonstrated to be significant sources of pesticide runoff (Link: Contributions of Organophosphorus Pesticides from Residential Land Uses during Dry and Wet Weather). Large Commercial Nurseries: Under Porter-Cologne, and pursuant to California's Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program, the Regional Board began issuing Waste Discharge Requirements (WDRs) to large nurseries in 1990, to address excessive nutrient discharges. In 2005 and 2006, these WDRs were revised to include TMDL limits for diazinon and chlorpyrifos. Nurseries are required to treat their stock with pesticides due to a state-imposed quarantine targeting fire ants. Chlorpyrifos is among the pesticides used for this purpose. Subsequent to the TMDL, the nurseries have switched to alternative products. The nurseries have also implemented BMPs to retain sediment (and associated bound pesticides) onsite and reuse the sediment in their potting mix. (Three of the four nurseries left the watershed in 2010 after termination of their long-term land leases). California Department of Pesticide Regulation (DPR): The DPR registers pesticides for use in California and issues licenses for professional pesticide applicators. DPR also collects usage data from licensed pesticide applicators and conducts studies to monitor the impact of pesticides used for the fire ant quarantine program. United States Environmental Protection Agency (US EPA): The US EPA registers pesticides for use at the federal level after conducting human health and ecological risk assessments. The US EPA provides oversight, technical assistance and grant funding to support monitoring, assessment and implementation of the State water quality programs including permitting, enforcement and restoration.

j Watershed Plan

The Newport Bay/San Diego Creek Watershed Diazinon and Chlorpyrifos TMDL and Implementation Plan, was adopted by the Regional Board in April 2003. The TMDL establishes chronic and acute numeric targets for diazinon and chlorpyrifos, and outlines a series of implementation actions with a timetable, to meet the TMDL targets. These include NPDES and WDR permit limits, outreach and education, agricultural best management practices (BMPs), and water quality monitoring.

k Restoration Work

Management measures implemented by stakeholders included:

- Education and outreach to residential pesticide users, and demonstration of alternative ant control strategies
- Implementation of common erosion and sediment control procedures at nurseries to prevent potting mix (with incorporated pesticides) from reaching waterbodies, and to reuse of sediment in potting mix. These activities funded in part by a $300,000 319h grant project during 2004-07: Reduction of pesticide runoff from Nurseries
- Water quality outreach to small nurseries (partly funded by a $370,000 state grant project during 2007-09: Orange County Nurseries Water Quality Improvement Project)
- Implementation of Integrated Pest Management (IPM) strategies by municipalities to reduce pesticide use through landscape design, plant selection, and use of non-toxic alternatives for pest control
- Creation of a demonstration center to train landscape architects, master gardeners, and municipal staff on IPM and outreach to targeted pesticide user groups (partly funded by a $1 million state grant during 2005-08: Mitigating Pesticide Runoff in Urbanized Environments

Evidence of Watershed-wide Improvement

l Impairments Removed (If applicable)

Water-column toxicity caused by diazinon and chlorpyrifos has been reduced to levels that are not detrimental to beneficial uses. Table 1 demonstrates that sufficient data exist to delist San Diego Creek for diazinon and chlorpyrifos.

Table 1: Delisting Scenario Using Data From 2009 to 2011 (Option 1)

Waterbody	Pollutant	Condition	No. of Samples	No. of TMDL Exceedances	Action
San Diego Creek Reach 2	Diazinon	Acute	65	0	Delist
		Chronic	61	0	Delist
	Chlorpyrifos	Acute	45	2	Delist
		Chronic	45	2	Delist
San Diego Creek Reach 1	Diazinon	Acute	63	0	Delist
		Chronic	59	1	Delist
	Chlorpyrifos	Acute	43	1	Delist
		Chronic	43	1	Delist

m Improving Trend in Water Quality

For many years, diazinon and chlorpyrifos were among the top pesticides used in California. These “broad-spectrum” pesticides were used for both urban applications (targeting ants, termites, fleas and other household and landscape pests), and for agricultural crop protection.

Reductions in Pesticide Use: In 1996, the Food Quality Protection Act directed the US EPA to use more stringent standards when registering pesticides for use (largely due to public health concerns). The US EPA subsequently revised its risk assessments and negotiated revised registration agreements with the manufacturers of diazinon and chlorpyrifos (

Table 2). The agreements specified the phase-out of most uses by 2005.

Table 2: Summary of U.S. EPA Re-registration Agreements for Diazinon and Chlorpyrifos

Use	Action (summary excerpts)	Schedule	
		Chlorpyrifos	Diazinon
Indoor	Cancel virtually all uses	Stop sale: Dec. 31, 2001 Stop use: Dec. 31, 2004	Stop sale: Dec. 31, 2002
Outdoor, non-agricultural	Reduced usage rates (e.g. golf courses, fire ants) or elimination (e.g. home lawn & gardens, parks)	Dec. 1, 2000	Dec. 31, 2004
Agricultural	Limits on usage for some crops	Dec. 31, 2000	Feb., 2001

The impact of the re-registration agreements on pesticide usage can be seen in the pesticide usage data collected by the California Department of Pesticide Regulation (DPR). DPR collects pesticide use data from licensed applicators, although this does not cover pesticide usage by the general public. In areas with substantial urbanization, home and garden uses (which are not reported to the DPR) may have accounted for about half the total diazinon and chlorpyrifos usage.

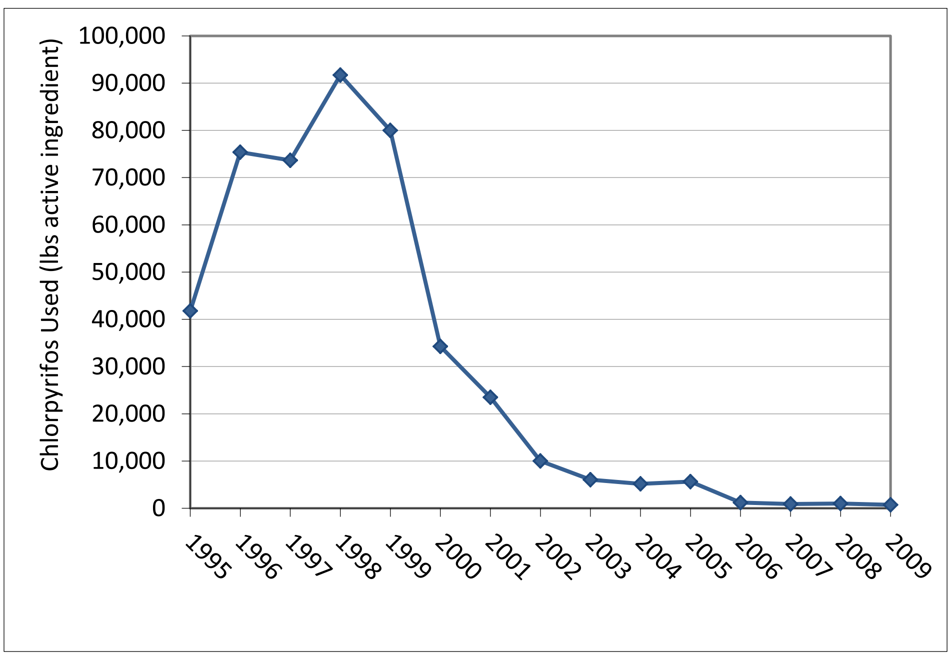

Figure 1: Reported Chlorpyrifos Use in Orange County, 1995-2009

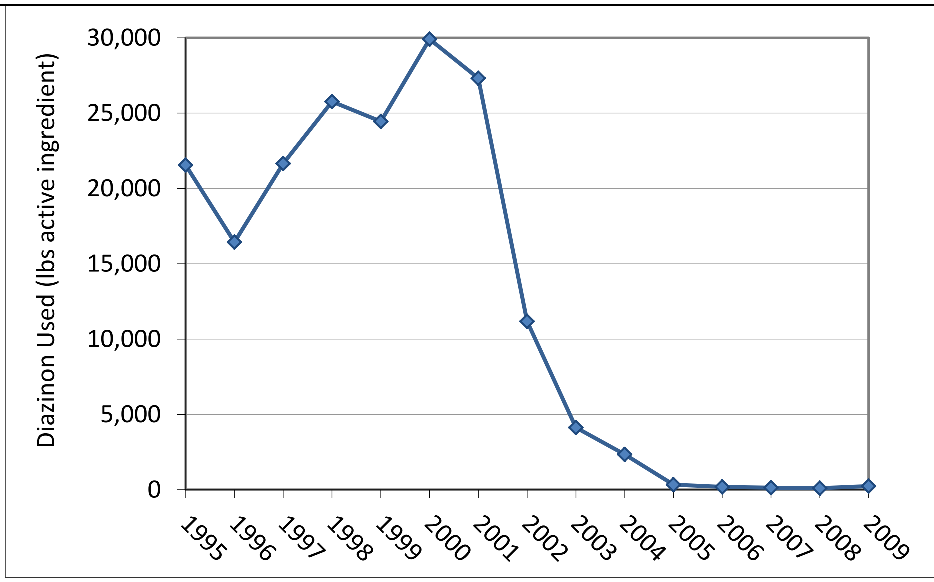

Figure 2: Reported Diazinon Use in Orange County, 1995-2009

Figure 1 and
Figure 2 show the annual *reported* use of chlorpyrifos and diazinon in Orange County for the 15 years from 1995 to 2009. Major reductions in use took place as the phase-out of uses proceeded from 2001 to 2005, with the decline in diazinon use slightly lagging behind that of chlorpyrifos (
Figure 2). Total reported use for both chlorpyrifos and diazinon in 2009 was reduced by 99 percent compared to the reported usage in 1999.

While the US EPA re-registration agreements were the primary cause of reduced diazinon and chlorpyrifos usage, it should be noted that US EPA's primary targets were indoor uses that were not likely to affect water quality in surface streams.

Additional actions by watershed stakeholders contributed to reductions in uses that were allowed to continue (e.g. nursery use) and likely contributed to the decline in purchase and use by homeowners during the phaseout period. These actions are summarized in Section K (above) and in Section O (see following section below).

Reductions in Pesticide Runoff: The reduction in usage has led to reductions in pesticide runoff concentrations in San Diego Creek and its tributaries. The 2003 TMDL required the County of Orange stormwater NPDES permittees to implement a monitoring program for diazinon and chlorpyrifos, and for water column toxicity. These requirements were implemented beginning in July 2005. (Earlier diazinon, chlorpyrifos, and toxicity data, collected between 1996 and 2001, were funded through two US EPA Clean Water Act grants [205j and 319h programs] or collected by the DPR).

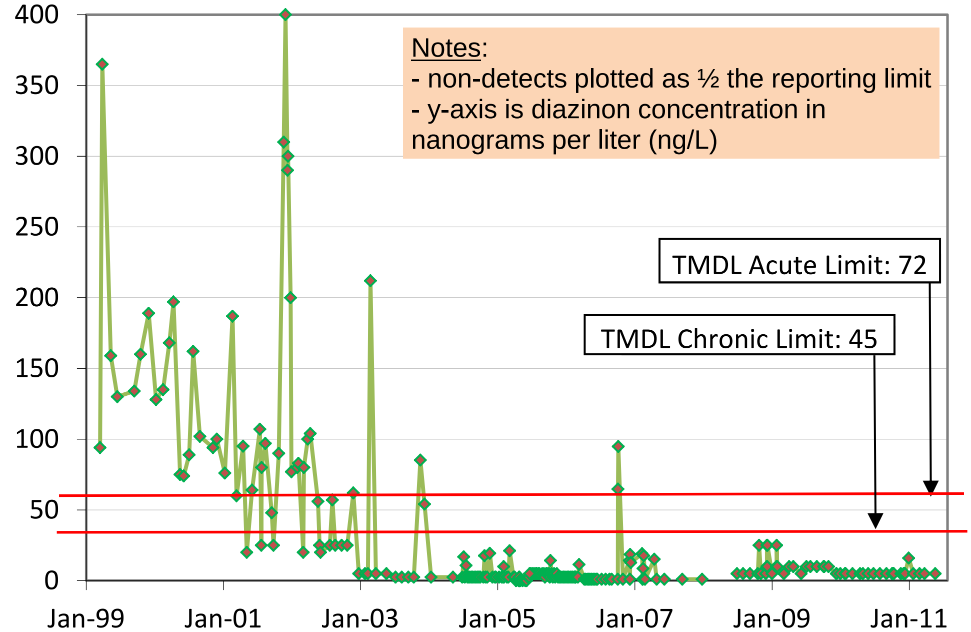

Figure 3, shows diazinon concentrations in Reach 1 of San Diego Creek. The apparent diazinon spikes in 2008-09 (Figure 3) are due to the anomalously high reporting limits (20-50 ng/L) that the lab used that year. Diazinon has actually not been detected since April 25, 2007. As stated in the legend for the figure, all non-detects are plotted as ½ the reporting limit. Diazinon concentrations have declined due to US EPA's cancellation of most uses of diazinon uses in residential areas, and to the voluntary switch to alternative pesticides by nurseries and other growers (row crops and orchards) that were still permitted to use diazinon. Education and outreach campaigns have also led to a general reduction in pesticide use, and to the adoption of landscape design and maintenance practices that rely on other methods to control pests. Those with already purchased stocks of diazinon and chlorpyrifos continue to use these pesticides but this use will be eliminated when the stocks are exhausted.

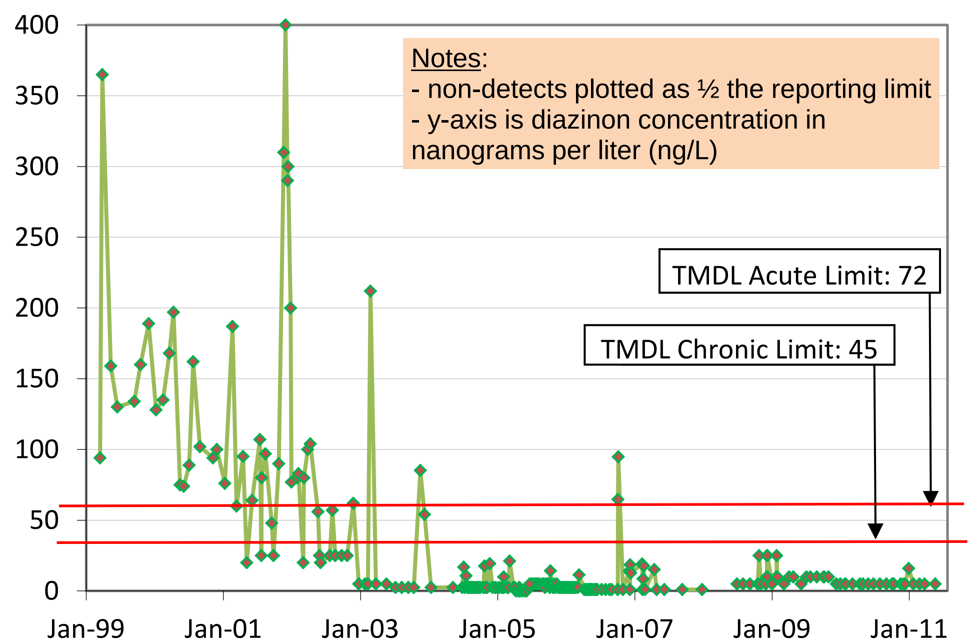

Figure 3: Diazinon (nanograms/liter) in Reach 1 of San Diego Creek

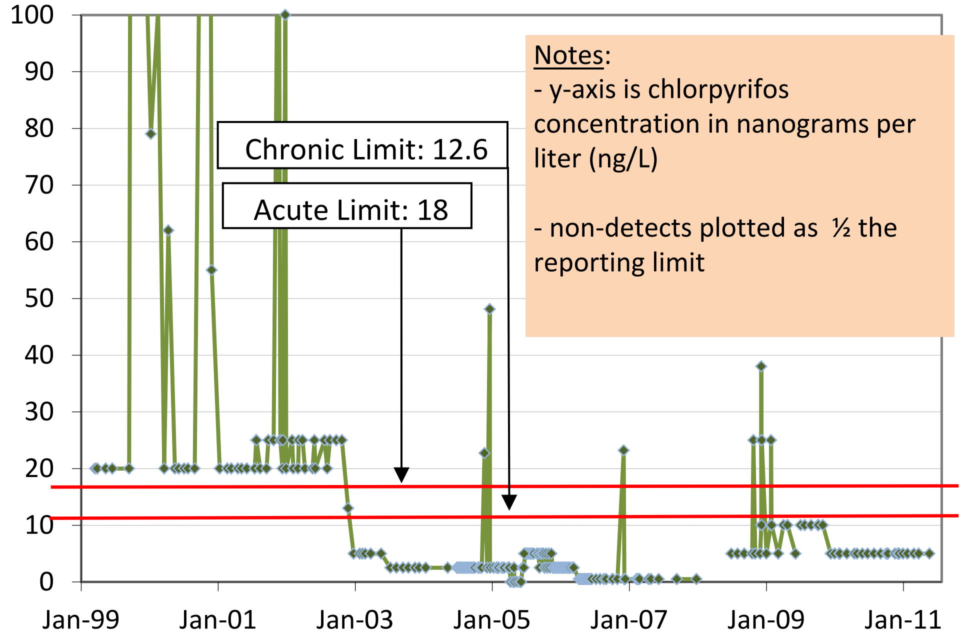

Figure 4: Chlorpyrifos (nanograms/liter) in Reach 1 of San Diego Creek

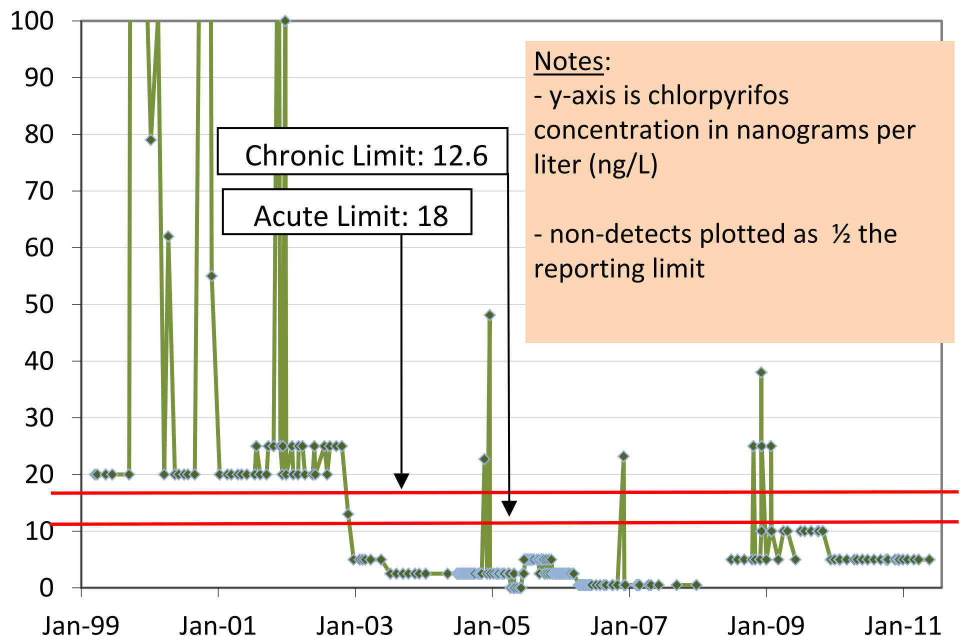

Figure 4 shows the similar declining trend for chlorpyrifos in Reach 1 of San Diego Creek. The apparent chlorpyrifos spikes in the 2008-09 year are due to high reporting limits of 20 ng/L and 50 ng/L that the County's lab contractor used, contrary to the requirements. As stated in the legend for the figure, all non-detects are plotted as ½ the reporting limit. The only true spike is on the 15th of December, 2008 when chlorpyrifos was detected at a concentration of 38 ng/L in runoff from a storm event. Other than this, there are no detections of chlorpyrifos after December 13, 2006 in this reach of San Diego Creek. Concentrations have declined below both acute and chronic TMDL targets, and are not expected to cause toxicity.

n Supporting Trends (one or more)	Reductions in Water-Column Toxicity: Evidence of an improving trend in the related parameter of aquatic life toxicity, is demonstrated by comparison of Figure 5, which summarizes available toxicity test data for the San Diego Creek Watershed from 1996-2001, with Figure 6 through Figure 9, which detail post-TMDL toxicity test data from 2005-2011.

Results are quantified as in Table 3, with the definitions "moderate" and "elevated" being used for the purposes of this report.

Table 3: Toxicity Reporting

Parameter		Formula	Toxicity Level		
			Non-Toxic	Moderate	Elevated
TUa	Acute Toxic Units	100/ LC50	0	0< TUa <1	>1
TUc	Chronic Toxic Units	100/ NOEC	1	1< TUc <2	>2

LC50 = concentration lethal to 50 percent of test organisms. NOEC = no observed effects level, TUa=acute toxic units, TUc = chronic toxic units

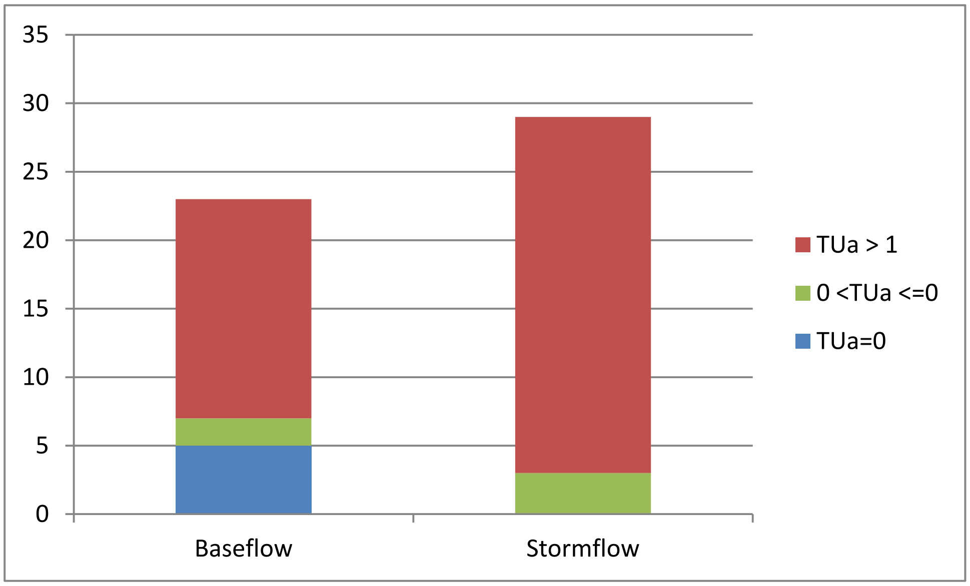

Figure 5: Acute Toxicity to *Ceriodaphnia* in San Diego Creek and its Tributaries (1996-2001) – excludes DPR toxicity testing of nursery runoff

Diazinon and chlorpyrifos were first linked to water column toxicity in San Diego Creek during a State-sponsored investigation in 1999 and 2000 (Link: presentation describing the study). Laboratory studies ascribed most of the observed toxicity to OP pesticides (diazinon and chlorpyrifos were the major OP pesticides being used at the time). The DPR also conducted toxicity testing in the San Diego Creek Watershed to evaluate the impacts on water quality from the DPR's mandatory fire ant quarantine program. The program required nurseries in Orange County to treat their stock with pesticides (with diazinon and chlorpyrifos being the major available options; Link: Surface and Groundwater Monitoring of Pesticides Used in the Red Imported Fire Ant Control Program).

Subsequent to the TMDL, the County of Orange incorporated toxicity tests into its permit-required monitoring program beginning with the 2005-06 reporting year (July 2005 through June 2006). The County conducts regular monitoring at two locations along San Diego Creek and at two locations in creeks that are tributary to San Diego Creek. Monitoring is conducted during both baseflow conditions, (which prevail 90 percent of the time) and during stormflow conditions. Both acute and chronic tests are conducted.

Figure 6 summarizes the acute toxicity results for *Ceriodaphnia* under baseflow conditions. Most test results were non-toxic, (ranging from 79% to 100%: overall 90% for the six years), a significant change from the results obtained during the pre-TMDL period when only 20% of *Ceriodaphnia* tests under baseflow conditions were non-toxic. Toxic results over 1 TUa occurred only in the 2008-09 reporting year, and this is also a significant improvement over the pre-TMDL period where 55% of the tests exhibited elevated toxicity.

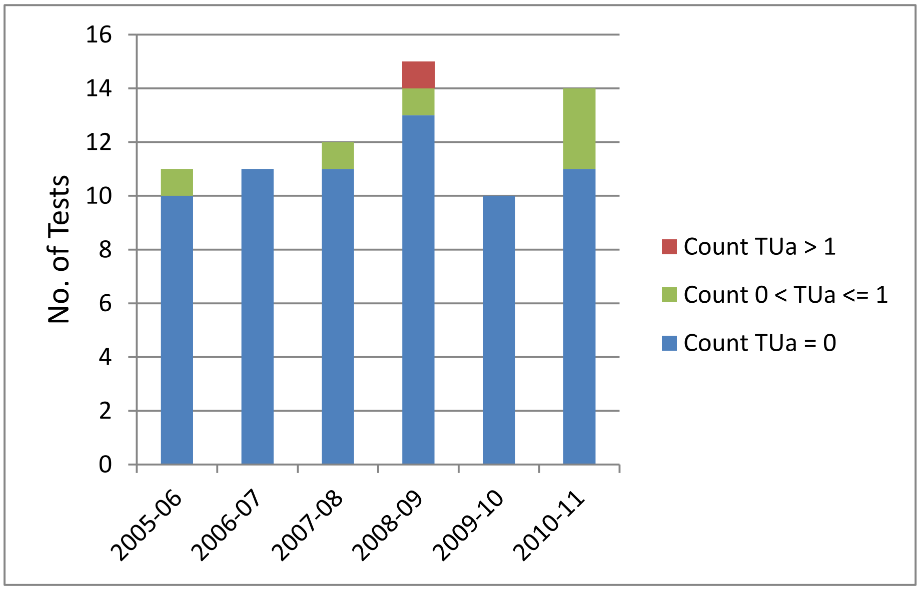

Figure 6: *Ceriodaphnia* Acute 48-hour Survival Test - Baseflow

Figure 7 summarizes the acute toxicity results for *Ceriodaphnia* under stormflow conditions. Most test results were non-toxic, (ranging from 63% to 100%; overall 84%). No tests found toxicity greater than 1 TUa. This is a significant improvement from the results obtained during the pre-TMDL period when all *Ceriodaphnia* tests under stormflow conditions exhibited toxicity, and 90% exhibited elevated toxicity (greater than 1 TUa). This specific test was not performed in 2010-11, but the results of the longer 7-day survival test for that year were all non-toxic, indicating that 100% of the samples could also be considered non-toxic for acute conditions in 2010-11.

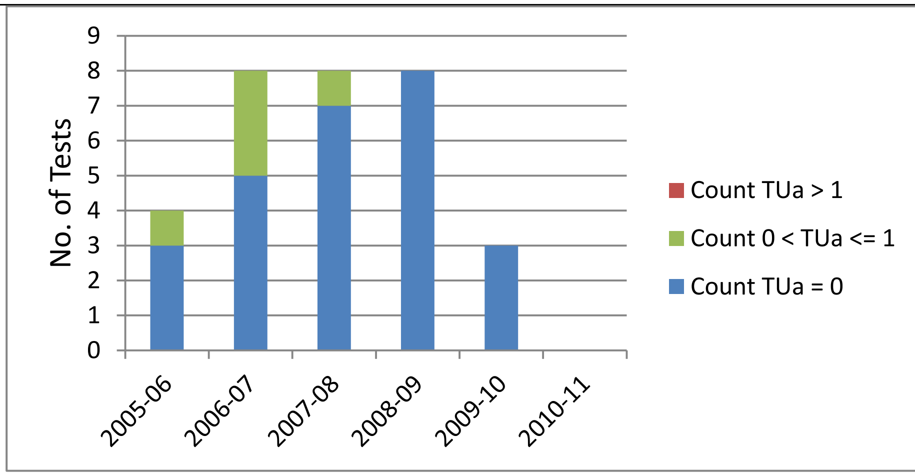

Figure 7: *Ceriodaphnia* Acute (48-hour) Survival Test - Stormflow

Few chronic tests were conducted during the pre-TMDL period because of the elevated toxicity found in the acute tests. Although there is no available comparison to pre-TMDL conditions for the chronic toxicity results they are included here to further illustrate post-TMDL water quality conditions.

Figure 8 summarizes the chronic toxicity results for *Ceriodaphnia* under baseflow conditions. Most test results were non-toxic, (ranging from 80% to 100%; overall 92%). Elevated toxicity (greater than 2 TUc) occurred only in 2008-09 and 2010-11.

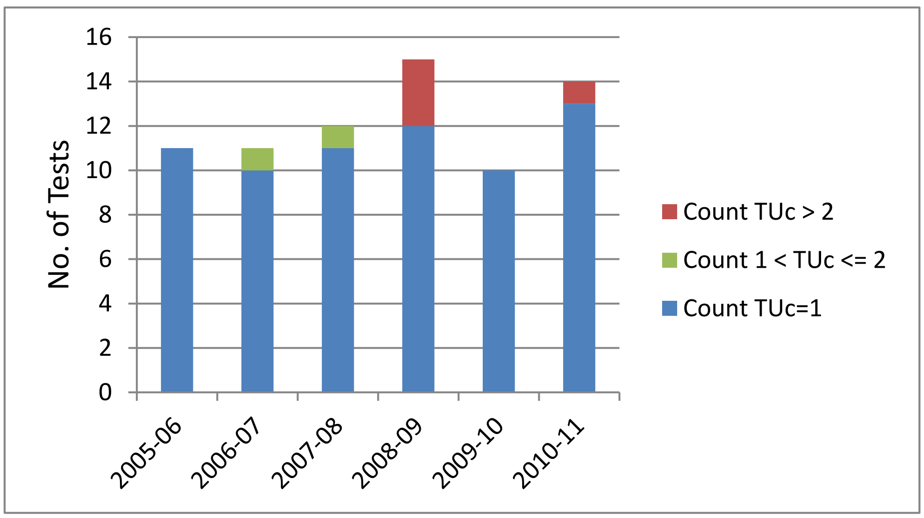

Figure 8: *Ceriodaphnia* Chronic (7-day) Survival Test - Baseflow

Figure 9 summarizes the chronic toxicity results for *Ceriodaphnia* under stormflow conditions. Most test results were non-toxic, (ranging from 75% to 100% annually; overall 95%).

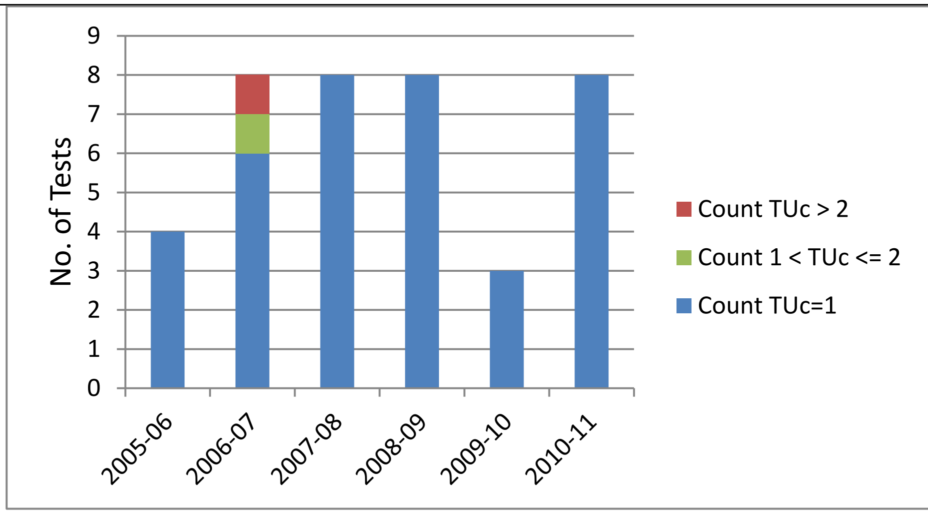

Figure 9: *Ceriodaphnia* Chronic (7-day) Survival Test Summary- Stormflow

o Evidence of implement-ation	Evidence of widespread nonpoint source or point source implementation and watershed implementation actions is demonstrated by: ▪ Construction and use of a Landscape Demonstration Center (link to website) at the University of California Cooperative Extension (UCCE) Research Station to train municipal staff, volunteers, and others, and educate the public. The demonstration center is located within the San Diego Creek Watershed and was constructed from 2004 to 2008 using $1 million in State grant funds. The UCCE has continued to maintain and operate the center for public education and outreach (links to outreach event brochures in 2011). ▪ Adoption of BMPs by nurseries, including voluntary cessation of diazinon and chlorpyrifos use for nursery crops even though those uses continued to be allowed by US EPA: These activities were funded through a CWA 319h grant focused on large commercial nurseries (2004-2007) and a $372,000 State grant (2007-2009) focused on smaller nurseries and retail outlets in the wider area of Orange County: (link to presentation: Water Quality Outreach Program to Nurseries in Orange County).
p No deteriorating trends	Use data for pesticides related to diazinon and chlorpyrifos, and sediment toxicity data are presented below (Table 4) to illustrate the absence of deteriorating trends in water quality parameters. Usage of malathion and carbaryl, which contributed to water column toxicity in the pre-TMDL period, has declined. In addition, as demonstrated above, water column toxicity has been reduced to minor levels, indicating that these related pesticides are not causing a deterioration in water quality. The major replacement pesticides for diazinon and chlorpyrifos are pyrethroids (bifenthrin, permethrin, cyfluthin, etc.) and fipronil (Table 4). Pyrethroid pesticides are strongly hydrophobic and typically detected in sediment rather than in the water column. The sediment toxicity test using *Hyalella azteca* (a common freshwater amphipod) is thus an appropriate test for detecting detrimental impacts from the increased use of replacement pyrethroid pesticides.

Table 4: Trends in Top Pesticides of Concern for Water Quality - Orange County

Pesticide Class	Pesticide	Use (lbs active ingredient)			10-Year Change
		1999	2003	2009	
Pyrethroids	**Permethrin**	10,500	73,700	35,900	**242%**
	Cyfluthrin	800	1,100	3,700	**363%**
	Bifenthrin	5,300	4,100	3,800	-28%
	Cypermethrin	5,900	4,200	2,700	-54%
phenyl pyrazole	**Fipronil**	0	9,900	4,000	**> 1000%**
Organo-phosphates (OPs)	Chlorpyrifos	80,000	6,000	700	-99%
	Diazinon	24,500	4,100	300	-99%
	Malathion	6,000	10,600	3,600	-40%
Carbamates	Carbaryl	2,800	1,600	800	-71%
	Methomyl	3,200	800	1	-100%
Fungicides	Captan	29,500	43,500	9,300	-68%
	Thiram	6,500	5,500	3	-100%
Molluscicide	Metaldehyde	6,200	5,000	2,700	-56%

Figure 10 presents a summary of the 10-day in-sediment *Hyalella azteca* toxicity tests from 2005-06 through 2010-11. No tests were performed in 2009-10. Toxicity was absent in 78% of the tests, with the percentage of non-toxic results each year varying from 53% to 100%.

The increase in pyrethroid pesticide use (Table 4) has not correlated with a significant increasing trend in sediment toxicity. This suggests that efforts to change pesticide use practices and to reduce pesticide runoff, have (for the most part) kept the concentrations of replacement pesticides below toxic thresholds.

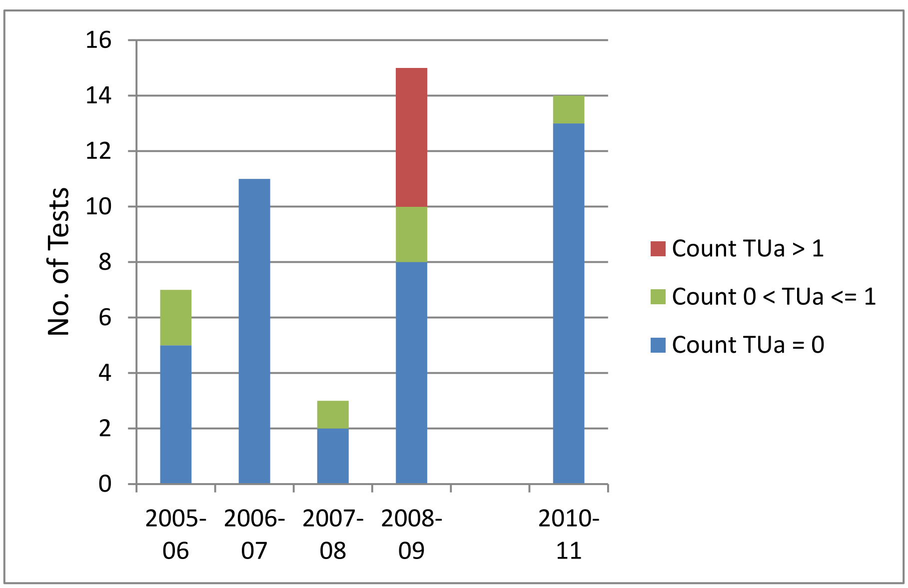

Figure 10: *Hyalella* 10-day In-Sediment Survival Test Summary

Although not quantified, anecdotal observation of the presence of birds that are dependent on aquatic invertebrates for a large part of their diet also suggests toxicity to aquatic invertebrates has been reduced to levels not impairing wildlife and aquatic beneficial uses. Figure 11 depicts a few of the many bird species in Peters Canyon Wash, the major tributary to San Diego Creek, in 2010 and 2011.

Figure 11: A few bird species that feed on aquatic invertebrates in a tributary to San Diego Creek (2010): white-faced ibis, black-necked stilt, least sandpiper, hooded merganser (clockwise from top left)