Sampling Urban Waters in Sacramento County

Pilot Monitoring for Pesticide Residues in Urban Creeks of Sacramento County

Morrison Creek, Sacramento County

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ABSTRACT

Pesticide use in the urban arena has the potential to contaminate urban surface waters due to offsite movement in irrigation or storm runoff. This report documents efforts by the Department of Pesticide Regulation's Surface Water Protection Program to investigate pesticide contamination in Sacramento County. Urban stream sites for water and sediment sampling were chosen in unincorporated areas of Sacramento County (two), and in the City of Folsom (two). Sites in Sacramento (Chicken Ranch Slough; Morrison Creek) reflected older, established, mixed use urban environments and sites in Folsom (Willow Creek; Willow Springs Reservoir) reflected newer, predominantly residential urban environments. Sampling was conducted weekly from April 3, 2007 through June 25, 2007 with one sample date (May 2, 2007) affected by rain. Water samples were analyzed for organophosphorus pesticides (15), carbamate insecticides and degradates (6), and triazine and substituted urea herbicides (4) as well as the simazine breakdown product diaminochlorotriazine. Streambed sediments were analyzed for pyrethroid insecticides (10).

Detections of pesticides in stream water were infrequent. Of the 25 pesticides and breakdown products analyzed for, five pesticides were detected in samples. These pesticides were malathion (10% of samples), diazinon (10%), carbaryl (33%), simazine (3%), and diuron (21%). Although carbofuran itself not detected, its break down product (3-hydroxy carbofuran) was detected in one sample. One diazinon detection (0.254 μg/L) and one malathion detection (0.05 μg/L) at Willow Springs Reservoir were above their lowest US EPA aquatic benchmark values for invertebrate toxicity. No other pesticides were detected at concentrations exceeding their lowest respective US EPA aquatic benchmarks.

In sediments, bifenthrin was detected at all sites, and cis- and trans-permethrin were detected at two sites. Toxicity units (TUs) were calculated for each sample based on organic-carbon normalized pyrethroid concentrations and Hyallela azteca LC_{50} toxicity data (Amweg *et al*. 2005; Maund,S. J. *et al*. 2002). Bifenthrin was a principal contributor to potential sediment toxicity, with an average contribution of greater than 90% of total TUs. TUs exceeded 0.5 in approximately 55% (20 of 37) of samples. TUs exceeding 1.0 were observed in more than 40% (14 of 37) of the samples (five samples from Chicken Ranch Slough, 9 samples from Willow Springs Reservoir). TUs exceeding 2.0 occurred in 88% of samples collected at Willow Springs Reservoir. TUs never exceeded 0.2 at Willow Creek.

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INTRODUCTION

Pesticide monitoring in urban freshwater environments is becoming more frequent, with frequent detections (Holmes et al. 2008; Weston, et al. 2009, 2010). Pyrethroids, organophosphorus insecticides (OPs), and, most recently, fipronil have been detected at concentrations potentially toxic to aquatic macro invertebrates residing in those creeks (Gan *et al.* 2012; Ensminger *et al*., 2012; Weston *et al*., 2005, 2009, 2010; Zhang, 2010). In streambed sediments, numerous pyrethroid insecticides have been detected at potentially toxic concentrations (Holmes *et al*., 2008). We initiated this survey of four Sacramento County urban streams in 2007 to assess the extent of pesticide contamination. The monitoring study was designed to assess: 1) Pesticides (carbamates, organophosphates, S-triazine and substituted urea herbicides) in urban creek waters from urban activities; and 2) Pyrethroids in bed sediments of these same waterbodies.

MATERIALS AND METHODS

Selection of Sample Collection Sites

Three criteria were used to select sample collection sites: 1) No agricultural use occurs upstream of the sampling site, 2) The sites represented a cross-section of older-established, mixed use neighborhoods regions or newer mixed-use but predominantly residential neighborhoods; and 3) that actual collection locations were on public lands for ease of access.

Four sites fit the above criteria (Figure 1). Two sites were in unincorporated areas of Sacramento County (Morrison Creek and Chicken Ranch Slough) and two sites were located in Folsom, CA (Willow Creek and Willow Springs Reservoir). Chicken Ranch Slough (CRS) and Morrison Creek (MC) flow through older mixed (commercial and residential) neighborhoods developed in the 1940s-1960s. Willow Creek (WC) and Willow Springs (WSR) represented newer mostly residential neighborhoods with construction occurring since 1995. The WC collection site resides at the tail-end of an extensive urban mixed-use drainage system, but does have some light industrial use (including a food processing plant) immediately upstream. An extensively vegetated wetland occupies 1 km of the upstream portion of WC immediately above the sample site.

Water Quality Measurements

Dissolved oxygen (DO), electrical conductivity (EC), pH, and water temperature were measured in situ for each sample collection event. DO, EC, and temperature were measured with a YSI 85 Dissolved Oxygen/Conductivity meter and pH was measured using a YSI 60 pH meter.

Sample Collection, Handling, and Transport

Samples were collected weekly over a 10 week period (April 23, 2007 – June 25, 2007). One sample series (7-May-2007) was collected the day (12-18 hours) following substantial rainfall (0.25”) in the greater Sacramento area.

Six-liters of water were collected at each sampling site, on each sampling date. Samples were collected into 1-liter amber bottles as close to center channel of stream flow as possible. Samples were collected either by hand immersion or by grab pole (with the glass bottle at the end of an extendable pole). Upon filling, sample bottles were sealed with Teflon-lined caps, placed into coolers, and covered with wet ice. Samples were transported to DPR's warehouse facility in West Sacramento, California, and stored in refrigerators at 4 ºC (Jones, 1999). Samples were transported to the California Department of Food and Agriculture's Analytical Chemistry Laboratory in Sacramento, California for extraction and analysis. Samples remained in the original sample bottle until extraction at the CDFA lab. Samples were extracted within 3 days of collection.

Sediments were collected at each sampling site on each sampling date following procedures in SOP FSWA 016.00 (Lyons, 2009, Appendix 1). Sediments were collected by trowel and separated into three ½ pint mason jars for analysis. Samples were collected in proximity to water sample collection locations, based on the availability of sediments. Sediment samples were analyzed for pyrethroids or total organic carbon (TOC) content. Following collection, samples were stored in coolers under wet ice and transported to DPR's warehouse facility in West Sacramento, California and frozen for storage.

Total Organic Carbon (TOC) analysis.

DPR analyzed sediments for total organic carbon (Appendix 1) using a TOC-V CSH/CNS analyzer with a SSM-5000A total organic carbon analyzer (Shimadzu Corporation, Kyoto, Japan). Samples were analyzed for percent carbon (Schumacher, 2002). Total Organic Carbon (TOC) was determined by subtracting the inorganic carbon (IC) from total carbon (TC); therefore, TOC = TC-IC. In cases where the inorganic carbon is zero, the total carbon value is considered to be comprised solely of total carbon; TOC = TC.

Pesticide Analysis

Chemical Analysis

Chemical analyses were performed by the California Department of Food and Agriculture's Center for Analytical Chemistry (Appendix 2). Separate aqueous samples were analyzed for a suite of OP pesticides, carbamate insecticides, and S-triazine and substituted urea herbicides. S-triazine and substituted urea herbicides samples were spiked with a triazine surrogate (propazine). Propazine results aided the assessment of analyte recoveries in the samples.

For all water analyses, the whole sample, including any suspended sediment, was extracted, and analyzed. Results are reported in µg/Liter (ppb) on a whole sample basis. Creek–bed sediment samples were analyzed for bifenthrin, cyfluthrin, cypermethrin, esfenvalerate, lambda-cyhalothrin, and permethrin. Results are reported in µg/gram wet weight, (wwt).

Quality Control

Quality control for chemistry analyses was performed in accordance with Standard Operating Procedure QAQC001.00 (Segawa, 1995). Ten percent of the total number of water samples were submitted for chemistry analyses as field duplicates and another ten percent as blind spikes.

Toxicity Units

Toxicity Units (TUs) in sediment were calculated based on organic carbon-normalized pyrethroid concentrations in each sediment sample, and LC_{50} for *Hyallela azteca* following the procedure of Amweg *et al*., 2006.

RESULTS AND DISCUSSION.

Pesticides were infrequently detected in water samples, and the majority of those detections were trace concentrations. Trace detections are defined as analyte concentrations that fall between the reporting limit and the method detection limit. The analytical chemist makes the determination if a trace detection is potentially the analyte of interest (Goh, 2002). Reporting limits (RL) for each pesticide are listed in Appendix 2.

Carbamate Insecticides

There were twelve trace detections of carbaryl, but none above the reporting limit (0.05 µg/L); Six detections occurred at CRS, four at MC one at WC, and one at WSR (Table 1, Appendix 3). Trace concentrations of carbaryl do not exceed Aquatic Life Benchmarks (ALBs) (Appendix 6). Carbofuran was not detected in any sample; however, its breakdown product 3-hydroxy-carbofuran was detected at 0.073 µg/L in one sample from CRS. USEPA has established no benchmarks for 3-OH-carbofuran.

Organophosphorus Pesticides

OP pesticides were detected in about 20% of water samples (Table 2, Appendix 4). Although samples were analyzed for fifteen OPs, only two OPs (diazinon and malathion) were detected. At CRS, diazinon was detected in a single sample at 0.0114 µg/L, and malathion was detected at trace levels in a separate sample. Both levels are below their respective ALBs. At MC, diazinon was detected in a single sample at 0.0126 µg/L, below the ALB. No OPs were detected in samples from WC. Three samples from WSR contained OPs. Malathion was detected in a one sample at trace amounts, with diazinon and malathion co-occurring in two samples. One sample contained diazinon at 0.254 µg/L (2.5 times the ALB) and the second sample contained diazinon at 0.0909 µg/L (90% ALB). Malathion concentrations in these two samples were 0.05 µg/L (1.5 times the ALB) and trace; respectively (Table 2).

S-triazine and Substituted Urea Herbicides

A trace detection of simazine was reported from a single sample collected at MC (Table 3, Appendix 5). Diuron was detected in eight samples collected at all four sites. Concentrations ranged from trace to 0.052 µg/L, none of which exceeded any ALB.

Pyrethroids in Sediment

Two pyrethroid insecticides (bifenthrin and permethrin) were detected. (Table 4, Appendix 7). Bifenthrin was present in more than 70% (26 of 37) of the sediment samples. Permethrin (2 isomers) was detected in 16 samples. Further breakdown showed that cis-permethrin isomer in 14 (38%) of samples and the trans-permethrin isomer in 6 (16%) of the samples.

Concentrations of bifenthrin ranged from 0.00127 µg/g wwt (wet weight) to 0.0628 µg/g wwt for all sites (Table 4; Appendix 7). Bifenthrin was detected in all sediment samples collected from both CRS and WSR. Bifenthrin was detected in 50% (4 of 8) of the MC samples and in 30% (3 of 10) of the WC samples.

Bifenthrin was the greatest contributor to pyrethroid TUs (greater than 90%) at all sites (Figure 7). By site, WSR had the highest potential to cause toxicity to aquatic invertebrates (Figure 8). Sediments from MC and CRS also showed potential to cause toxicity but less than that of WSR. Based on TU calculations, it is not expected that pyrethroids play a role in toxicity sediment towards aquatic invertebrates at WC

Total Organic Carbon

Pyrethroid toxicity has been correlated with organic carbon content of sediments (Holmes et al; 2008). TOC concentration varied between sites (Table 5; Appendix 8). TOC was very similar for CRS and MC. Median TOC concentration at CRS was 3.40% (range= 2.25 - 6.15). Median TOC at MC was 3.55% (range= 2.28 - 5.18). TOC at both these sites was approximately one-half the TOC at WC Median TOC WC 6.56% (range= 5.24 – 8.32). WSR had the highest TOC of all sites, median 8.34% (range= 5.33 - 12.28). Inorganic carbon values for all samples from this study ranged from -0.112 to -0.175 percent, due to uncertainty of the standard curve at such low concentrations. Such values indicate very little or no Inorganic Carbon and are generally accepted to be 0; therefore for this study, TOC = TC. TOC (Appendix 9) and IC standards were run twice daily.

Water Quality and Flow Data

pH, temperature (°C), dissolved oxygen (DO), and electrical conductivity (EC) summary data for all sites are presented in Table 6. Complete water quality data is presented in Figures 10 and 11, and Appendix 10. Water flows at CRS, MC, and WC were inconsistent and generally too slow to measure accurately. Flow at WSR was very consistent but too low to measure accurately.

Conclusions

Detections of pesticides in water were infrequent. As expected, pesticides with predominantly agricultural use were not detected in samples. Numerous pesticides were reported as trace detections only.

Carbaryl is registered for homeowner use and was detected at all sites (DPR 2012, Pesticide Label Database). 3-hydroxy-carbofuran, a breakdown product of the pesticide carbofuran, was detected in Chicken Ranch Slough. In 2007, only one product containing carbofuran was registered for application to ornamental turf, allowing applications to golf courses. Since CRS passes through a country club, a likely source of the 3-hydroxy-carbofuran was from applications of carbofuran to the golf course. No other ornamental turf/golf course specific pesticides were detected at CRS.

Malathion is also currently registered for homeowner use and was detected at 2 sites (DPR 2012, Pesticide Label Database). These sites, CRS and WSR both run directly through neighborhoods, and proximity of applications to the site of sampling may have affected detections. Diazinon however, is no longer registered for use by homeowners, with all home-use registrations cancelled by 2005. Its presence in waters from urban sites can be attributed to continual use of existing stocks by homeowners, and should over time decline to non-detect levels.

Simazine is registered for use on rights-of-way and on shelterbelts (windbreaks), but no homeowner use products were actively registered at the time of the study (DPR 2012, Pesticide Label Database). Potential sources of simazine at MC would then be uses for weed control along roadways or commercial areas within the MC drainage system.

Diuron was detected at all sites, and there were homeowner use products registered at the time of this study (DPR 2012; Pesticide Label Database). However, these products were algae control products for use in ponds, pools, and ornamental fountains. Several other products are registered for use along rights of ways, along canal banks, and in ornamental settings.

Bifenthrin was the main pyrethroid detected in sediments and accounted for the majority of the TUs. TUs varied among the sites; WSR highest followed by CRS and MC. TUs were high enough at these sites to potentially harm aquatic organisms. Pyrethroids (Bifenthrin) were only detected in three (of 10) samples collected from WC. TUs calculated from these detections showed little potential for toxicity to sediment dwelling organisms. The presence of the wetland immediately upstream of the WC sampling location may have affected pyrethroid concentrations.

The physical characteristics of the four sites may have contributed to the difference in TUs calculated. TOC of WSR was high 8.3% corresponding with high bifenthrin concentrations and high TUs. CRS and MC had similar TOC levels (3.4% vs. 3.6%) corresponding to different TUs medians (3.1 vs. 2.9 respectively). WC showed high TOC content (6.6 %) but with correspondingly low TUs (0.2); the presence of a large (1 km) vegetated wetland upstream of the sample collection site may be a factor affecting pyrethroid deposition thereby limiting TUs.

Proximity to the source of contamination may also be a vital factor in pyrethroid detections. The site at WSR is immediately adjacent to (approximately 10 meters from) the storm drain outfall from a 150 home neighborhood. The farthest house was only 650 meters from the sample collection location. Further mapping of the streams for all sites is warranted. Flow through the drain was constant and consistent over the course of the study indicating a continuous source of runoff from the homes in the upstream neighborhood.

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Table 1. Carbamate Insecticide Detections in Surface Water Compared with Aquatic Life Benchmarks Established by U.S.EPA.

Water Body	*# Detects*	*Concentration Range (µg/L)*	*Lowest Aquatic Life Benchmark (µg/L)*†
Chicken Ranch Slough			
Carbaryl	7*	trace	0.85/0.5
3-OH-Carbofuran	1	0.073	‡
Carbaryl	4	trace	0.85/0.5
Carbaryl	1	trace	0.85/0.5
Carbaryl	1	trace	0.85/0.5

† Chronic/Acute Aquatic Life Benchmarks. Chronic values are for freshwater fish or invertebrates. (U.S. EPA 2011).

‡ No Aquatic Life Benchmark criteria established.

* Includes trace detection of 11/Jun2 2007 sample and its field duplicate.

Table 2. Concentrations of Organophosphate Insecticides in Sacramento County Surface Waters Compared with Aquatic Life Benchmarks Established by U.S.EPA.

Water Body	*# Detects*	*Concentration Range (μg/L)*	*Lowest Aquatic Life Benchmark (μg/L)*†
Chicken Ranch Slough			
Diazinon	1	0.0114	0.17/0.11
Malathion	1	trace	0.000026/0.005
Diazinon	1	0.0126	0.17/0.11
Malathion	3	trace – 0.05§	0.000026/0.005
Diazinon	2	0.0909 – 0.254§	0.17/0.11

† Chronic/Acute Aquatic Life Benchmark (U.S.EPA 2011). Most conservative value. Values are for invertebrates.

‡ No organophosphates were detected in Willow Creek samples.

§ Detection exceeded both chronic and acute benchmarks.

Table 3. Concentrations of Herbicides in Sacramento County Surface Waters Compared with Aquatic Life Benchmarks Established by U.S.EPA.

Water Body	***# Detects***	***Concentration Range (µg/L)***	***Lowest Aquatic Life Benchmark (µg/L)†***
Chicken Ranch Slough			
Diuron	1	trace	26/2.4
Simazine	1	trace	960/36
Diuron	4	trace	26/2.4
Diuron	1	trace	26/2.4
Diuron	2	trace – 0.052	26/2.4

† Chronic/Acute Aquatic Life Benchmarks. Most conservative value. Chronic values are for freshwater fish or invertebrates. Acute values are for non-vascular plants.

Table 4. Pyrethroid Detections in Sediment Compared and Corresponding Toxicity Unit.

Water Body	*# Detects*	*Concentration Range (µg/g wet weight)*	*TU Range*
Chicken Ranch Slough			
Bifenthrin	10	0.00542 – 0.0160	0.390 – 1.738
cis-Permethrin	9	0.00594 – 0.0147	0.020 – 0.086
trans-Permethrin	6	0.00572 – 0.0104	0.016 – 0.061
Bifenthrin	4	0.005 – 0.0082	0.422 – 0.795
Bifenthrin	3	0.00127 – 0.00163	0.094 – 0.181
Bifenthrin	9	0.0229 – 0.0628	1.845 – 4.015
cis-Permethrin	5	0.00548 – 0.0104	0.017 – 0.034

Table 5. Total Organic Carbon in Streambed Sediments.

Water Body	*# Samples*	*Mean TOC (Percent†)*	*TOC Range (Percent)*
Chicken Ranch Slough			
Total Carbon	10	3.40	2.25 - 6.15
Total Carbon	9	3.55	2.28 - 5.18
Total Carbon	10	6.56	5.24 - 8.32
Total Carbon	10	8.34	5.33 - 12.28

† *TOC = TC-IC. IC content of sediments collected at these sites was zero, so TOC=TC.*

Table 6. Water Quality Measurements.

Water Body	*pH*	*Temperature ºC*	*DO mg/L*†	*SpC µS/cm*‡
Chicken Ranch Slough				
Median	7.5	20.44	6.44	354.9
Range	7.16-7.77	15.8 - 23.5	3.02-8.80	152.7-376.9
Median	7.31	22.89	5.44	201.4
Range	6.2-8.0	19.5-25.3	2.7-9.72	181.2 - 214.8
Median	7.42	20.8	7.72	236.89
Range	6.93 - 7.78	15.9 - 23.8	5.81 - 10.08	216.8-258.2
Median	6.84	19.357	6.04	177.65
Range	6.61-7.30	16.7-21.7	4.36-8.56	141-236.9

† Dissolved Oxygen

‡ µS/cm = µSiemens/cm. Specific conductance is temperature compensated conductivity.

Figure 1. Rivers and Creeks in Sacramento County. Sample collection locations marked with X. Locations are as follows: 1) Chicken Ranch Slough, 2) Morrison Creek, 3) Willow Creek, and 4) Willow Springs Reservoir. Incorporated city areas are yellow and unincorporated Sacramento County lands are green. Morrison Creek is the boundary between the City of Sacramento and Sacramento County.

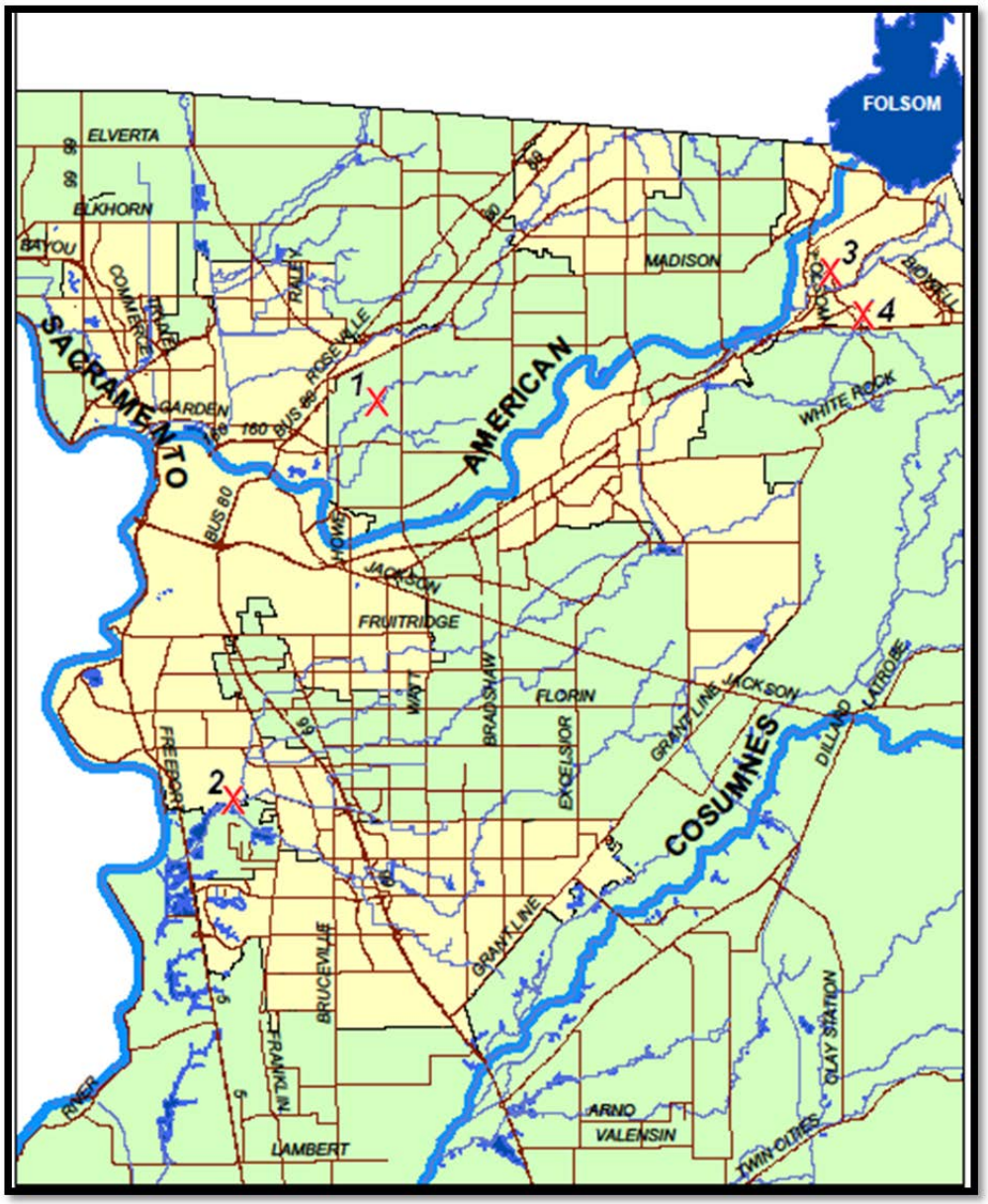


Figure 2. Chicken Ranch Slough Sampling Site (38 36’27.97”N 121 24’21.25”W).

Chicken Ranch Slough, is located within the unincorporated areas of Sacramento County. The sample collection site was located in Santa Anita Park (Near Marconi & Fulton Avenues). Water samples were collected at the bend in CRS approximately 20-25 meters from Hernando Road. Sediment samples were collected between Hernando road (0 meters) and the end of CRS as pictured (100 Meters downstream of Hernando Road). The base layer of CRS substrate was composed of hard-pack clay with spotty depositions of sediment, laced with sand, silt, and leafy matter debris. A layer of silt was deposited unevenly along the streambed. Upstream of Hernando Road, CRS is concrete lined with limited deposition of sediments or leafy matter.

Figure 3. Morrison Creek Sampling Site (38 27’ 40.28”N x 121 27’43.45”W).

Morrison Creek is located on the border of the City of Sacramento and Sacramento County. MC is fed by an extensive network of creeks (Florin, Elder, Union House (Beacon), Strawberry, Laguna and Elk Grove Creeks) with its headwaters in Eastern Sacramento County near Prairie City. Water flow at MC was lazy but continuous. The substrate at MC was thick mud (more than 50cm deep). Sample collection was initiated on May 1, 2007, one week later than the other sites due to access requirements. Samples were collected approximately 50 meters downstream of the confluence with Union House Creek, and approximately 5km upstream of the confluence (via pumping plant) with the Sacramento River. Since Laguna Creek and Elk Grove Creek confluence with MC 500 meters downstream of the sample collection site, their flows did not impact sample collection.

Figure 4. Willow Creek Site (38 39’37.28”N 121 10’48.55”W).

Willow Creek is located in the City of Folsom approximately 300 meters to the NE of the intersection of Folsom Blvd and Parkside Drive. The sampling site was situated under the bridge on Parkside Drive. Water samples were collected from the center of stream flow, (between the nearest and second row of support columns) approximately 5-7 meters from the near shore. Sediment samples were collected from still waters between the near shore and second row of columns on both sides of the flowing portion of the creek. For approximately 1.5 km upstream of the sampling site, WC winds through an extensive riparian wetland with minimal urban input. Approximately 2.5 km upstream from the wetland section, Humbug creek confluences with Willow Creek. Both Humbug and Willow Creeks continue upstream for approximately 5 km to their respective sources. Although both creeks are urban, they remain extensively riparian and are not channelized. Numerous culverts add residential runoff from 1,000s of homes) to the WC system.

Figure 5. Residential neighborhood upstream of the Willow Springs Reservoir sample collection sites. Y indicates water sample collection (from the culvert pictured in Figure 6) and X indicates sediment collection location.

Willow Springs Reservoir (WSR) is a receiving waterbody located in the City of Folsom. WSR is bounded on North and East by Marsh Hawk Road, to the south by an extensive vegetated wetland, and to the west by homes along the eastern edges of Donnelly and Mallard Circles. Input into the reservoir is from Willow Springs, and from runoff through storm drains from the surrounding neighborhoods. Output from WSR into the wetland is through a spillway; no outflow was recorded during the study.

Water samples from WSR were collected from a storm drain (Figure 6) draining a neighborhood of approximately 150 residences (bound by Riley Street to the North and by Oak Avenue Parkway and McAdoo Drive to the East and West respectively). The location of this storm drain is marked as Y in Figure 5 above. Sediments could not be collected at Y as the substrate was solely willow and cottonwood roots. Sediments were instead collected at X above. Both water and sediment at this location comes solely from the upstream neighborhood, pesticides detected in this water is also likely sourced to runoff from this neighborhood.

Figure 6. Willow Springs Reservoir Sampling site (138 39”20.19”N x 121 08’37.51”W). Samples were collected directly from the mouth of the culvert.

Figure 7. Pyrethroid contribution to TUs; bifenthrin accounts for 90%+ pyrethroid TUs at all sites. Medians (range) for the calculated Toxic Units are: CRS 0.91 (0.41 – 1.89), MC, 0.42 (0 – 1.00), WC 0 (0 – 0.19), and WSR 2.42 (1.9 – 4.05).

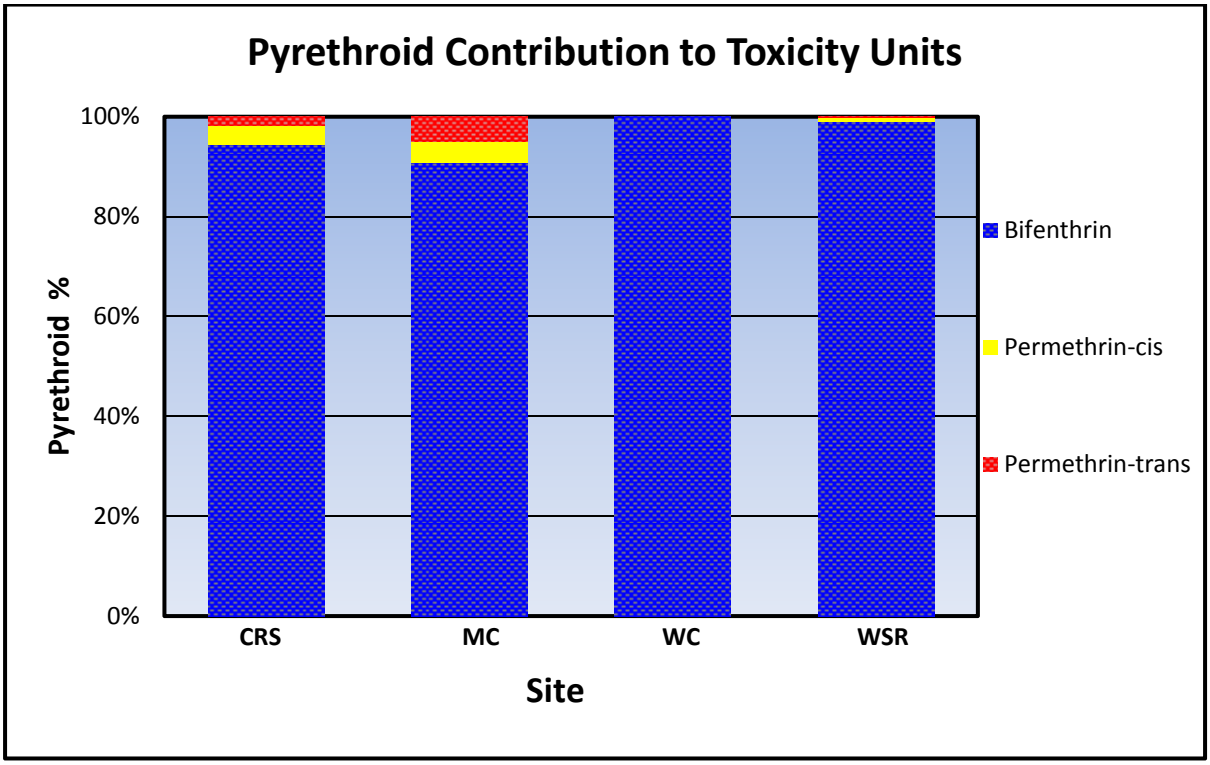
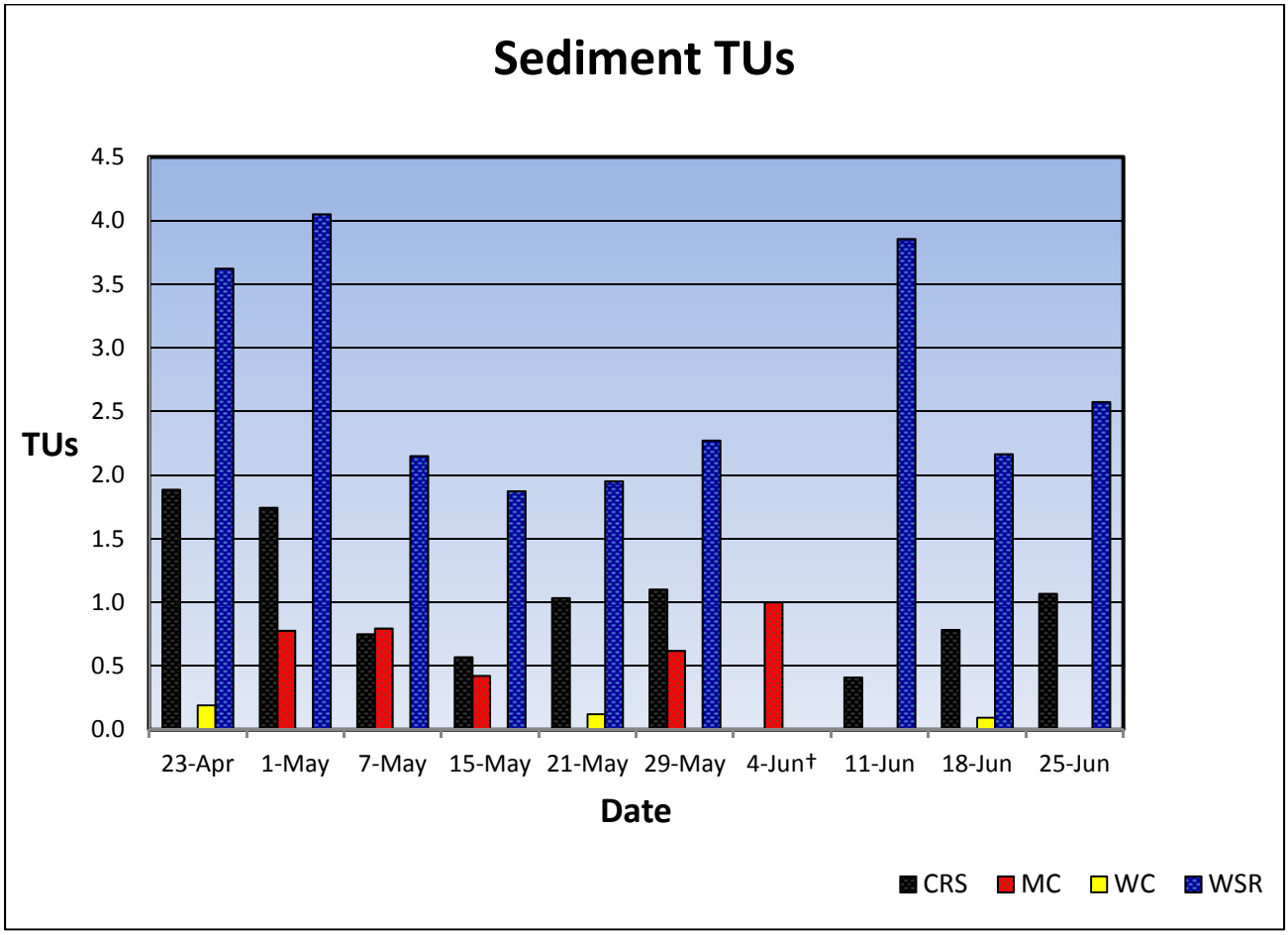


Figure 8 Toxicity units for sediments by site over the course of the Study. CRS (Chicken Ranch Slough); MC (Morrison Creek); WC (Willow Creek); and WRS (Willow Springs Reservoir). Sediments collected at WC shows the least potential for pyrethroid toxicity, while sediments collected at WSR shows the greatest potential for pyrethroid toxicity. .



† Samples from Morrison Creek and Willow Springs Reservoir were not analyzed.

Figure 9. Organic carbon composition of collected sediments. CRS (Chicken Ranch Slough); MC (Morrison Creek); WC (Willow Creek); and WRS (Willow Springs Reservoir). MC sample was not collected April 23, 2007.

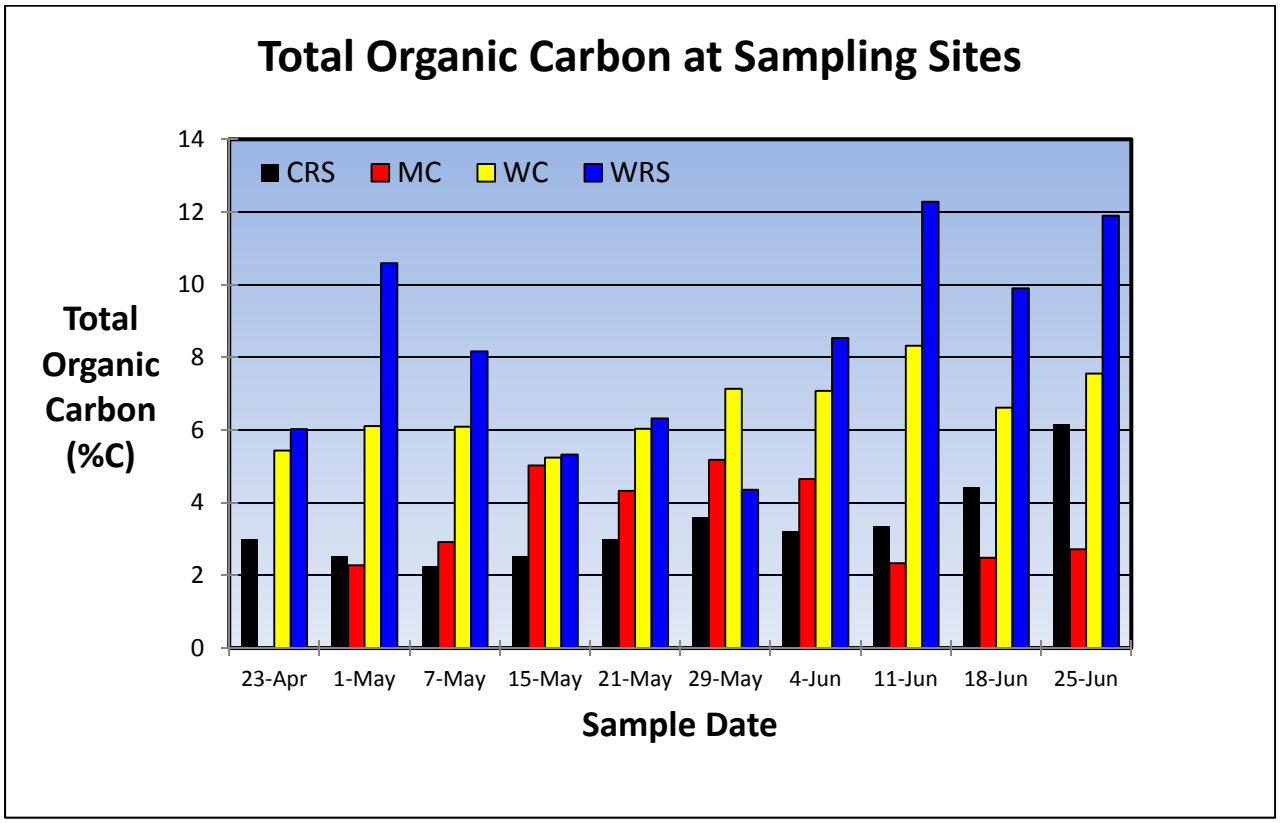
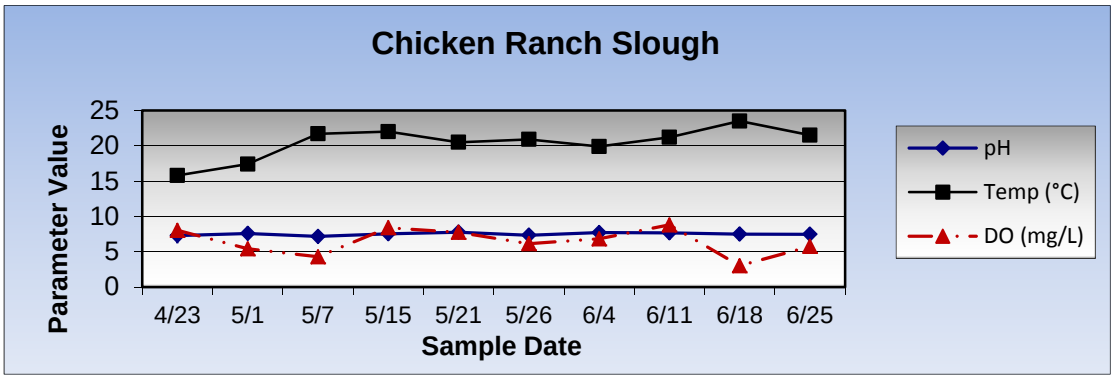
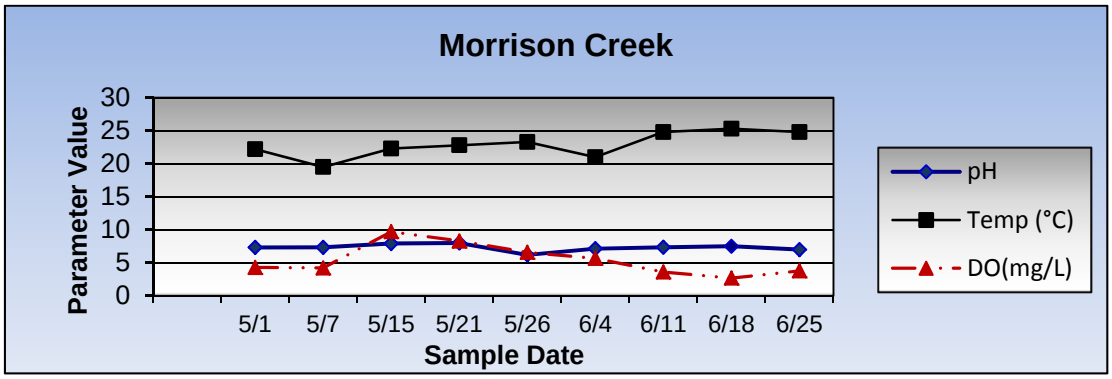
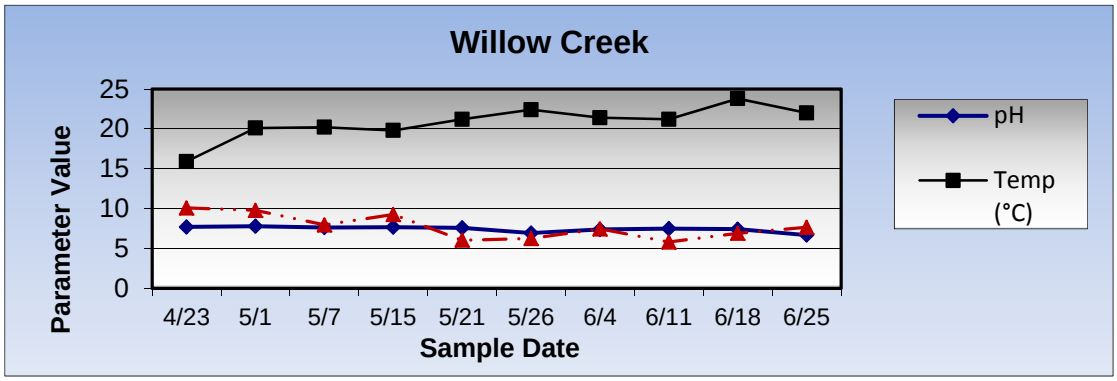


Figure 10: Environmental Data: Temperature, pH, and Dissolved Oxygen content at the time of sample collection. Morrison Creek was not sampled on April 23, 2007.







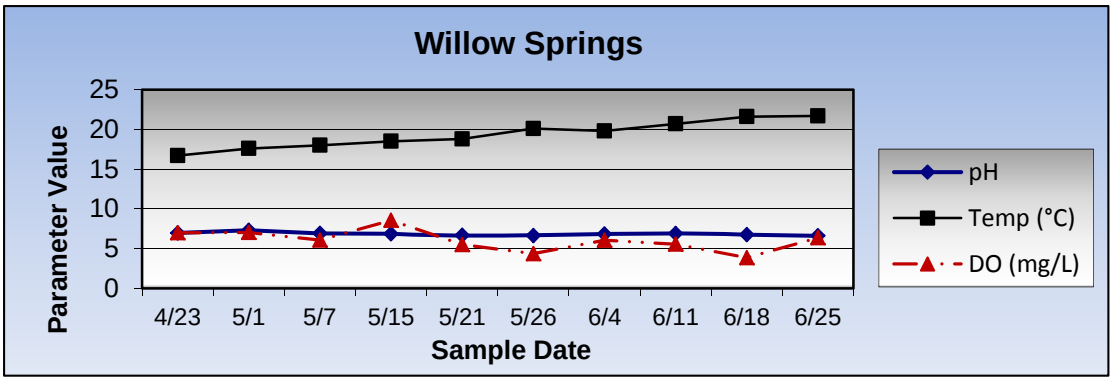
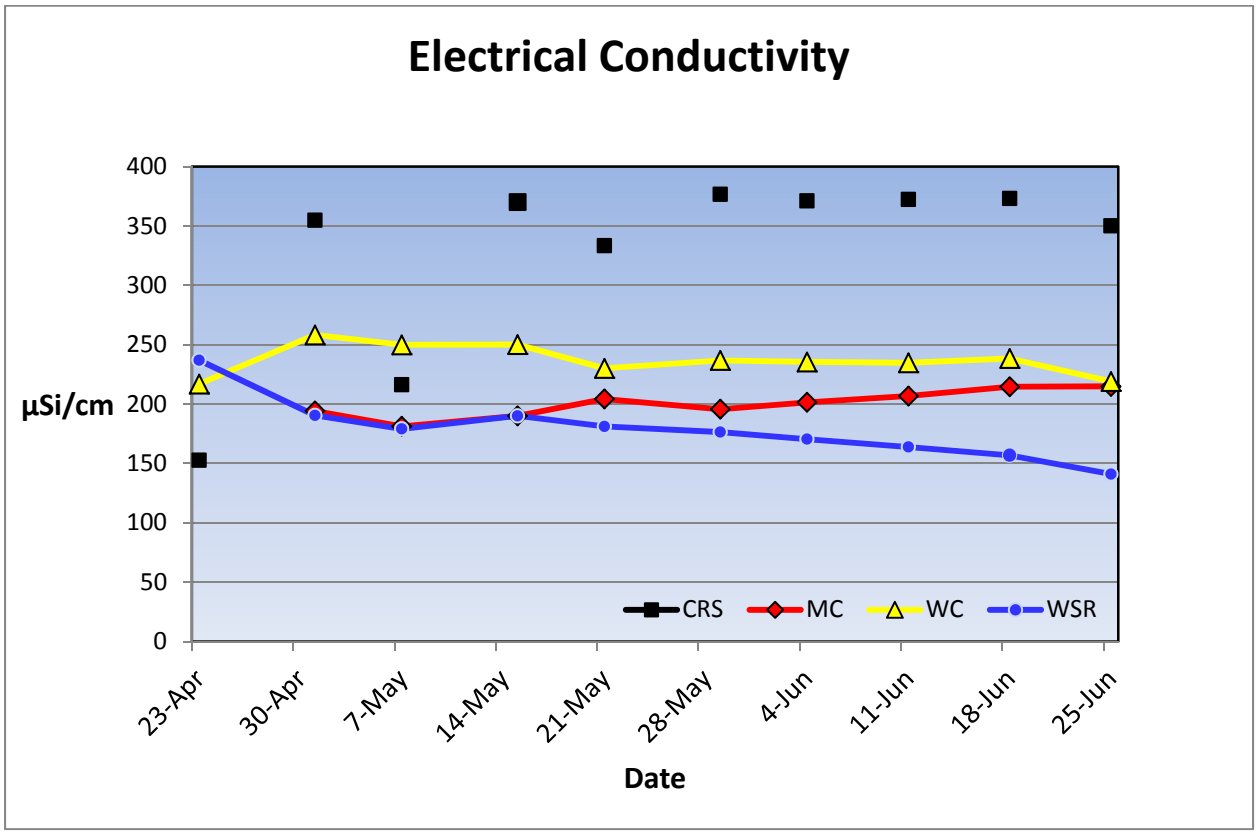


Figure 11. Environmental Data: Electrical Conductivity. CRS (Chicken Ranch Slough); MC (Morrison Creek); WC (Willow Creek); and WRS (Willow Springs Reservoir). MC sample was not collected April 23, 2007.



Appendix 1: Materials and Methods:

Several collection and analytical procedures were modified for this study. These include: FSWA 016.00 (Mamola, 2005) which outlines the procedures for collecting soil and streambed sediments, and METH008.00 (Lyons 2009) which outlines procedures for preparing sediment samples for analysis. Although TOC analysis followed methods outlined by Schumacher, 2002 more specific details are presented below.

Streambed Sediment Sample Collection

The top 2-3 centimeters of sediments were collected from the streambed using a hand trowel following procedures outlined in SOP FSWA 016.00 (Mamola, 2005), and modified as follows. Each full trowel was split using a metal spatula and divided evenly into three, one-half pint Mason jars. Sediment was collected until each jar was at least ½ full. Gross organic material (leaves, sticks, algae) were carefully removed during sample collection and discarded. Excess water was decanted carefully (to prevent sediment loss) from sample jars.

At WC and MC, all subsamples were collected within 1-2 meters of the initial sub-sample, at WSR, subsamples were collected within 2-4 meters of each other. At CRS most subsamples were collected within 5-10 meters of each other. Over the course of the study (10 weeks), sediment samples from MC, WC, and WSR were collected within 5-10 meters of each other. At CRS, sediment deposition was spotty, requiring samples to be collected over a wider area; approximately 50 meters of streambed was sampled over the course of the study.

Sediment Processing Prior to Carbon Analysis

Sediment samples following procedures outlined in DPR methods METH008.00 (Lyons 2009), and modified as follows: Samples were prepared for analysis by first thawing and then oven dried (@ 98 ºC) for 12 hours. Sediments were broken into small chunks and leaves, sticks, twigs, and other gross organic matter were removed. Samples were returned to the oven for further drying (12-18 hours), removed from the oven, and cooled overnight. Sediments were lightly ground, and sieved through a 2.0 mm sieve. Sediment components that did not pass through the sieve were lightly ground in the sieve; organic components, rocks, and gravels were removed and discarded. Material passing through the sieve was ground by mortar and pestle. Grindings were sieved through a 1mm sieve; materials not passing through the sieve (sand particles, small gravel, stems/twigs/fibers) were discarded. Material was then finely ground in the mortar, and sieved through a 0.5 mm sieve. The resulting powder was returned to the sample jar and tightly sealed, and analyzed for organic and inorganic carbon content.

Organic and Inorganic Carbon Analytical Procedures:

DPR analyzed sediments for total organic carbon using a TOC-V CSH/CNS analyzer with a SSM-5000A total organic carbon analyzer (Shimadzu Corporation, Kyoto, Japan). Samples were analyzed for percent carbon methods developed by Schumacher, 2002. Total Organic Carbon TOC was determined by subtracting the inorganic carbon (IC) from total carbon (TC); TOC = TC-IC. In cases where the inorganic carbon is zero, the total carbon value is considered to be comprised solely of total carbon; TOC = TC. Inorganic carbon values for all samples from this study ranged from -0.112 to -0.175. Such values indicate unreliability of the standard curve at 0 values and are generally accepted to be 0; therefore for this study, TOC = TC.

From each sample, a minimum of two sub-samples were analyzed for Total Carbon (TC) and two sub-samples were analyzed for Inorganic Carbon (IC). Total Organic Carbon was calculated as follows: [TC] – [IC] = [TOC]. Samples were measured into ceramic crucibles and weighed. For all samples, a target weight of 75 mg (range 73.5-115.7 mg) was sought. Weights of each sub-sample were consistently within 0.5 mg (range 0 - 6 mg) of each other for TC analysis and 5 mg for IC analysis. TC samples were covered with ceramic wool for splatter prevention. IC samples were acidified with 0.5 ml 3N-H_3PO_4 *in situ* at time of injection.
Operating conditions were:

TC analysis – Oven 900 ºC; O_2 Flow Rate 0.5 cfm; and
IC analysis – Oven 200 ºC; O_2 Flow Rate 0.5 cfm.

Four backup samples were analyzed and four primary sediment samples were re-analyzed for QA/QC purposes.

Appendix 2: Reporting Limits

Reporting limits for pesticides analyzed for this study. Pesticides are listed by elution order.

Carbamates:	**RL(**µg/L**)**
Aldicarb Sulfone	0.05
Aldicarb Sulfoxide	0.05
Oxamyl	0.05
Methomyl	0.05
3-Hydroxy-Carbofuran	0.05
Aldicarb	0.05
Carbofuran	0.05
Carbaryl	0.05
Mesurol	0.05

Organophosphates	**RL(µg/L)**
Ethoprop	0.05
Disulfoton	0.04
Malathion	0.04
Methidathion	0.05
Fenamiphos	0.05
Azinphos-methyl	0.05
DDVP (dichlorvos)	0.05
Thimet (Phorate)	0.05
Fonofos	0.04
Dimethoate	0.04
Methyl Parathion	0.03
Tribufos (DEF)	0.05
Profenofos	0.05
Diazinon	0.01
Chlorpyrifos	0.01

Herbicides	**RL(**µg/L**)**
Simazine	0.05
Diuron	0.05
Bromacil	0.05
DACT	0.05
Propazine	0.05

Pyrethroid Insecticides:	**RL(**µg/g**)**
Resmethrin	0.0015
Bifenthrin	0.001
L-Cyhalothrin epimere	0.001
L-cyhalothrin	0.001
Permethrin – cis	0.001
Permethrin – trans	0.001
Cyfluthrin	0.001
Cypermethrin	0.001
Fenvalerate/Esfenvalerate	0.001
Deltamethrin	0.001

Appendix 3: Pesticides in Water - Carbamates

Chicken Ranch Slough

	Aldicarb SO	*Aldicarb SO2*	*Oxamyl*	*Methomyl*	*3-OH-CBF*†	*Aldicarb*	*Carbofuran*	*Carbaryl*	*Mesurol*
23-Apr	nd‡	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	trace	nd
15-May	nd	nd	nd	nd	nd	nd	nd	trace	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	trace	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	trace	nd
11-Jun§	nd	nd	nd	nd	nd	nd	nd	trace	nd
11-Jun§	nd	nd	nd	nd	nd	nd	nd	trace	nd
18-Jun	nd	nd	nd	nd	**0.073 µg/L**	nd	nd	trace	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd

Morrison Creek

	Aldicarb SO	*Aldicarb SO2*	*Oxamyl*	*Methomyl*	*3-OH-CBF*	*Aldicarb*	*Carbofuran*	*Carbaryl*	*Mesurol*
23-Apr	ns*	ns	ns	ns	ns	ns	ns	ns	ns
1-May	nd‡	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	trace	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	trace	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	trace	nd
18-Jun	nd	nd	nd	nd	nd	nd	nd	trace	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd

† 3-OH-CBF 3-hydroxy carbofuran; breakdown product of carbofuran.
‡ Nd = Non-detect; no pesticide detected.
§ Field duplicate samples.
* NS. No sample collected.

Pesticides in Water: Carbamates (cont.)

Willow Creek

	Aldicarb SO	*Aldicarb SO2*	*Oxamyl*	*Methomyl*	*3-OH-CBF*†	*Aldicarb*	*Carbofuran*	*Carbaryl*	*Mesurol*
23-Apr	nd‡	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	trace	nd
18-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun§	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun§	nd	nd	nd	nd	nd	nd	nd	nd	nd

Willow Springs Reservoir

	Aldicarb SO	*Aldicarb SO_2*	*Oxamyl*	*Methomyl*	*3-OH-CBF*	*Aldicarb*	*Carbofuran*	*Carbaryl*	*Mesurol*
23-Apr	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May§	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May§	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	trace	nd
18-Jun§	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun§	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd

† 3-OH-CBF 3-hydroxy carbofuran; breakdown product of carbofuran.
‡ Nd = Non-detect; no pesticide detected.
§ Field duplicate samples.

Appendix 4: Pesticides in Water - Organophosphates

Chicken Ranch Slough

	Etho†	*Diazinon*	*Disulf*	*Chlor*	*Malathion*	*Meth*	*Fenam*	*Azin-Me*	*DDVP*	*Thimet*	*Fono*	*Me-Para*	*DEF*	*Profen*
23-Apr	nd‡	nd	nd	nd	trace	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	**0.0114 µg/L**	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Morrison Creek

	Etho†	*Diazinon*	*Disulf*	*Chlor*	*Malathion*	*Meth*	*Fenam*	*Azin-Me*	*DDVP*	*Thimet*	*Fono*	*Me-Para*	*DEF*	*Profen*
23-Apr	ns§	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	**0.0126 µg/L**	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

†Organophosphate abbreviations: Etho = Ethoprop; Disulf. = Disulfoton; Chlor = Chlorpyrifos; Meth. = Methidathion; Fenam. = Fenamiphos; Azin-Me. = Azinphos-Methyl; Fono = Fonofos; Me-Para. = Methyl=Parathion; Profen = Profenofos.

‡ nd = Non-detect; no pesticide detected.

§ ns. No Sample collected.

Pesticides in Water: Organophosphates (cont.)

Willow Creek

	Etho†	*Diazinon*	*Disulf*	*Chlor*	*Malathion*	*Meth*	*Fenam*	*Azin-Me*	*DDVP*	*Thimet*	*Fono*	*Me-Para*	*DEF*	*Profen*
23-Apr	nd‡	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Willow Springs Reservoir

	Etho†	*Diazinon*	*Disulf*	*Chlor*	*Malathion*	*Meth*	*Fenam*	*Azin-Me*	*DDVP*	*Thimet*	*Fono*	*Me-Para*	*DEF*	*Profen*
23-Apr	nd	nd	nd	nd	trace	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	**0.254 µg/L**	nd	nd	**0.05 µg/L**	nd	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	**0.0909 µg/L**	nd	nd	trace	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun*	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun*	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

† Organophosphate abbreviations: Etho = Ethoprop; Disulf. = Disulfoton; Chlor = Chlorpyrifos; Meth. = Methidathion; Fenam. = Fenamiphos; Azin-Me. = Azinphos-Methyl; Fono = Fonofos; Me-Para. = Methyl=Parathion; Profen = Profenofos.

‡ nd = Non-detect; no pesticide detected.

* Field duplicate samples.

Appendix 5: Pesticides in Water - Herbicides

Chicken Ranch Slough

	Simazine	*Diuron*	*Bromacil*	*Hexazinone*	*DACT*	*Propazine**
23-Apr	nd†	trace	nd	nd	nd	92.0%
1-May	nd	nd	nd	nd	nd	94.5%
7-May	nd	nd	nd	nd	nd	85.0%
15-May	nd	nd	nd	nd	nd	92.5%
21-May	nd	nd	nd	nd	nd	99.0%
29-May	nd	nd	nd	nd	nd	87.0%
29-May	nd	nd	nd	nd	nd	85.0%
4-Jun	nd	nd	nd	nd	nd	102.0%
11-Jun	nd	nd	nd	nd	nd	98.0%
18-Jun	nd	nd	nd	nd	nd	75.5%
25-Jun‡	nd	nd	nd	nd	nd	78.0%
25-Jun‡	nd	nd	nd	nd	nd	86.5%

Morrison Creek

	Simazine	*Diuron*	*Bromacil*	*Hexazinone*	*DACT*	*Propazine**
23-Apr	ns§	ns	ns	ns	ns	ns
1-May	nd†	trace	nd	nd	nd	97.0%
7-May	trace	trace	nd	nd	nd	86.0%
15-May	nd	nd	nd	nd	nd	89.5%
21-May	nd	nd	nd	nd	nd	85.0%
29-May	nd	trace	nd	nd	nd	106.0%
4-Jun	nd	trace	nd	nd	nd	111.0%
11-Jun	nd	nd	nd	nd	nd	91.0%
18-Jun	nd	nd	nd	nd	nd	92.0%
25-Jun	nd	nd	nd	nd	nd	79.0%

† nd = Non detect.
‡ Field duplicate samples.
§ No sample collected.
* Propazine added as a surrogate.

Pesticides in Water: Herbicides (cont.)

Willow Creek

	Simazine	*Diuron*	*Bromacil*	*Hexazinone*	*DACT*	*Propazine**
23-Apr	nd†	nd	nd	nd	nd	94.5%
1-May	nd	nd	nd	nd	nd	95.0%
7-May	nd	nd	nd	nd	nd	92.5%
15-May	nd	nd	nd	nd	nd	97.5%
21-May‡	nd	nd	nd	nd	nd	95.5%
21-May‡	nd	nd	nd	nd	nd	98.0%
29-May	nd	nd	nd	nd	nd	95.5%
4-Jun	nd	trace	nd	nd	nd	101.0%
11-Jun	nd	nd	nd	nd	nd	93.5%
18-Jun	nd	nd	nd	nd	nd	81.5%
25-Jun	nd	nd	nd	nd	nd	82.0%

Willow Springs Reservoir

	Simazine	*Diuron*	*Bromacil*	*Hexazinone*	*DACT*	*Propazine**
23-Apr	nd†	**0.052 µg/L**	nd	nd	nd	101.0%
1-May	nd	ns§	nd	nd	nd	88.5%
7-May	nd	trace	nd	nd	nd	87.5%
15-May	nd	nd	nd	nd	nd	94.5%
21-May	nd	nd	nd	nd	nd	98.5%
29-May	nd	nd	nd	nd	nd	95.5%
4-Jun	nd	nd	nd	nd	nd	105.0%
11-Jun‡	nd	nd	nd	nd	nd	87.0%
11-Jun‡	nd	nd	nd	nd	nd	91.5%
18-Jun‡	nd	nd	nd	nd	nd	77.5%
18-Jun‡	nd	nd	nd	nd	nd	87.0%
25-Jun	nd	nd	nd	nd	nd	82.5%

† nd = Non detect.
‡ Field duplicate samples.
§ No sample collected.
* Propazine added as a surrogate.

Appendix 6. Freshwater Benchmark Values

Aquatic Life (Freshwater) Benchmark Values (µg/L) for the pesticides detected (USEPA, 2011).

Pesticide	***Fish***		***Invertebrates***		***Nonvascular Plants***	**Vascular Plants**
	Acute[1]	**Chronic[2]**	**Acute[3]**	**Chronic[4]**	**Acute[5]**	**Acute[6]**
Diazinon	45	< 0.55	0.11	0.17	3,700	—
Malathion	16.4	8.6	0.03	0.035	>2,500	>7,900
3-OH Carbofuran†	—	—	—	—	—	—
Carbofuran	44	5.7	1.12	0.75	—	—
Diuron	200	26	80	200	2.4	15
Simazine	3,200	960	500	2,000	36	140
Carbaryl	110	6.8	0.85	0.5	660	1,500

[1] Benchmark = Toxicity value x LOC. Acute fish toxicity values used are the lowest 96-hour LC_{50} in a standardized test (rainbow trout, fathead minnow, or bluegill). The LOC is 0.5.

[2] Benchmark = Toxicity value x LOC. Chronic fish toxicity values used are the lowest NOEAC from a life-cycle or early life stage test (rainbow trout or fathead minnow). The LOC is 1.

[3] Benchmark = Toxicity value x LOC. Acute invertebrate toxicity values used are the lowest 48- or 96-hour EC_{50} or LC_{50} in a standardized test (midge, scud, or daphnids). The LOC is 0.5.

[4] Benchmark = Toxicity value x LOC. Chronic invertebrate toxicity values used are the lowest NOAEC from a life-cycle test with invertebrates (midge, scud, or daphnids). The LOC is 1.

[5] Benchmark = Toxicity value x LOC. Acute nonvascular plant toxicity values used are usually a short-term (<10 days) EC_{50} (green algae or diatoms). The LOC is 1.

[6] Benchmark = Toxicity value x LOC. Acute vascular plants toxicity values used are a short-term (<10 days) EC_{50} (usually with duckweed). The LOC is 1.

† No benchmark value established

Appendix 7: Pyrethroids in Sediment (µg/g wwt)

Chicken Ranch Slough

	Res†	Bifenthrin	Permethrin-cis	Permethrin-trans	Fenpro	λ -cy-epi	λ-Cy	Cyflu	Cyper	Fen/Esfen	Delta
23-Apr	nd‡	14.21	14.70	10.40	nd	nd	nd	nd	nd	nd	nd
1-May	nd	13.18	11.70	8.02	nd	nd	nd	nd	nd	nd	nd
7-May	nd	5.42	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	8.72	8.23	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	8.88	10.90	5.72	nd	nd	nd	nd	nd	nd	nd
29-May	nd	10.70	10.00	6.53	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	7.27	7.13	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	5.63	5.94	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun	nd	12.60	10.20	5.83	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	16.00	9.36	6.19	nd	nd	nd	nd	nd	nd	nd

Morrison Creek

	Res†	Bifenthrin	Permethrin-cis	Permethrin-trans	Fenpro	λ -cy-epi	λ-Cy	Cyflu	Cyper	Fen/Esfen	Delta
23-Apr	ns§	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
1-May	nd	5.28	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	6.73	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	5.00	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	8.20	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	ns	ns	ns	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

† Res. = Resmethrin; Fenpro. = Fenpropathrin; λ -cyh-ep = λ-Cyhalothrin-epimer; λ-Cy. = λ-Cyhalothrin; Cyflu. = Cyfluthrin; Cyper. = Cypermethrin; Fen/Esfen. = Fenvalerate/Esfenvalerate; Delta = Deltamethrin.

‡ nd = Non-detect; no pesticide detected.

§ NS. No sample collected.

Appendix 5: Pyrethroids in Sediment (µg/g wwt) (cont.)

Willow Creek

	Res†	Bifenthrin	Permethrin-cis	Permethrin-trans	Fenpro	λ -cy-epi	λ-Cy	Cyflu	Cyper	Fen/Esfen	Delta
23-Apr	nd	1.63	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	1.29	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun	nd	1.27	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Willow Springs Reservoir

	Res†	Bifenthrin	Permethrin-cis	Permethrin-trans	Fenpro	λ -cy-epi	λ-Cy	Cyflu	Cyper	Fen/Esfen	Delta
23-Apr	nd	41.4	7.23	nd	nd	nd	nd	nd	nd	nd	nd
1-May	nd	58.80	10.40	nd	nd	nd	nd	nd	nd	nd	nd
7-May	nd	33.10	nd	nd	nd	nd	nd	nd	nd	nd	nd
15-May	nd	23.50	7.59	nd	nd	nd	nd	nd	nd	nd	nd
21-May	nd	29.00	nd	nd	nd	nd	nd	nd	nd	nd	nd
29-May	nd	22.90	5.48	nd	nd	nd	nd	nd	nd	nd	nd
4-Jun	nd	ns	ns	ns	nd	nd	nd	nd	nd	nd	nd
11-Jun	nd	62.80	5.80	nd	nd	nd	nd	nd	nd	nd	nd
18-Jun	nd	42.50	nd	nd	nd	nd	nd	nd	nd	nd	nd
25-Jun	nd	53.00	nd	nd	nd	nd	nd	nd	nd	nd	nd

† Res. = Resmethrin; Fenpro. = Fenpropathrin, λ -cyh-ep λ-Cyhalothrin-epimer; λ-Cy. = λ-Cyhalothrin; Cyflu. = Cyfluthrin; Cyper. = Cypermethrin; Fen/Esfen. = Fenvalerate/Esfenvalerate Delta = Deltamethrin.

‡ nd = Non-detect; no pesticide detected.

§ NS. No sample collected.

Appendix 8
Total and Inorganic Carbon Composition of Sediments.

Chicken Ranch Slough

Date	*Sample #*	*% TC/OC*†	*SD*‡	*%CV*§	*% IC**	*SD*	*%CV*
23-Apr	509	2.982	0.15	4.73	0	0.00	0.00
1-May	535	2.528	0.09	3.39	0	0.00	0.00
7-May	523	2.249	0.10	4.10	0	0.00	0.00
15-May	538	2.520	0.05	1.89	0	0.00	0.00
21-May	559	2.981	0.17	5.81	0	0.01	0.01
29-May	571	3.603	0.07	1.87	0	0.00	0.00
4-Jun	583	3.222	0.16	4.85	0	0.00	0.00
11-Jun	595	3.363	0.10	3.05	0	0.00	0.00
18-Jun	608	4.422	0.06	1.46	0	0.00	0.00
25-Jun	620	6.146	0.25	4.07	0	0.00	0.00

Morrison Creek

Date	*Sample #*	*% TC/OC*†	*SD*‡	*%CV*§	*% IC**	*SD*	*%CV*
1-May	526	2.277	0.15	6.74	0	0.00	0.00
7-May	514	2.917	0.12	3.75	0	0.00	0.00
15-May	547	5.025	0.10	1.91	0	0.00	0.00
21-May	550	4.328	0.16	3.74	0	0.00	0.00
29-May	562	5.182	0.14	2.70	0	0.00	0.00
4-Jun	574	4.653	0.23	5.03	0	0.00	0.00
11-Jun	586	2.337	0.02	1.06	0	0.00	0.00
18-Jun	599	2.484	0.11	4.28	0	0.00	0.00
25-Jun	611	2.718	0.03	1.21	0	0.00	0.00

† Total Carbon/Organic Carbon. Mean value of the replicates. TC=OC when IC=0.
‡ Standard Deviation of the replicates.
§ Coefficient of Variance.
* Inorganic Carbon. Mean value of the replicates.

Appendix 8:
Total and Inorganic Carbon Composition of Sediments Collected (cont.)

Willow Creek

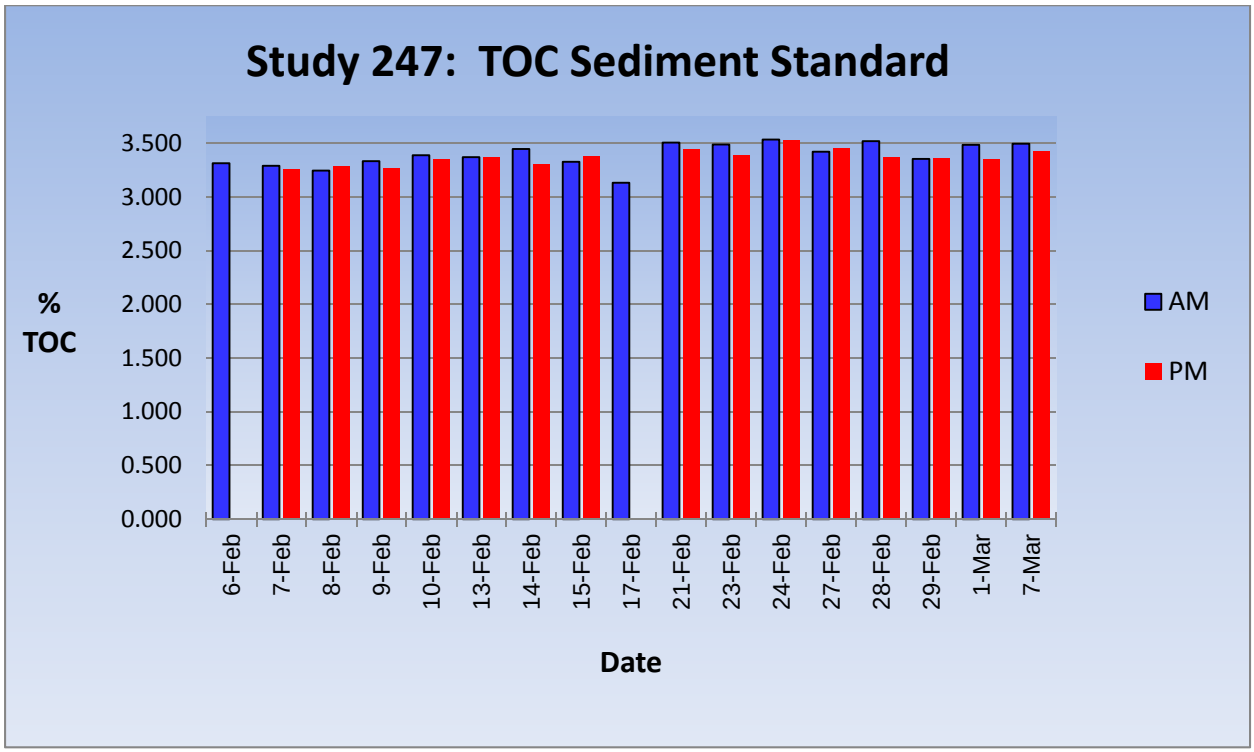
Date	*Sample #*	*% TC/OC*†	*SD*‡	*%CV*§	*% IC**	*SD*	*%CV*
23-Apr	507	5.437	0.23	3.98	0	0.00	0.00
1-May	532	6.111	0.10	1.63	0	0.00	0.00
7-May	520	6.091	0.12	1.94	0	0.00	0.00
15-May	541	5.240	0.10	1.89	0	0.00	0.00
21-May	556	6.033	0.20	3.32	0	0.00	0.01
29-May	568	7.133	0.32	4.43	0	0.00	0.00
4-Jun	580	7.077	0.08	1.16	0	0.00	0.00
11-Jun	592	8.320	0.29	3.44	0	0.00	0.00
18-Jun	605	6.617	0.09	0.97	0	0.00	0.00
25-Jun	617	7.554	0.14	1.88	0	0.00	0.00

Willow Springs Reservoir

Date	*Sample #*	*% TC/OC*†	*SD*‡	*%CV*§	*% IC**	*SD*	*%CV*
23-Apr	505	6.026	0.16	3.85	0	0.00	0.00
1-May	529	10.590	0.28	2.66	0	0.00	0.00
7-May	517	8.164	0.22	3.64	0	0.00	0.00
15-May	544	5.327	0.06	1.17	0	0.00	0.00
21-May	553	6.319	0.39	6.18	0	0.01	0.01
29-May	565	4.356	0.25	5.82	0	0.01	0.00
4-Jun	577	8.530	0.33	3.83	0	0.00	0.00
11-Jun	589	12.280	0.50	4.06	0	0.00	0.00
18-Jun	602	9.899	0.41	4.23	0	0.00	0.00
25-Jun	614	11.900	0.58	5.00	0	0.00	0.00

† Total Carbon/Organic Carbon. Mean value of the replicates. TC=OC when IC=0.
‡ Standard Deviation of the replicates.
§ Coefficient of Variance.
* Inorganic Carbon. Mean value of the replicates.

Appendix 9: QA/QC - TOC Sediment Standards



Analytic results for the total organic carbon standard. Variations of the total organic carbon detected between daily replicates was less than 3 % and over the course of analysis was less than 5%. Standards were generally run twice daily over the course of sample analysis. Combustion gas cylindar was depleted on 17/February2012 hence no afternoon standard. New combustion gas cylindar installed 18/February/2012. Organic Carbon Composition of the Marine Sediment Standard 3.36%.

Appendix 10: Environmental Data -

Temperature, pH, and Dissolved Oxygen Content of Waters at Time of Sample Collection.

Chicken Ranch Slough

Date	*Time*	*pH*†	*Temp (°C)*†	*DO(mg/L)*	*EC(uS/cm)*	*Salinity(ppt)*	*Temp (°C)*
23-Apr	14:00	7.29	15.8	8.03	152.7	0.1	15.8
1-May	15:15	7.58	17.4	5.42	354.7	0.2	17.4
7-May	14:00	7.16	21.7	4.29	216.3	0.1	21.3
15-May	13:30	7.54	22.0	8.4	370	0.2	21.7
21-May	14:10	7.77	20.5	7.74	333.3	0.2	20.5
29-May	14:40	7.33	20.9	6.14	376.5	0.2	20.9
4-Jun	13:30	7.71	19.9	6.83	371.1	0.2	19.9
11-Jun	13:30	7.67	21.2	8.8	372.2	0.2	21.5
18-Jun	14:55	7.49	23.5	3.02	373.1	0.2	23.6
25-Jun	14:00	7.47	21.5	5.75	350	0.2	21.4

Morrison Creek

Date	*Time*	*pH*†	*Temp (°C)*†	*DO(mg/L)*	*EC(uS/cm)*	*Salinity(ppt)*	*Temp (°C)*
23-Apr	ns‡	ns	ns	ns	ns	ns	ns
1-May	12:30	7.32	22.2	4.31	194.1	0.1	21.7
7-May	10:00	7.34	19.5	4.24	181.2	0.1	19.7
15-May	9:20	7.92	22.3	9.72	190	0.1	22.3
21-May	10:00	8.00	22.8	8.3	204.2	0.1	23.0
29-May	10:15	6.20	23.3	6.6	195.6	0.1	23.0
4-Jun	10:30	7.14	21.0	5.68	201.4	0.1	21.0
11-Jun	10:00	7.35	24.8	3.62	206.7	0.1	24.5
18-Jun	10:06	7.51	25.3	2.7	214.5	0.1	25.3
25-Jun	9:00	7.00	24.8	3.79	214.8	0.1	24

† pH and temperature from YSI 60 pH meter.
‡ ndc. Not sampled. Morrison Creek was not sampled on this date.

Appendix 10: Environmental Data (cont.)

Temperature, pH, and Dissolved Oxygen Content of Waters at Time of Sample Collection.

Willow Creek

Date	*Time*	*pH*†	*Temp (°C)*†	*DO (mg/L)*	*EC(uS/cm)*	*Salinity(ppt)*	*Temp (°C)*
23-Apr	12:40	7.69	15.9	10.08	216.8	0.1	15.9
1-May	14:30	7.78	20.1	9.78	258.2	0.1	20.1
7-May	13:00	7.62	20.2	7.95	249.8	0.1	20.1
15-May	12:00	7.66	19.8	9.26	250	0.1	19.8
21-May	13:15	7.58	21.2	6.04	230	0.1	21.2
29-May	13:30	6.93	22.4	6.252	236.7	0.1	22.4
4-Jun	12:30	7.37	21.4	7.45	235.4	0.1	21.3
11-Jun	12:00	7.48	21.2	5.81	234.7	0.1	21.1
18-Jun	1:30	7.41	23.8	6.9	238.3	0.1	23.9
25-Jun	13:00	6.68	22.0	7.65	219	0.1	21.2

Willow Springs Reservoir

Date	*Time*	*pH*†	*Temp (°C)*†	*DO (mg/L)*	*EC(uS/cm)*	*Salinity(ppt)*	*Temp (°C)*
23-Apr	11:55	6.96	16.7	7.00	236.9	0.1	16.7
1-May	13:40	7.30	17.6	7.03	190.4	0.1	17.6
7-May	11:25	6.91	18	6.07	179	0.1	18.0
15-May	11:00	6.86	18.5	8.56	190	0.1	18.5
21-May	11:45	6.67	18.8	5.51	181.1	0.1	18.7
29-May	12:00	6.64	20.1	4.36	176.3	0.1	19.4
4-Jun	11:30	6.84	19.8	6.05	170.4	0.1	19.7
11-Jun	11:15	6.9	20.7	5.56	163.8	0.1	20.4
18-Jun	12:00	6.75	21.6	3.86	156.8	0.1	21.2
25-Jun	10:30	6.61	21.7	6.37	141	0.1	21.8

† pH and temperature from YSI 60 pH meter.