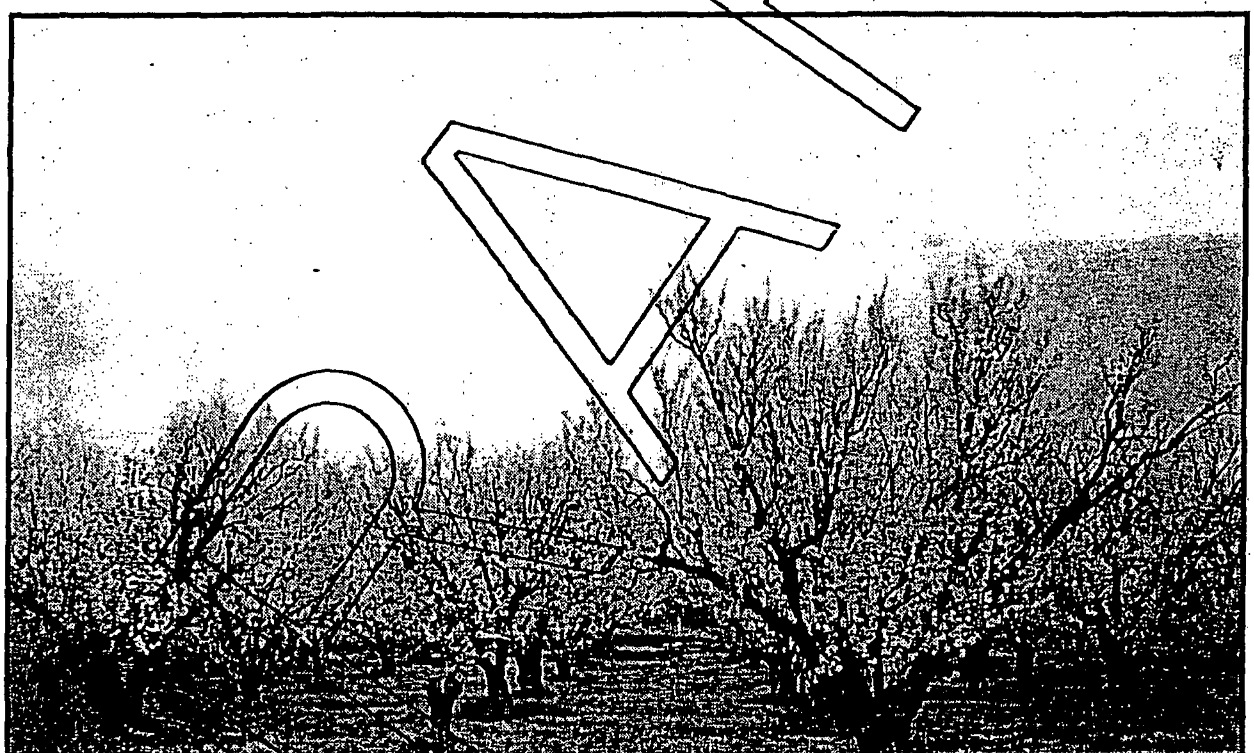
Copy — 48

472

RS

Sources and Concentrations of Diazinon in the Sacramento Watershed during the 1994 Orchard Dormant Spray Season



June 1998

Central Valley Regional Water Quality Control Board

Staff involved in the preparation of this report

Robert Holmes
Christopher Foe
and
Victor de Vlaming

Forward

This project was funded by the State Water Resources Control Board with monitoring and assessment funds under contract number 3-004-150-0 with the United States Geological Survey and with Central Valley Regional Water Quality Control Board monitoring funds to conduct a diazinon loading study in the Sacramento River Watershed.

cover photo: Victor de Vlaming

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

A million pounds of dormant spray active ingredients are applied annually in the Central Valley on half a million acres of stonefruit and almond orchards in January and February. Diazinon accounts for about half the use. Toxic concentrations of diazinon were measured in the San Joaquin and in the Sacramento River in February 1993 after the three largest storms of the month (Kuivila and Foe, 1995)[1]. Diazinon was traced as far seaward in the Sacramento-San Joaquin Delta/Estuary as the City of Martinez. Diazinon-caused toxicity was observed 60 miles downstream of Sacramento. Studies have not been conducted in the Sacramento River watershed to determine the source of the diazinon.

These findings are of regulatory significance as the Central Valley Regional Water Quality Control Board's (CVRWQCB) Basin Plan contains a narrative toxicity objective stating that "all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses . . . in aquatic life." Related to this toxicity water quality objective, the Sacramento River and Sacramento-San Joaquin Delta-Estuary were placed on the Clean Water Act's 303(d) list by the CVRWQCB as impaired water bodies because of detecting toxic concentrations of diazinon in addition to other toxic chemicals, including chlorpyrifos.

Enyme linked immunosorbent assays (ELISA) are a recently developed procedure that utilizes antibodies to measure concentrations of chemicals. An antibody has been developed specifically for diazinon. The procedure is appealing because it has a low detection limit and may be completed within hours facilitating real-time follow-up studies. Traditionally, State of California agencies have employed a capillary gas chromatograph/ion trap mass spectrometer (GC/MS) to quantify chemical concentrations. GC/MS is time consuming and analytical data are often not available for several weeks. The accuracy and precision of the ELISA procedure on surface water samples has not been assessed.

[1] Water samples collected in the Sacramento River at the City of Sacramento during one storm caused complete *Ceriodaphnia* mortality using the U.S. EPA three species bioassay procedure. Diazinon was assumed to be the primary cause of mortality.

Objectives of this study were threefold: (1) monitor diazinon concentrations in the Sacramento River after three rainstorms in January/February 1994 to ascertain whether insecticide pulses were present, (2) if pulses were observed, then determine the geographic sources of the insecticide, and (3) compare the accuracy and precision of ELISA and GC/MS methods to determine the utility of the ELISA procedure for analyzing surface water samples

Water year 1994 was critically dry. As in February 1993 (Kuivila and Foe, 1995), flow and diazinon concentrations increased in the Sacramento River at Sacramento in January/February 1994 after the three largest rain storms. Peak diazinon concentrations were 236, 253, and 51 ng/L. Eighty-five miles upstream at the City of Colusa, flow and pesticide concentration also increased after each storm. Maximum diazinon concentrations were 88, 200, and 105 ng/L. The primary source of the diazinon at the City of Sacramento during the first storm was from the Feather River drainage. Important sources to the Feather River were Jack Slough and the Bear River. The primary sources of diazinon in the Sacramento River at Sacramento during the second and third storms were the upper Sacramento Basin above Colusa and from the Sacramento Slough drainage. The principle sources of diazinon in the upper Sacramento River were not defined, but appeared to be located in the area between Bend and Vina. Important sources of diazinon in Sacramento Slough were the Main Drain inputs, Wadsworth Canal, and the Department of Water Resources (DWR) pumping stations at Obanion and Sacramento Avenue.

Comparison of instream diazinon concentrations with the California Department of Fish and Game's (DFG) recommended water quality criteria for protection of aquatic life demonstrated that the Sacramento River at Sacramento in January/February 1994 exceeded the DFG acute and chronic criteria for nine and 19 days, respectively. Similar multiple exceedances were also observed in the Sacramento River at Colusa, the Feather River at Yuba City and at HWY 99, Sacramento Slough at Pass Road and at Karnak, and at Colusa Drain. The DFG recommends that once every three years the acute criteria may be exceeded for an hour and the chronic one for four days without causing damage to aquatic ecosystems. The frequency of exceedance of the diazinon criteria was greater than recommended by DFG in several areas of the Sacramento watershed in January/February 1994.

One hundred and fifty-five field samples were analyzed by both ELISA and GC/MS. No statistical difference was noted in the accuracy and precision of the two methods suggesting that the diazinon ELISA procedure is acceptable for monitoring of surface waters.

INTRODUCTION

The Sacramento River Watershed encompasses over 16 million acres with about one percent[1] of the land mass being planted in stonefruit and almond orchards. Almonds and prunes constitute 90 percent of this acreage (Table 1). The highest density of orchards typically occurs in the deeper, well-drained soil adjacent to waterways in Butte, Glenn, Colusa and Sutter Counties. An annual application of dormant spray is recommended for all almond and stonefruit orchards in early winter primarily for the control of boring insects.

Approximately 500,000 pounds of dormant spray insecticide are applied annually in the Central Valley on half a million acres of stonefruit and almond orchards primarily to control boring insects. The pesticides are typically applied in January and February. Four insecticides are primarily employed with diazinon accounting for about half the market[2]. Toxic concentrations of diazinon were measured in the San Joaquin and in the Sacramento River in February 1993 after the three largest storms of the month (Kuivila and Foe, 1995). Dormant spray concentrations in the San Joaquin River at Vernalis caused 100 percent *Ceriodaphnia* mortality in U.S. EPA three species bioassay procedures (U.S. EPA, 1989) for 12 days while acute toxicity was observed in the Sacramento River at the City of Sacramento for one day. Diazinon pulses from both watersheds were traced as far seaward in the Sacramento/San Joaquin Estuary as the City of Martinez, 75 miles below the City of Sacramento. Toxicity was observed as far west as Chipps Island, 60 miles downstream of Sacramento.

These findings are of regulatory significance as the CVRWQCB's Basin Plan contains a narrative toxicity objective: "all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses . . . in aquatic life." In 1989, U.S. EPA endorsed (54FR23868) use of the EPA three species bioassays in assessing compliance with state narrative toxicity objectives. Both the Sacramento and San Joaquin Rivers and the downstream Estuary have been placed on the Clean Water Act 303(d) list by the CVRWQCB as

[1] 171,000 acres.

[2] 73,000 pounds of diazinon were applied to orchards in Butte, Colusa, Glenn, Sutter, Tehama, Yolo, and Yuba counties during January and February 1994.

impaired water bodies in part because of toxic concentrations of diazinon during dormant spray season.

Follow-up studies in the San Joaquin Basin confirmed that the application of dormant spray on orchards was the primary source of diazinon (Foe, 1995; Domagalski, 1996; Kratzer 1997). Loading studies (Kratzer, 1997) demonstrated that the Tuolumne and Merced Rivers and several small westside tributaries in Stanislaus County were the primary source of the insecticide. The results were surprising as some of the largest densities of orchards are along the Stanislaus River where little off site movement of diazinon was observed. These results are significant as they help focus the control actions on the primary locations responsible for the majority of the pesticide observed in the San Joaquin River and in the southern Estuary. No similar studies have been conducted in the Sacramento Basin to determine the source of the diazinon observed in the Sacramento River.

Enyme linked immunosorbent assays (ELISA) are a recently developed procedure that use antibodies to measure chemical concentration. An antibody has been developed specifically for diazinon. The procedure is appealing because it has a low detection limit and may be completed within hours without the purchase of large amounts of equipment. Traditionally, State of California agencies have employed a capillary gas chromatograph/ion trap mass spectrometer (GC/MS) to quantify chemical concentrations. The GC/MS analysis is time consuming and analytical data are often not available for several days making real time follow up studies difficult. The accuracy and precision of the ELISA procedure was not known for field samples.

Objectives of this study were threefold. First, monitor diazinon concentrations in the Sacramento River watershed after rainstorms to ascertain whether pulses were present. Second, if concentrations of concern were observed, determine the sources of the insecticide. As part of this project, we compared the accuracy and precision of ELISA and GC/MS methods to determine the utility of the ELISA procedure on field samples.

METHODS AND MATERIALS

Site Description And Sampling Locations: Water samples were collected at 30 sites (Figure 1) on the Sacramento River and tributaries in the winter of 1994. Sampling was associated with rainstorms. All samples were subsurface grab samples collected in one liter amber glass bottles. Samples were placed on ice for transport to the laboratory where they were stored at 4°C until analysis. Seven primary sampling sites were selected for daily monitoring after rainstorms (Appendix A, Table 1). These were located on the Sacramento River and on its major tributaries downstream of high densities of orchards. Orchards in Butte and Glenn Counties are predominately located along the upper Sacramento River and its tributaries. Water samples collected in the town of Colusa (Site 7) should detect any insecticides in stormwater runoff from the upper Sacramento River, with the exception of central Butte County. Orchards in central Butte County drain to Butte Slough above Pass Road (Site 5). Orchards in Sutter County predominately drain to Sacramento Slough between Pass Road and Karnak (Site 4). Orchards in Yuba County are located along the east side of the Feather River between Yuba City and HWY 99. Rainwater runoff from this area should be reflected in the insecticide loads from the Feather River at HWY 99 (Site 2). Flow information was available for each primary site enabling calculation of diazinon loads.

Secondary sampling sites were located along tributaries to the Sacramento River, Feather River, and Butte Slough for the purpose of identifying major sources of diazinon within each subbasin (Appendix A, Table 2). Samples were to be collected at least once during each rainfall event at the secondary sites.

Flow data were not available for all these locations, making source identification more qualitative in nature. Limited sampling occurred on the upper Sacramento River between Colusa and Red Bluff when it became apparent that a notable portion of the diazinon load originated in those areas. Sampling was from major bridges crossing the river (Appendix A, Table 2).

Precipitation: Rainfall data were obtained from the Desert Research Center's Atmospheric Science Center for four locations in the northern Central Valley: Cities of Sacramento, Colusa, Marysville, and Red Bluff. Rainfall information was collected for multiple sites as the valley is over 100 miles long and thus precipitation at any one location is not likely to be representative of the entire watershed.

Diazinon Analysis: Three types of diazinon analysis were conducted: Millipore Enzyme-Linked Immunosorbent Assay (ELISA) at U.C. Davis; Gas Chromatograph Mass Spectrometer (GC/MS) at the U.S. Geological Survey (USGS) central laboratory in Arvada, Colorado; and /or GC/MS at the USGS laboratory in Sacramento.

Enzyme-Linked Immunosorbent Assay: All water samples (n=332) were analyzed by ELISA following Millipore recommended procedures (1993)[3] at U.C. Davis Aquatic Toxicology Laboratory within 14 days of collection. The Millipore ELISA detection limit for diazinon is 30 ng/L. An ELISA quality assurance program consisting of 178 samples (47 percent of the total sample number) was conducted: (1) 12 blank samples were analyzed, (2) 15 duplicate

---

[3] ELISA kits used in this study were distributed by Millipore Corporation. The Millipore ELISA division has since been acquired by Strategic Diagnostics Inc., 128 Sandy Drive, Newark, DE 19713-1147.

analyses were performed on the same sample, (3) 152 samples were analyzed by GC/MS; 38 by the USGS in Sacramento, and 114 by the USGS central laboratory, and (4) approximately 16 percent of the samples were analyzed by GC/MS at both USGS facilities.

<u>Gas Chromatograph Mass Spectrometer Analysis</u>: Within ten days of collection, forty percent (n=152) of the samples were filtered through a 0.7 micron glass fiber filter and then extracted on solid phase C18 resin column cartridges. The cartridges were then stored in a freezer until shipped to the USGS central laboratory for elution and analysis by GC/MS. The central laboratory detection limit and mean percent recovery for diazinon are 8 ng/L and 77 percent, respectively (Table 2). No correction was made in this study for the less than complete recovery of diazinon. Complete details of the analytical procedure are described by Zaugg *et al.* (1995).

Ten percent (n=48) of the samples were prepared in a similar fashion for analysis at the USGS Sacramento laboratory which uses the same procedures (Zaugg *et al.*, 1995). The detection limit and mean percent recovery for diazinon at the USGS laboratory in Sacramento was 38 ng/L and 74 percent, respectively (Table 3). The Sacramento USGS GC/MS analysis was needed because methidathion, another dormant spray insecticide, was not reported in the central laboratory scan.

A quality assurance program was also performed on samples analyzed by GC/MS to assess accuracy and precision of the analytical process. Twenty deionized blank water samples were submitted to the USGS central laboratory to ascertain background contamination. These were prepared in the same way as the field samples. Five samples (three percent of the total) were split and were submitted blind to the USGS central laboratory as intralaboratory splits to ascertain repeatability of the analytical method. In addition, a surrogate deuterated diazinon sample was amended into USGS central laboratory samples to establish the efficiency of diazinon extraction and analysis.

Diazinon Degradation Experiment: A degradation experiment was conducted to assess the rate of loss of diazinon held in amber glass containers in the dark at <4.0^0 C. These experiments were necessary because some field samples were held for 14 days before analysis. The experiment consisted of spiking three one liter samples of both laboratory and Butte Creek water with 350 ng/L diazinon and measuring insecticide concentration 0, 10, 38, and 60 days later (spiked samples stored in dark at 4^{o}C). Results were compared by analysis of variance to establish whether a loss occurred through time.

Water Flow Data: Flow data were obtained from the 1994 USGS's Water Data Report (USGS, 1994) and the Department of Water Resources' (DWR) California Data Exchange Center (CDEC, 1995). CDEC flow data was used almost exclusively at all primary sampling locations except at the HWY 99 bridge on the Feather River (Site 2). No flow information is available for the Feather River at its confluence with the Sacramento River. Therefore, the flow of the Feather River was estimated by summing the flow of the Sacramento River at the City of Colusa with that of Colusa Drain and Sacramento Slough and subtracting the flow of the Sacramento River at Verona.

Diazinon Mass Loading Calculations: Estimations of mass loading are helpful in determining sources of chemical contaminants. Loads were calculated by multiplying the measured diazinon concentration at a site by the mean daily flow (results expressed as kilograms diazinon per day). If multiple estimates of diazinon concentration were available, then values were averaged to calculate a mean concentration for use in the mass load estimate.

__Travel Time:__ To compare loads at different points in a watershed, one must have some estimate of water mass travel time. The travel time of water masses between the confluence of each Sacramento River tributary and the City of Sacramento was estimated from distance and water velocity measurements (DWR, 1962 - Table 4). Travel time estimates between 12 and 36 hours were rounded to one day while estimates falling between 36 and 60 hours were rounded to two days. Velocity measurements were not available for Butte Creek or the Feather River. Travel times were calculated by assuming a velocity of 1.25 miles per hour (Table 4).

RESULTS AND DISCUSSION

Results are presented below in three sections. First, the data from the pesticide quality assurance/quality control program is summarized with an emphasis on determining whether ELISA procedures might be substituted for GC/MS analysis. Second, diazinon concentrations and loads are presented for both tributaries and the mainstem Sacramento River during dry and wet weather. The main objective was to determine whether exceedances of the California Department of Fish and Game (DFG) Hazard Assessment criteria for diazinon (Menconi and Cox, 1994) occurred and to locate the geographic source(s) of diazinon observed in the river at the City of Sacramento after rainstorms. In addition, information is summarized on other common pesticides detected during storm flows.

Quality Assurance and Quality Control Program

A quality assurance and quality control (QA/QC) program was carried out to assess the reliability of both the GC/MS and ELISA, and to determine whether the ELISA procedure could be used in place of GC/MS analysis for field monitoring.

GC/MS: The GC/MS program consisted of the submission of blanks, intra- and interlaboratory splits of the same sample, and amendments of deuterated diazinon. First, no chemicals including diazinon, were measured in any of the 20 blank samples analyzed at the USGS's central laboratory. Second, five intralaboratory split samples were analyzed at the USGS central laboratory (Appendix B, Table 1). In these five samples, the mean percent difference in diazinon concentration was 22 percent. Third, 25 interlaboratory split samples were analyzed by both the

USGS Sacramento laboratory and the central laboratory (Appendix B, Table 2). The mean percent difference was 19 percent (Appendix B, Table 2). These data are plotted in Figure 1 of Appendix B and the relationship was found to have a r^2 value of 0.93. Paired samples were compared by t-test to establish whether a difference might exist. None was noted ($P>0.10$) so both data sets were combined for subsequent analysis. Finally, the mean percent recovery of

164 deuterated diazinon amendments was 95 percent (Appendix B, Table 3).

<u>ELISA:</u> The ELISA QA/QCprogram at U.C. Davis Aquatic Toxicology Laboratory consisted of laboratory blanks, intralaboratory splits and interlaboratory comparisons employing ELISA and GC/MS analyses. No diazinon was detected in any of the 12 blank samples analyzed by ELISA. Fifteen samples were reanalyzed by ELISA to ascertain the repeatability of the results. The mean percent difference was 20 percent (Appendix B, Table 4). This value appears similar to the 22 percent difference observed in duplicate GC/MS analyses of other field samples.

Both ELISA and GC/MS were used to analyze 155 samples (Appendix B, Table 1). Thirty-eight of these GC/MS analyses were conducted at the Sacramento USGS laboratory and 117 at the central laboratory. Data are plotted in Figure 2 of Appendix B ($r^2 = 0.75$). A paired t-test was used to assess whether a difference might exist between methods; none was detected ($P>0.3$). Thus, the ELISA and GC/MS results were considered comparable and were combined in the subsequent analysis.

In conclusion, results of both the GC/MS and ELISA QA/QC program appeared satisfactory. Furthermore, no difference was evident in the accuracy and precision of the two methods, suggesting that ELISA is an acceptable procedure for determining diazinon concentrations in surface water monitoring.

__Diazinon degradation:__ No change was noted in the concentration (analyzed by ELISA) of diazinon amended into laboratory and Butte Creek water after two months storage in amber glass containers at <4^0C ($P>0.05$, ANOVA; Appendix B, Figure 3) suggesting that little error was caused by delaying the analysis of some field samples for up to 14 days.

Sources

Diazinon concentration and load data are presented below for portions of the Sacramento Watershed draining areas of high orchard density. Information on diazinon concentration is important as it indicates locations where insecticides may be a threat to aquatic life. To assess whether toxicity impacts on aquatic life could exist, diazinon concentrations were compared to the DFG Hazard Assessment criteria. Load information is important because it indicates the major sources of contamination. Such information is needed to identify areas where control action is necessary to insure the protection of aquatic organisms. The strategy consisted of collecting concentration and load information at key locations in each basin during both dry and wet periods, as well as conducting detailed follow-up work in those locations which appeared to contribute the greatest amount of diazinon.

Precipitation: Water year 1994 was classified as critically dry in the Sacramento basin.[4] Rainfall patterns at the Cities of Red Bluff, Colusa, Marysville, and Sacramento are presented in Table 5. Two significant storms occurred during the study: the first in late January and the second in early February. Each dropped 1.5 inches or more of rain throughout the Central Valley. A third, more minor, storm occurred in late February. Daily precipitation patterns at all locations appeared similar with the following exceptions: rainfall during the first storm was nearly an inch more at Marysville than at either Colusa or Sacramento while precipitation totals for the third storm at Red Bluff were at least double those at all other locations. The second storm appeared to be of similar magnitude throughout the Valley.

Dormant Spray Usage: Seventy-five percent of the diazinon was applied in the Sacramento Basin during January 1994 (Figure 2). Presumably, most of the insecticide was sprayed during the first three weeks of the month as the last week was wet.[5] Butte, Glenn, Sutter and Yuba Counties accounted for 90 percent of the use. Pesticide application rates, with the exception of Colusa County, were consistent with the reported orchard acreage (Table 1, Figure 2). Colusa County is reported to have a larger acreage in trees than was reflected in the pesticide use data.

DRY WEATHER

Diazinon Concentration: Diazinon concentrations were measured on five occasions during dry weather in 1994: 12, 17, 21, and 31 January and 4 February (Figure 3, and Appendix C,

---

4 Water year types are classified in California according to the natural water production of the major basins.

5 2.5 inches of rain fell between 23 and 26 January at Red Bluff (Table ________).

Table 1). These dates were selected because they were preceded by at least three days of dry weather (Table 5). The highest diazinon concentrations were observed in Sacramento Slough at Karnak (Site 4). On all occasions diazinon concentrations in the Slough exceeded the DFG chronic water quality criterion, and on three days the acute criterion. In contrast, the chronic criterion was only exceeded elsewhere on four occasions (Colusa Basin Drain on 31 January, Feather River on 12 January, and Sacramento River at Sacramento on 17 and 31 January). The Karnak data are particularly troubling as the Sutter National Wildlife Refuge is located immediately upstream and the watershed supports a late Fall Salmon Run. Juvenile salmon should be migrating down Sacramento Slough during February (Reynolds et. al., 1993).

No upstream dry weather pesticide data were collected for either the Feather or Sacramento Rivers as neither watershed routinely exceeded the DFG hazard assessment criteria. However, limited information was obtained at Pass Road on Butte Creek, some 36 miles upstream of Karnak, because of the diazinon exceedances. The Pass Road site is above the Sutter National Wildlife Refuge. Potential diazinon sources here are from orchards in the vicinity of Chico draining into Upper Butte Creek and from orchards surrounding the Main Drain site (Figure 1). Diazinon concentrations were always lower at Pass Road than at Karnak suggesting that major inputs were below Pass Road (Figure 4). However, on all dates diazinon concentrations at the Pass Road site exceeded the DFG's chronic water quality criterion.

Loads: Daily dry weather diazinon loads were similar (196-258 gms/day) in all tributaries where orchards are a major land use with the exception of Colusa Drain (Figure 5; Appendix C, Table 2). This observation is notable as the flow of the Sacramento and Feather Rivers are about seven times greater than Sacramento Slough. High concentrations of diazinon in Sacramento Slough are responsible for its contribution to load. Colusa Drain always exported negligible amounts of diazinon.

Dry weather diazinon load information is available only for upper Butte Creek at Pass Road (Figure 6). On each sampling date the load increased downstream at Karnack. Mean daily loads were about four times greater at Karnak than at Pass Road suggesting that about 25 percent of the diazinon originated above Pass Road and about 75 percent below this point. The major sources of diazinon below Pass Road are likely to be Wadsworth Canal and the DWR pumping stations at Obanion and Sacramento Avenue.

WET WEATHER

First Storm - Diazinon Concentrations: Two inches of rain fell between 22 and 25 January in the City of Sacramento after a ten day dry period, three inches were recorded at the Cities of Marysville and Red Bluff (Table 5).

Baseline dry weather diazinon concentration and river flow before the storm at Sacramento ranged from <30 to 50 ng/L and from 10,000 to 15,000 CFS, respectively (Figure 7; Appendix C, Tables 1 and 2). Flow and diazinon concentrations began to increase at Sacramento on 24 January, peaked on the 27th at 24,000 CFS and 236 ng/L and returned to background levels by 4 February. Eighty-five miles upstream at Colusa, pesticide concentrations also began to rise on January 24th, but peaked a day later on the 25th at 90 ng/L and returned to baseline by the 29th (Figure 8).

Comparison of instream pesticide concentrations with the DFG Hazard Assessment criteria demonstrated that the acute criterion was exceeded for one day at Colusa (25 January) and for five days (24 to 28 January) at Sacramento (Figure 9, Table 6). Computation of a diazinon concentration four day running average demonstrates that instream values exceeded the DFG chronic criterion at the City of Colusa for five days (24 to 28 January) and at Sacramento for eleven days (24 January to 3 February; Table 6). It is assumed, although no data were collected, that the 85 miles of river between Colusa and Sacramento also exceeded the chronic criterion for the five day time period between 24 to 28 January as both the up and downstream locations were above the criterion throughout the time period.

Higher diazinon concentrations were observed in the Feather River than in the Sacramento River (Figure 10). Diazinon concentration in the Feather River at Hwy 99 began to rise on 25 January, peaked on the 26th and returned to baseline by the 29th. Twenty miles upstream at Yuba City, diazinon concentrations were rising on the 24th, peaked on the 25th and decreased to background concentrations by the 28th (Figure 10).

Comparison of Feather River diazinon concentrations to DFG hazard assessment water quality criteria demonstrates that the recommended acute value was exceeded for four days at both

Yuba City (24 to 27 January) and at HWY 99 (25 to 28 January; Table 6, Figure 10). Furthermore, four day instream running average concentrations exceeded the DFG chronic criterion at Yuba City for five days (24 to 28 January) and at HWY 99 for eight days (24 to 31 January). Comparison of the timing of up and downstream exceedances suggest that the intervening 20 miles of River between Yuba City and HWY 99 likely exceeded the DFG acute and chronic water quality criteria for at least three (25 to 27 January) and five (24 to 28 January) days, respectively. Diazinon concentrations were available for tributaries only for 24 January (Figure 10). All sample concentrations, except for the Yuba River at Marysville, exceeded the DFG acute water quality criterion.

During the first storm, the highest diazinon concentrations were observed in Sacramento Slough (Figure 9). Diazinon concentrations at Pass Road began to rise by 25 January, peaked on the 26th but had not returned to baseline by the 28th when sampling ceased (Figure 11). Thirty-six miles downstream at Karnak, diazinon concentration began to rise on the 25th, a day later than at Pass Road, peaked on the 27th at 1400 ng/L, but had not returned to baseline by the last day of sampling (31 January). All diazinon concentrations recorded at Pass Road, and seven of eight measurements at Karnak, exceeded the DFG acute water quality criterion (Figure 11, Table 6). Diazinon concentration was measured on 24 January only in the primary agricultural tributaries to the lower Sacramento Slough/Butte Creek between Karnak (Site 4) and Pass Road (Site 5). The 24th was at least one day prior to the entry of the largest pesticide concentrations. Concentrations in the Main Drain (Site 15), Wadsworth Canal (Site 14), DWR pumping station at Obanion (Site 13), and at Sacramento Avenue (Site 12) all exceeded the DFG acute water quality criterion (Figure 11).

Diazinon concentrations in Colusa Basin Drain were the lowest recorded for any major input to the lower Sacramento River (Figure 9). Diazinon concentrations exceeded the DFG acute water quality criterion on 27 January (94 ng/L) only, though, the four day running average diazinon concentration exceeded the chronic criterion for five days (24 to 28 January, Table 6).

First Storm - Diazinon Loads: Measured diazinon loads (kg/day) in the Sacramento River at Sacramento and predicted contribution from each tributary are presented in Figure 12. Measured loads were calculated by multiplying the daily flow rate of the river at a site by the observed diazinon concentration at that site. Predicted loads were estimated by summing the contribution of each tributary after accounting for travel time to Sacramento. Differences between the predicted and measured loads are an indication of the reliability of the load estimates. Substantial error may have occurred in estimating travel time, in employing a single daily grab sample to estimate pesticide concentrations, and analytical errors in measuring diazinon concentrations and river flow rates. The largest single source of error was probably caused by collecting a single grab sample daily.

The sum (four day total) of the predicted daily loads from tributaries over estimated actual measurements at Sacramento by about sixty percent during the first storm (Figure 12). The largest difference occurred on 27 January when the measured load was only about forty percent of the predicted one.

At Sacramento, maximum load was measured on 27 January (Figure 12). About 90 percent of the load appeared to have originated from the Feather River. One possible explanation that the predicted load was greater than estimated is that the maximum diazinon concentration in the river at Sacramento may have been about double the measured value and may have persisted for less than a day. Similar pulses with high amplitude and short duration have been observed in the San Joaquin River basin after large storms (Kratzer, 1997). Diazinon loads decreased at Sacramento in succeeding days mainly because of decreased contributions from the Feather River. The maximum load from Sacramento Slough peaked one day later than the Feather River and declined slowly. This resulted in the pesticide pulse at Sacramento having a "tail." Contributions from the Sacramento River above Colusa were relatively constant throughout the storm at about 1.2 kg/day, while Colusa Basin Drain contributed less than one percent of the total load.

Comparison of the diazinon load of the Feather River at Yuba City and at HWY 99 demonstrate that the watershed above Yuba City contributed only 250-400 gms/day or about 4 percent of the total load at HWY 99 (Figure 13). Therefore, 96 percent of the diazinon must have originated from below Yuba City. The load estimate at Yuba City does not include input from Jack Slough, which enters the river on the side opposite from our sampling site. While limited concentration information is available for the tributaries, it is apparent that Jack Slough and the Bear River may have been major sources of diazinon to the Feather River below Yuba City (Figure 10).

Sacramento Slough was the second most important source of diazinon in the Sacramento River at the Sacramento site (Figure 12). Comparison of the daily load of diazinon at Pass Road and at Karnak demonstrated that, on average, the load at Pass Road was only about 25 percent of that at

Karnak (Figure 14). This implies that about 75 percent of the diazinon load measured at Karnak entered below Pass Road. Again, while little information is available for the lower portion of the slough, likely sources appear to be Wadsworth Canal and the DWR pumping stations at Obanion and Sacramento Avenue (Figure 11).

Second Storm - Diazinon Concentrations: The second rainfall event was preceded by a seven day dry period and occurred between 6 and 11 February. Flow and diazinon concentrations increased in the Sacramento River and peaked on 10 February at Sacramento (Figure 7; Appendix C, Tables 1 and 2). At Colusa, flow and insecticide maxima occurred two days earlier, as in the first storm, on 8 February at 25,000 CFS and 200 ng/L, respectively (Figure 8).

Comparison of Sacramento River diazinon concentrations with the DFG water quality criteria demonstrated that the acute criterion was exceeded for two days at Colusa (8 and 9 February) and for four days at Sacramento (8 and 11 February; Figure 15, Table 6). The four day running average concentration at both cities exceeded the DFG chronic criterion for six days (7 to 12 February). It seems safe to assume that the intervening eighty-five river miles between Colusa and Sacramento exceeded the DFG acute water quality criterion for at least two days (8 and 9 February) and the chronic criterion for six days (7 to 12 February) as both up and downstream sites did during the same time period.

On the Feather River diazinon concentrations peaked at both Yuba City and at HWY 99 on 8 February at 120 and 147 ng/L (Figure 10), respectively. Both sites exceeded the DFG water quality criterion of 80 ng/L on 8 and 9 February. The four day running average concentration exceeded the chronic water quality criterion at Yuba City for four days (7 to 10 February) and at HWY 99 for eight days (7 to 13 February, Table 6).

Lower Feather River tributaries were sampled on three dates (8 to 10 February) during the second storm (Figure 10). All measurements taken on Jack Slough exceeded the DFG acute water quality criterion while only one Yuba River sample did so. Measurements on Honcut Creek exceeded the chronic criterion while diazinon concentrations on Bear River were below detection (Figure 10).

Diazinon concentrations were measured for eight days in Sacramento Slough at Karnak and Pass Road (7 to 14 February) and for three days in their principal agricultural tributaries (8 to 10 February; Figure 11). Diazinon concentrations at Pass Road were greater than at Karnak for the first three days of the storm whereupon concentrations became larger downstream. All tributaries except the pumping stations at Obanion and Sacramento Avenue discharged water with higher concentrations than at the Slough site on all three days monitored. Obanion and Sacramento Avenue inputs provided dilution flows. The high diazinon concentrations at Karnak may have originated in Wadsworth Canal, as it discharged water with 1,900 to 4,500 ng/l diazinon. All diazinon concentrations measured in the Sacramento Slough drainage exceeded the DFG acute water quality criterion, some by as much as 40 to 60 fold (Appendix C, Table 1).

Insecticide concentrations were measured for eight days at Colusa Basin Drain (Figure 15; Appendix C, Table 1). Diazinon concentrations were about three times greater than during the first storm and averaged 244 ng/l. Diazinon concentrations exceeded the DFG acute criterion for seven days at this site (Table 6).

Second Storm - Diazinon Loads: The difference between the predicted and measured diazinon loads at Sacramento during the second storm was less than in the first storm (Figure 16), with the exception of the first day (9 February), than during the first storm. The average percent difference between the observed and measured loads was 25 percent. In contrast to the first storm, the diazinon load at Sacramento exceeded the predicted load. Flow data were not available for the Feather River on 9 February so an assessment of Feather River diazinon loads are impossible to make and this undoubtedly contributed to the large difference between predicted and measured loads for that date.

The largest loads at the beginning of the storm were from the Sacramento River above Colusa and to a lesser extent from the Feather River. As the storm progressed, inputs from Sacramento Slough increased while loads from the upper Sacramento River and from the Feather River declined. Colusa Basin Drain never contributed a significant diazinon load.

The observation that the Sacramento River above Colusa might be a major source of diazinon was unexpected and, consequently, no monitoring sites were established to ascertain the source(s) in the upper Sacramento River.

The second most important source of diazinon was Sacramento Slough. Comparison of loads in Sacramento Slough at Karnak and at Pass Road demonstrated that 47 to 66 percent of the load originated below Pass Road (Figure 14), this result being similar to the first storm. Major sources of diazinon below Pass Road were likely to have been from Wadsworth Canal and from the DWR pumping stations at Obanion and Sacramento Avenue as on each occasion the concentrations of diazinon at these two sites were the highest in Sacramento Slough. The Main Drain may have been a major source of diazinon to Butte Creek above Pass Road.

Diazinon loads in the Feather River, while less important than from the upper Sacramento River and from Sacramento Slough, were also estimated. The results demonstrate, like in the first storm, that 61 to 94 percent of the load originated below Yuba City (Figure 13). A major source may have been Jack Slough (Figure 10).

<u>**Third Storm--Diazinon Concentrations**</u>: The third storm was the smallest with about an inch of rain in Sacramento on 17 and 19 February (Table 5). Twice this amount fell in Redding. As with the first two storms, the flow of the Sacramento River at Sacramento increased and peaked on the 22nd, two to three days after the last precipitation (Figure 7). However, unlike previous storms, only a small increase in ambient diazinon concentration was observed. The average four day concentration at Sacramento, between the 21st and the 24th, exceeded the DFG chronic water quality criterion (Figure 17). Kuivila and Foe (1995) also noted a marked decrease in diazinon concentrations in the Sacramento River during the third storm of the month in 1993. The cause is unknown, but the authors speculated that two storms may be sufficient to 'cleanse' the watershed of diazinon after dormant spray applications.

At Colusa, both flow and diazinon concentration increased rapidly and peaked on

21 February at 20,900 CFS and 105 ng/l, respectively (Figure 8). Diazinon concentrations exceeded the DFG acute criterion for one day (21 February) and the four day running average value exceeded the chronic criterion for four days (18 to 21 February, Figure 17; Appendix C, Table 1). Limited sampling was conducted above Colusa (Table 7). These data are difficult to interpret as no flow measurements were available for Tehama and Hamilton City (Appendix C, Table 2). However, the results suggested that one or more sources exist between Bend and Vina. As a result, 27 miles of river (Red Bluff to Vina) exceeded the DFG acute criterion on the 17th, 49 miles (Vina to Butte City) on the 19th, and 40 miles (Ord Bend to Colusa) on the 21st. More sampling is required to determine the location of the sources of diazinon in the upper Sacramento River.

The Feather River, consistent with other storms, reacted the most rapidly of all the Sacramento River tributaries and had a peak diazinon concentration at HWY 99 on the 17th, the first day of the storm (Figure 10). Diazinon concentration on the 17th was 58 ng/l (Appendix C, Table 1). Jack Slough again appeared to be an important diazinon source. The DFG acute water quality criterion was exceeded in the Slough on all four sampling dates.

Sacramento Slough, as during previous storms, had the highest diazinon concentrations of any monitored tributary (Figure 17). Concentrations at Karnak were above the DFG acute criterion for five days (17 to 21 February) and above the chronic criterion for all seven days monitored (Figure 11; Appendix C, Table 1). Diazinon concentrations did not appear to change rapidly at the Karnak site. Concentrations in the Slough at the beginning of the third storm appeared similar to those measured at the end of the second one (Appendix C, Table 1). So, it is not known whether the diazinon measured during the third storm resulted primarily from continued runoff from the second one or was 'new' runoff. Upstream monitoring suggested that the Main Drain, Wadsworth Canal, and DWR pumping stations at Obanion and Sacramento Avenue were important sources (Figure 11). Sixteen of twenty samples collected at these four sites exceeded the DFG acute criterion; 17 samples exceeded the chronic criterion.

Diazinon concentrations in Colusa Basin Drain also increased, producing a double peak on the 21st and 24th (Figure 17). The cause of the bimodal peak is not known though it may have been due to the bimodal rainfall pattern. Diazinon concentrations exceeded the DFG acute and four day running average criterion for two and seven days, respectively (Figure 17; Appendix C, Table 1).

<u>Third Storm - Diazinon Loads:</u> Fourteen and a half kilograms of diazinon were exported from the Sacramento River Basin during the third storm (Appendix C, Table 2). This is about a third of the load transported past the City of Sacramento during each of the previous two storms.[6] It is not known whether the decrease in diazinon load occurred because the third storm had the smallest amount of rain or whether the previous two storms "washed off" most of the available insecticide. Kuivila and Foe (1995) also noted a decrease in loads exported from both the Sacramento and San Joaquin basins after the second storm of the month.

---

[6] 39.1 and 43.6 kilograms of diazinon were calculated to have been exported during the first and second storms, respectively (Appendix C, Table 2).

The majority of the diazinon load originated from the upper Sacramento River during the third storm (Figure 18). As previously explained, the sources of the insecticide are not known, though much of it appeared to have originated in the 40 mile reach between Bend and Vina (Table 7).

Sacramento Slough was the second most important source of diazinon (Figure 18), exporting an estimated 2.5 kg/day of diazinon, or about 17 percent of the total load, from the Sacramento River watershed (Appendix C, Table 2). Unlike previous storms, the load seems to have come about equally from above and below Pass Road (Figure 14). As noted above, major sources appear to be the Main Drain, Wadsworth Canal, and the DWR pumping stations at Obanion and Sacramento Avenue.

In conclusion, water year 1994 was critically dry. As in February 1993, flow and diazinon concentrations increased in the Sacramento River at Sacramento after the three largest rain storms of the month, peak concentrations being 236, 253, and 51 ng/l. Eighty-five miles upstream at Colusa, flow and diazinon concentrations also increased after each rainstorm, maximum concentrations being 88, 200, and 105 ng/l. The primary source of the diazinon during the first storm was from the Feather River. Important Feather River sources were Jack Slough and the Bear River. The primary sources of diazinon in the Sacramento River during the second and third storms were from the Sacramento River above Colusa and from Sacramento Slough. The principal source(s) of diazinon in the upper Sacramento River were not identified, but appear to be located between Bend and Vina. Important sources of diazinon in Sacramento Slough were the Main Drain, Wadsworth Canal and the DWR pumping stations at Obanion and Sacramento Avenue. Colusa Basin Drain was never a major source of diazinon.

Comparison of instream diazinon concentrations to the DFG's water quality criteria reveals that the Sacramento River at Sacramento during January/February 1994 exceeded the acute and chronic criteria for nine and 19 days, respectively (Table 6). Similar multiple exceedances also were observed in the Sacramento River at Colusa, the Feather River at Yuba City and at HWY 99, Sacramento Slough at Pass Road and Karnak, and in Colusa Basin Drain. DFG recommends that their acute criterion may not be exceeded more than once every three years for an hour and their chronic criterion for no more than four days. Obviously, the frequency of exceedance of both the acute and chronic diazinon criteria was much greater than that during January/February 1994 in many Sacramento Basin waterways.

Other Chemicals: Thirty pesticides were detected in the USGS central laboratory scan (Appendix D, Table 1). No chemical concentration, with the exception of diazinon, was above a recommended water quality criterion or toxicity effect level found in the published literature. This included chlorpyrifos and malathion, two other dormant spray insecticides. No information was available for permethrin and esfenvaleratc. Pesticides identified in the GC/MS scan at USGS Sacramento laboratory are in Appendix D, Table 2.

Interestingly, the herbicide simazine was ubiquitous at low concentrations throughout the basin.[7] Simazine is commonly applied in the watershed on almonds and on right of way (Department of Pesticide Regulation, 1997). Atrazine, another triazine herbicide, was common in the Sacramento River at Colusa, the Feather River at HWY 99, and at Colusa Basin Drain.[8] Concentrations of atrazine increased in Sacramento Slough at Karnak and in samples collected at the DWR pumping station at Sacramento Avenue after 17 February, suggesting a recent local application. Atrazine is commonly applied to corn and along road sides (Department of Pesticide Regulation, 1997).

Carbofuran and molinate were detected in the discharge from all waterways where rice is grown. Thiobencarb, another commonly used rice herbicide, was detected in only 58 percent of the samples. The three chemicals are typically applied in rice culture in May and June about six months earlier. The Central Valley Water Quality Control Plan for the Sacramento River has a conditional prohibition for discharge of irrigation return flows containing carbofuran, molinate and thiobencarb if concentrations are above the Basin Plan performance goals.. Measured concentrations were below performance goals for all three pesticides.[9]

---

7 Simazine was detected in 94 percent of all samples at concentrations between 10 and 1,200 ng/l (Table 1, Appendix D).

8 Atrazine was detected in 46 percent of all samples at concentrations between 3 and 5,300 ng/l (Table 1, Appendix D).

9 Values for carbofuran, molinate, and thiobencarb ranged between 23 to 370, 22 to 420, and 2 to 42 ng/l. Performance goals for the three pesticides are 0.4, 10, and 1.5 ug/L, respectively (Central Valley Basin Plan, 1990)

ACKNOWLEDGMENTS

We thank Michael Marchetti for assisting in the collection of samples, and Dr. Joseph Domagalski for managing the USGS contract. Dennis Westcot, Jerry Bruns, and Val Connor provided valuable comments on a previous draft.

LITERATURE CITED

California Data Exchange Center. 1993. Accessed by internet at http://cdec.water.ca.gov./ Data maintained by California Department of Water Resources, Division of Flood Control, Sacramento, CA

Crepeau, K.L., J.L. Domagalski, and K.M. Kuivila. 1994. Methods of analysis and quality assurance practices of the U.S. Geological Survey Organic Laboratory, Sacramento, CA. Determination of pesticides in water by solid phase extraction and capillary-column gas chromatography/mass spectrometry. OFR-94-362. U.S. Geological Survey, Sacramento, CA

Department of Pesticide Regulation, 1997. Pesticide use report database.

Department of Water Resources. 1962. Bulletin no.111 Sacramento River Water Pollution Survey. Appendix A hydrography, hydrology, and water utilization.

Domagalski, J. 1996. Pesticides and pesticide degradation products in stormwater runoff: Sacramento River Basin, Sacramento, CA. Water Resources Bulletin.32:5, pp 953-964.

Foe, C. 1995. Insecticide concentration and invertebrate bioassay mortality in agricultural return water from the San Joaquin Basin. Staff report. California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA. 150 pp.

Kratzer, C.R. 1997. Transport of diazinon on the San Joaquin River Basin, California. U.S. Geological Survey Open File Report 97-411. National Water Quality Assessment Program.

Kuivila, K. and C. Foe. 1995. Concentration, transport and biological impact of dormant spray pesticides in the San Francisco Estuary, California. *Env. Tox. and Chem.* 14:1141-1150.

Menconi, M. and C. Cox. 1994. Hazard assessment report of the insecticide diazinon to aquatic organisms in the Sacramento-San Joaquin River System. California Department of Fish and Game. Environmental Services Division Administration report 94-2. 58 pp.

Reynolds, F.L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: A plan for action. State of California, the Resources Agency, Department of Fish and Game.

U.S. Department of Commerce. 1987. Census of Agriculture. Volume 1. Geographic area series. Bureau of Census, Wash. D.C.

U.S. EPA. 1989. Short term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. EPA -600/4-89/01.

U.S. Geological Survey. 1994. Water Resources Data California Water year 1994. Northern Central Valley Basin, and the Great Basin from Honey Lake Basin to Oregon State line. 431 pp.

Zaugg, S.D., M.K. Sandstrom, S.G. Smith, and K.M. Fehlberg. 1995. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory. --Determination of pesticides in water by C-18 solid phase extraction and capillary-column GC/MS with selected ion monitoring, U.S. Geological Survey Open File Report 95-181, 49p.

Tables

Table 1. Summary of stonefruit and almond acreage in the northern Sacramento River Valley. The data are from the U.S. Department of Commerce (1987).

	Orchards							
County	Almonds	Apples	Apricots	Peaches	Pears	Plums	Prunes	Sum of Orchards
Butte	37,870	150		2,118			10,071	50,209
Colusa	16,900						4,800	21,700
Glenn	14,659						7,229	21,888
Sutter	4,299	411	33	7,189	648	48	20,663	33,291
Tehama	6,928			69			8,660	15,657
Yolo	7,546		664	119	515		2,175	11,019
Yuba	1,840			3,834			11,934	17,608
Total	90,042	561	697	13,329	1,163	48	65,532	171,372

Table 2. Recovery and precision data from six determinations of compounds amended at 100 ng/L into laboratory water at the U.S. Geological Survey Central Laboratory (Zaugg et al. 1995).

Compound	Mean observed concentration (ng/L)	Mean recovery (%)	Preliminary estimated MDL (ng/L)
Alachlor	86	86	9
Atrazine	89	89	17
Chlorpyrifos	83	83	5
Cyanazine	96	96	13
Dacthal (DCPA)	82	82	4
Diazinon	77	77	8
EPTC	80	80	5
Ethafluralin	54	54	13
Ethoprop	80	80	12
HCH, alpha-	77	77	7
Malathion	90	90	14
Metolachlor	92	92	9
Metribuzin	42	42	12
Molinate	82	82	7
Napropamide	83	83	10
Parathion-methyl	73	73	35
Pendimethalin	46	46	18
Phorate	77	77	11
Prometon	77	77	8
Simazine	76	76	8
Tebuthiuron	88	88	15
Terbufos	74	74	12
Thiobencarb	85	85	8
Trifluralin	47	47	12
Atrazine, desethyl	12	12	3
Carbaryl	151	151	.046
Carbofuran	108	108	13
Terbacil	75	75	30
Dimethoate	11	11	.024

ng/L, nanogram per liter; MDL, method detection limit

10/11/99 Used 0.005 ppb MDL for pronamide.
Not listed in report + no response from C. Foe.
cm

Table 3. Recovery of insecticides spiked at 100 ng/L into organic free Sacramento River water (Crepeau et al. 1994)

Compound	Mean observed concentration (ng/L)	Mean recovery (%)	Modified estimated MDL (ng/L)
Carbofuran	82	82	44
Diazinon	74	74	38
Methidathion	75	75	31
Molinate	89	89	110
Simazine	74	74	60

ng/L, nanogram per liter; MDL, method detection limit

Table 4. Distance and estimated travel time of water to the City of Sacramento (Site 1) from all primary orchard sampling sites. Travel times are rounded to whole days (i.e. 12 - 36 hours = 1 day, 36 - 60 hours = 2 days). River velocities are from DWR (1962).

Location (Site #)	River miles above Sacramento	Velocity (mph)	Travel Time (Hours)	Travel Time (Days)
City of Colusa (7)	85	1.50	60	2
Colusa Drain (6)	30	1.25	24	1
Karnak (4)	21	1.25	17	1
Feather River (2)	20	1.25	16	1
City of Sacramento (1)	0	1.00	0	0

Table 5. Daily precipitation (inches) in Red Bluff, Colusa, Marysville, and Sacramento for January 1 through February 28, 1994 (Desert Research Institute, 1997).

Location	Date																													
Red Bluff	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January	0.21	0	0	0.11	0.01	0	0	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0.16	1.16	0.59	0.68	0.02	0	0	0	0	0
February	0	0	0	0	0	1.43	0.71	0.14	0	0.34	0	0	0	0	0	0	1.16	0	1.09	0.22	0.13	0	0	0	T	0.61	0	0			
Colusa																															
January	0	0.05	0	0.03	0.12	0	0	0.08	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.44	0.06	0.38	0.02	0	0	0	0
February	0	0	0	0	0	0.58	1.22	0.14	0	0.03	0.01	0	0	0	0	0	0.35	T	T	0.49	0	0	0	0	0	0.12	T	0			
Marysville																															
January	0	0	0	0.28	0.11	0	0	0	0.05	T	0	0	0	0	0	0	0	0	0	0	0	0	0.98	0.64	0.6	0.62	0	0	0	0	0
February	0	0	0	0	0	0.2	1.5	0.3	0	0.01	0.08	0	0	0	0	0	0.5	0.05	0	0.6	0.08	0	0	0	0	0.19	0.03	0			
Sacramento																															
January	T	0	T	0.06	0	0	0	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.47	0.79	0.43	0	0	0	0	0	0
February	0	0	0	0	T	0.82	0.67	0.23	0	0.03	0	0	0	0	0	0.09	0.54	0.01	0.54	0	0.03	0	0	0	0	0.19	0	0			

T = Trace

Table 6. Summary of the number of days that the California DFG water quality criteria for protection of freshwater aquatic life were exceeded in the Sacramento Basin during the 1994 orchard dormant spray season. DFG recommends that the acute criterion may be exceeded for one hour and the chronic one for up to 4 days once every three years without causing ecological damage.

Location	First Storm (days)		Second Storm (days)		Third Storm (days)		All Storms (days)	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
Sacramento R. @ Sacramento	5	11	4	6	0	2	9	19
Sacramento R. @ Colusa	1	5	2	6	1	1	4	12
Feather R. @ Yuba City	4	5	2	4	0	0	6	9
Feather R. HWY 99	4	8	2	7	0	0	6	15
Sacramento Sl. @ Pass Road	5	5	7	8	5	6	17	19
Sacramento Sl. @ Karnak	7	8	8	8	5	7	20	23
Colusa Drain	1	5	5	5	2	7	8	17

Table 7. Diazinon concentration and loads in the upper Sacramento River Basin during the third storm of 1994. The distance (miles) and travel time (days) between each site and the City of Colusa are indicated in the last two rows. Blanks indicate that no sample was collected.

	Diazinon concentration (ng/L) / diazinon load (kg/day)							
Date	Bend	Red Bluff	Tehama	Vina	Hamilton	Ord Bend	Butte City	Colusa
17 Feb	<30[1]/	80/1.8	120/	168/4.5	50/	<30/		17/0.3
18 Feb	<30/		50/	120/4.3	134/	90/3.5	110/4.1	41/4.6
19 Feb			<30/	<30/	30/	36/1.1		40/1.4
20 Feb	<30/							33/1.1
21 Feb			<30/	65/2.3	70/	100/4.4		105/5.4
Distance (miles)	114	101	85	74	55	40	25	0
Travel time (days)[2]	2	1	1	1	1	1	0	0

[1]ELISA detection limit.

[2]Assumes a travel velocity of 3.0 miles per hour (Department of Water Resources, 1962).

Figures

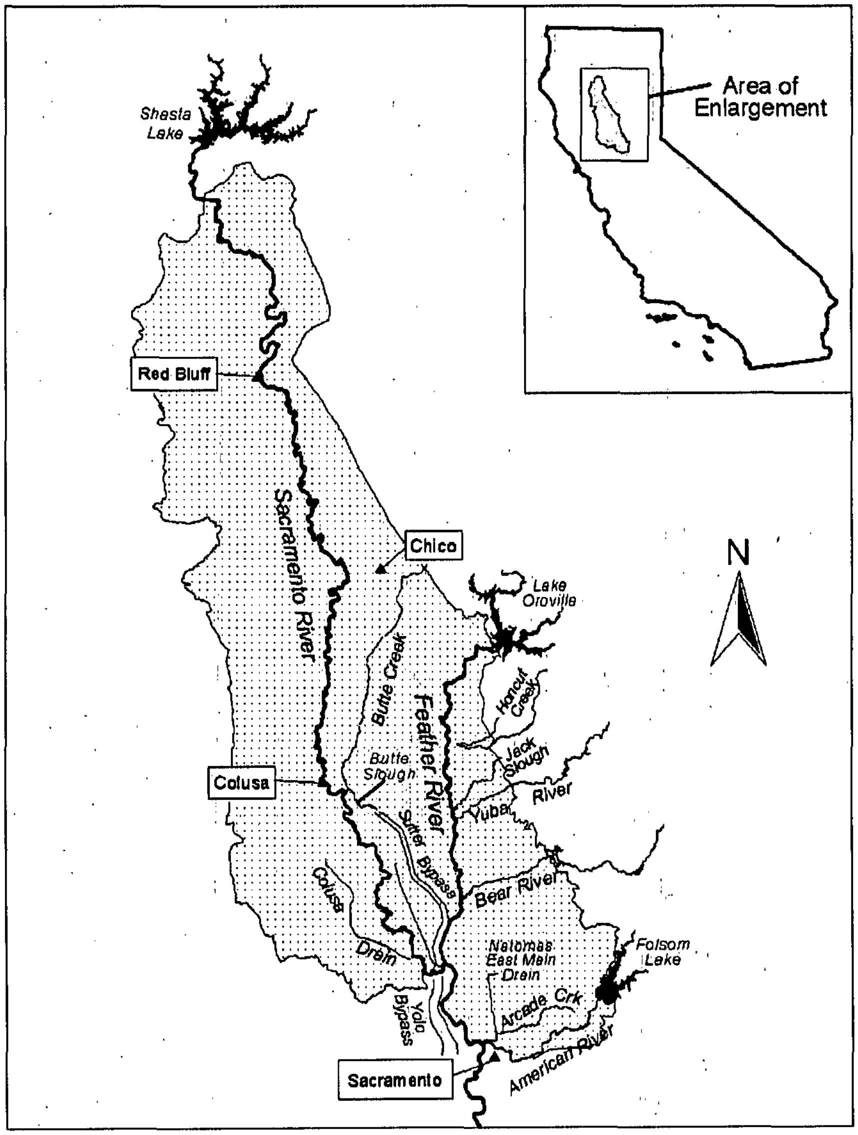


Figure 2.1. The Sacramento Valley

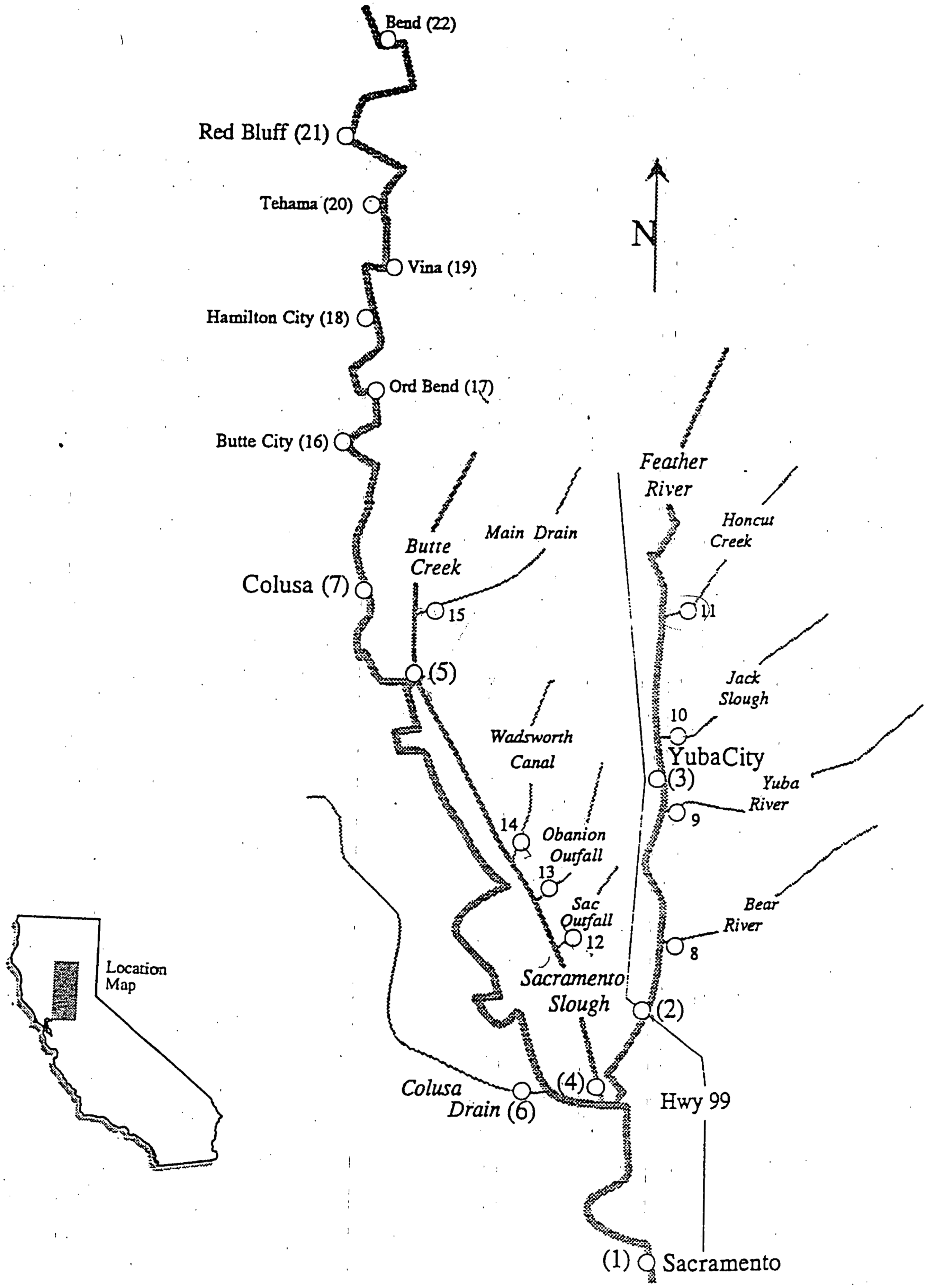


Figure 1. Map of sampling sites (not to scale). Primary sites are numbered 1 through 7, secondary sites are numbered 8 through 22. See text for description of the sampling strategy.

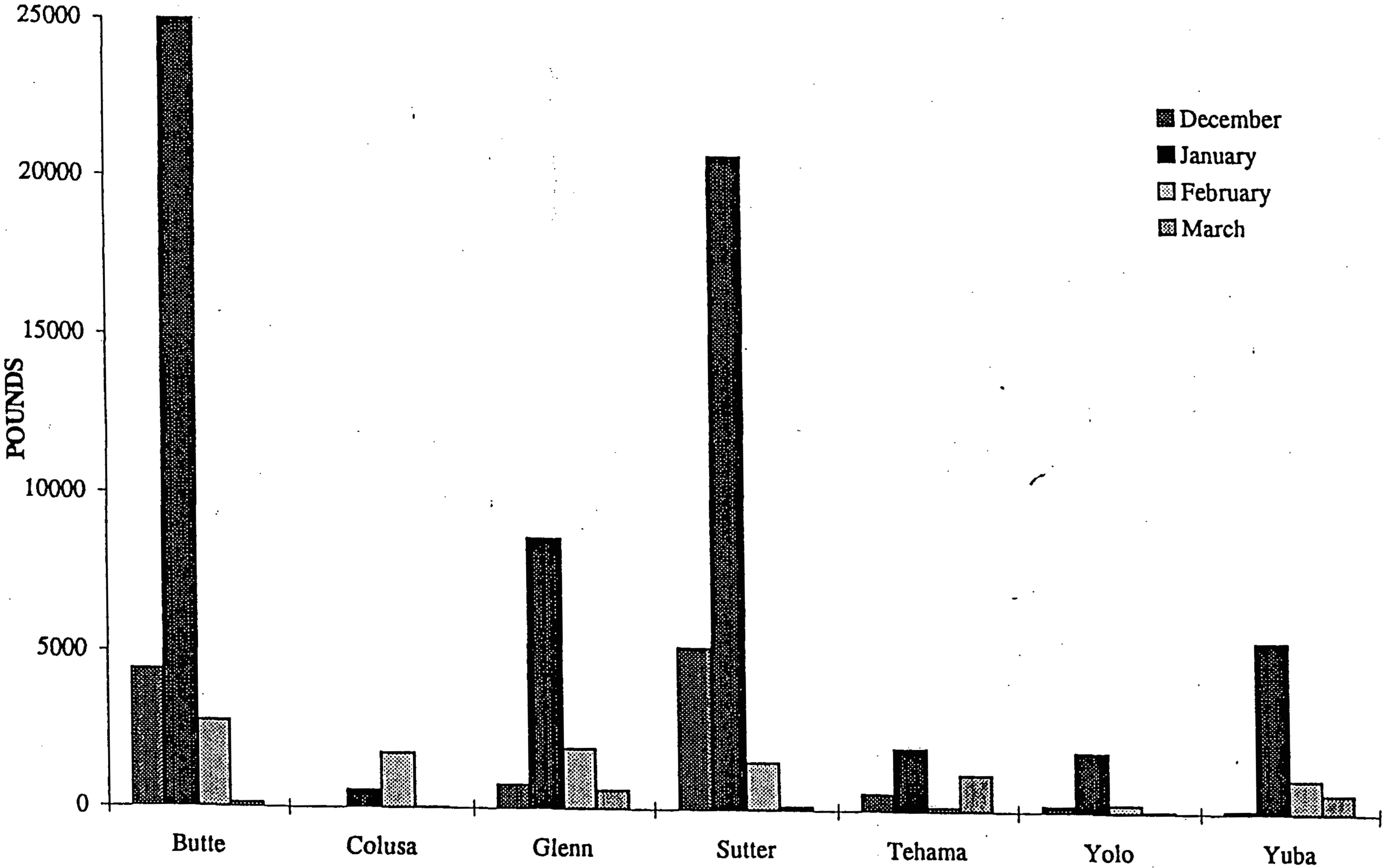


Figure 2. Summary of diazinon use on stonefruit and almond orchards in 1993 - 94. Data from the Department of Pesticide Regulation (1997).

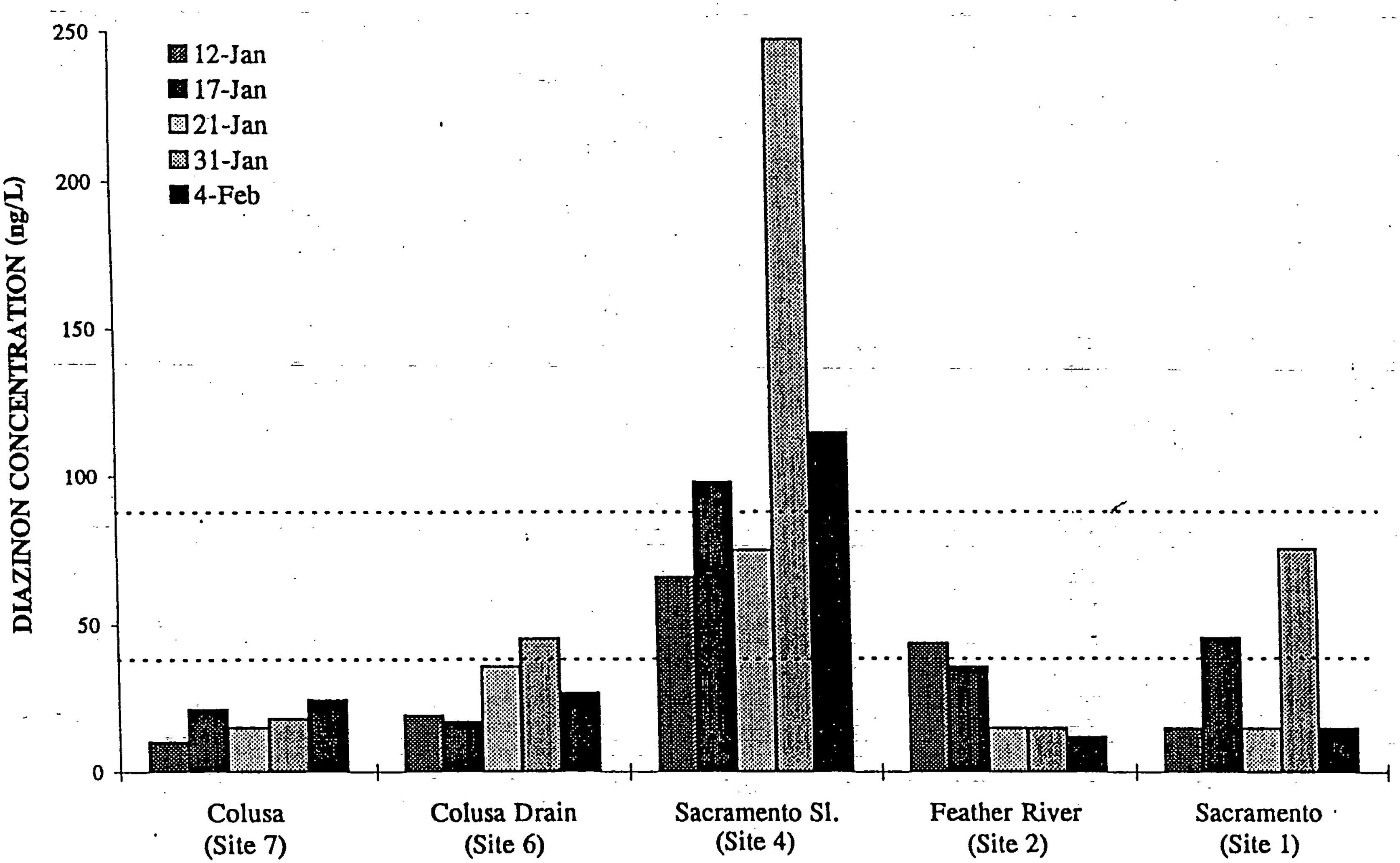


Figure 3. Diazinon concentrations (ng/L) in the Sacramento River at Sacramento and in principal tributaries draining orchard areas during dry weather in 1994. The two horizontal lines at 40 and 80 ng/L are the California DFG acute and chronic water quality criteria for protecting aquatic life.

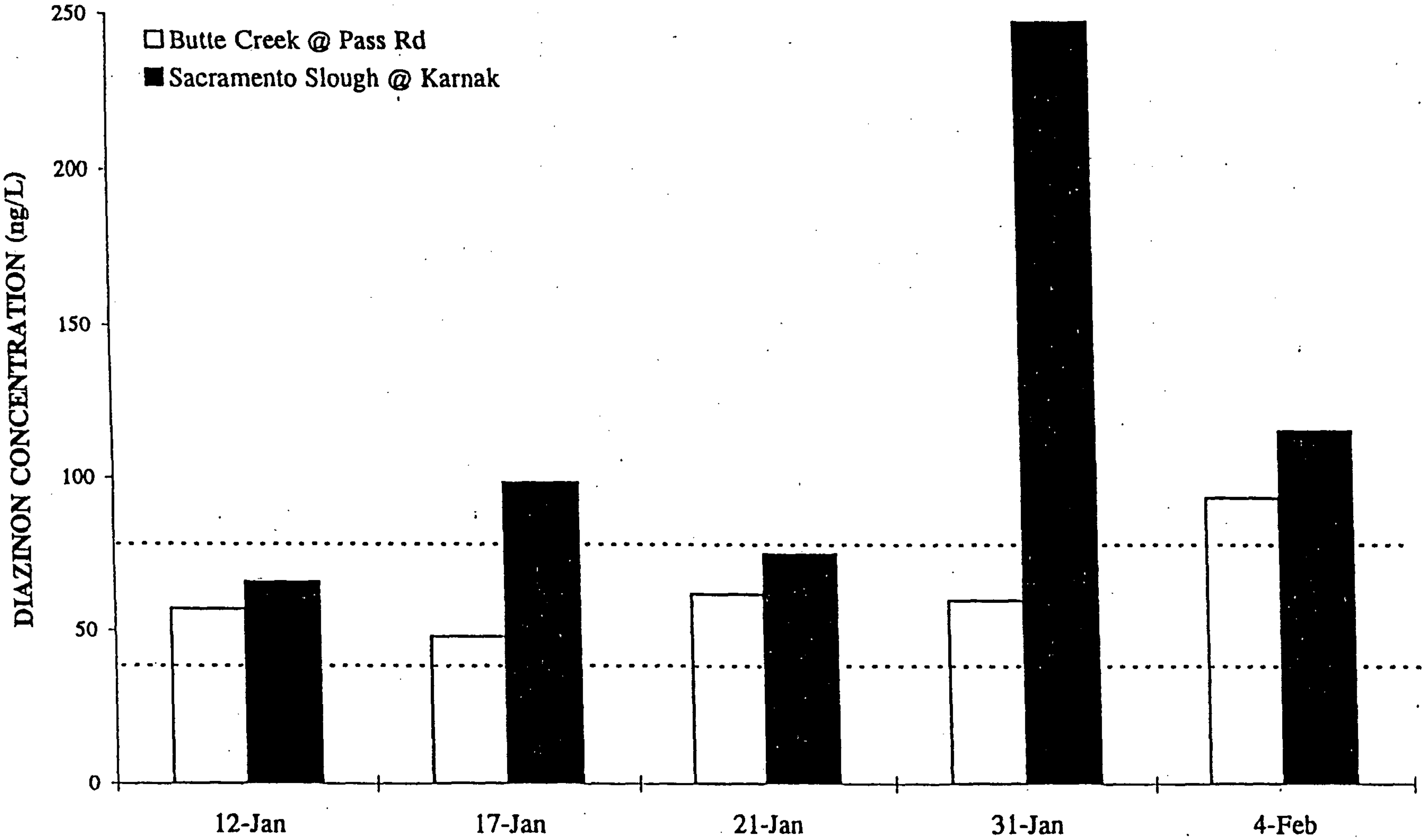


Figure 4. Comparison of diazinon concentrations at Karnak on Sacramento Slough (Site 4) and 36 miles upstream at Pass Rd. (Site 5) during dry weather. The two horizontal lines at 40 and 80 ng/L are the DFG acute and chronic water quality criteria for protecting aquatic life.

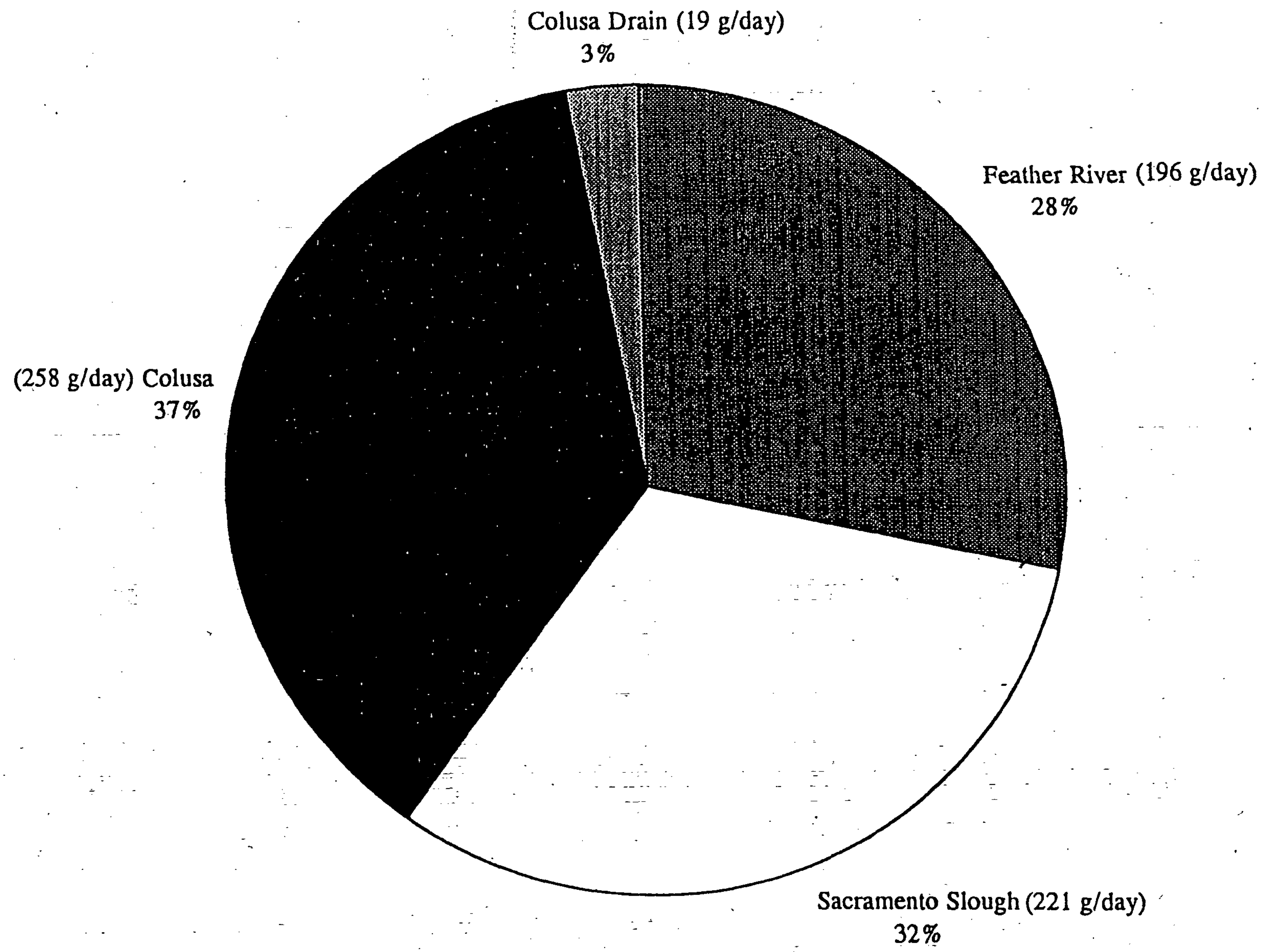


Figure 5. Average percent contribution of diazinon to the Sacramento River at the City of Sacramento from principal waterways draining orchard areas during winter dry weather periods.

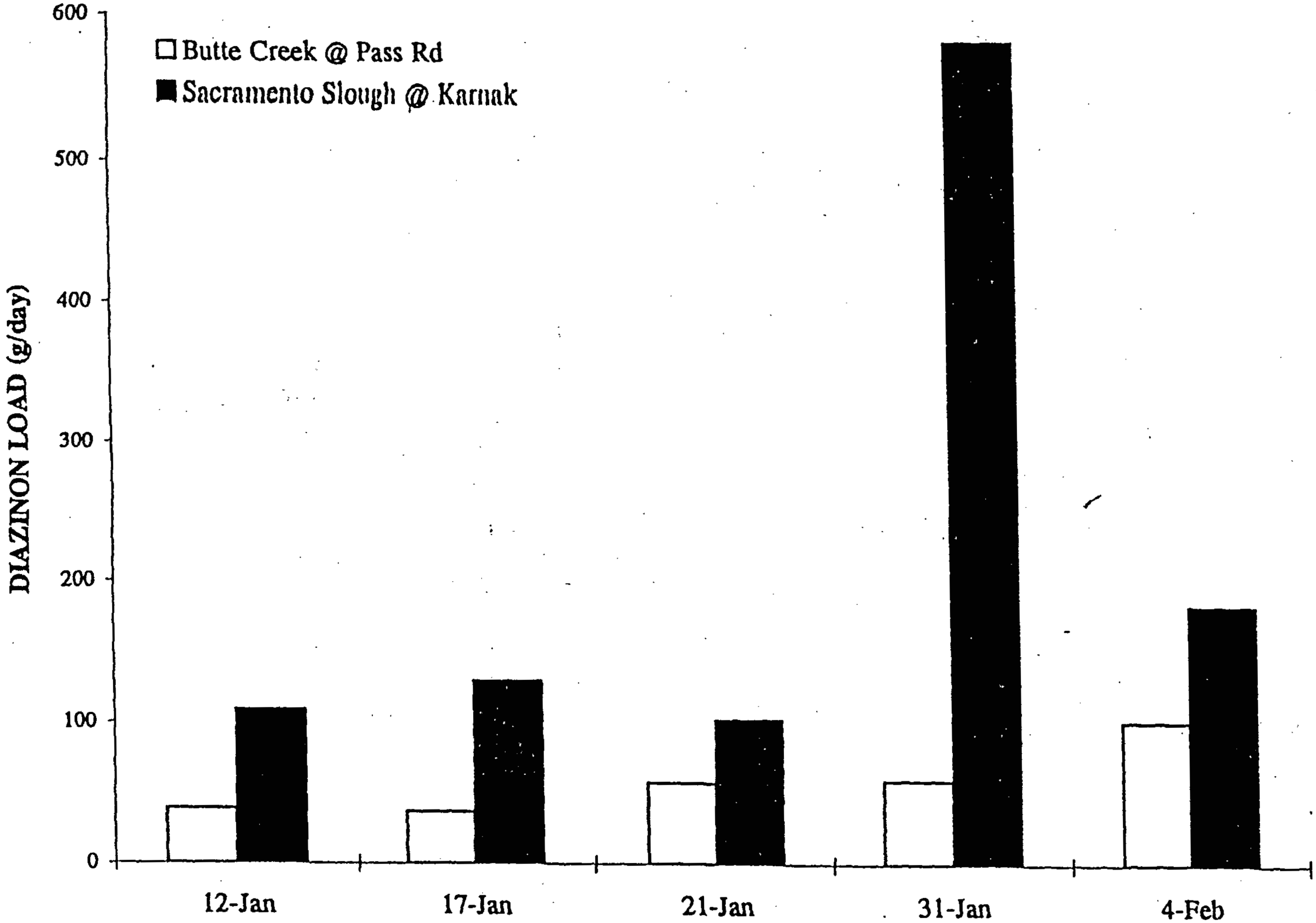


Figure 6. Comparison of diazinon loads (g/day) during dry weather at Karnak on Sacramento Slough (Site 4) and 36 miles upstream on Butte Creek at Pass Rd. (Site 5).

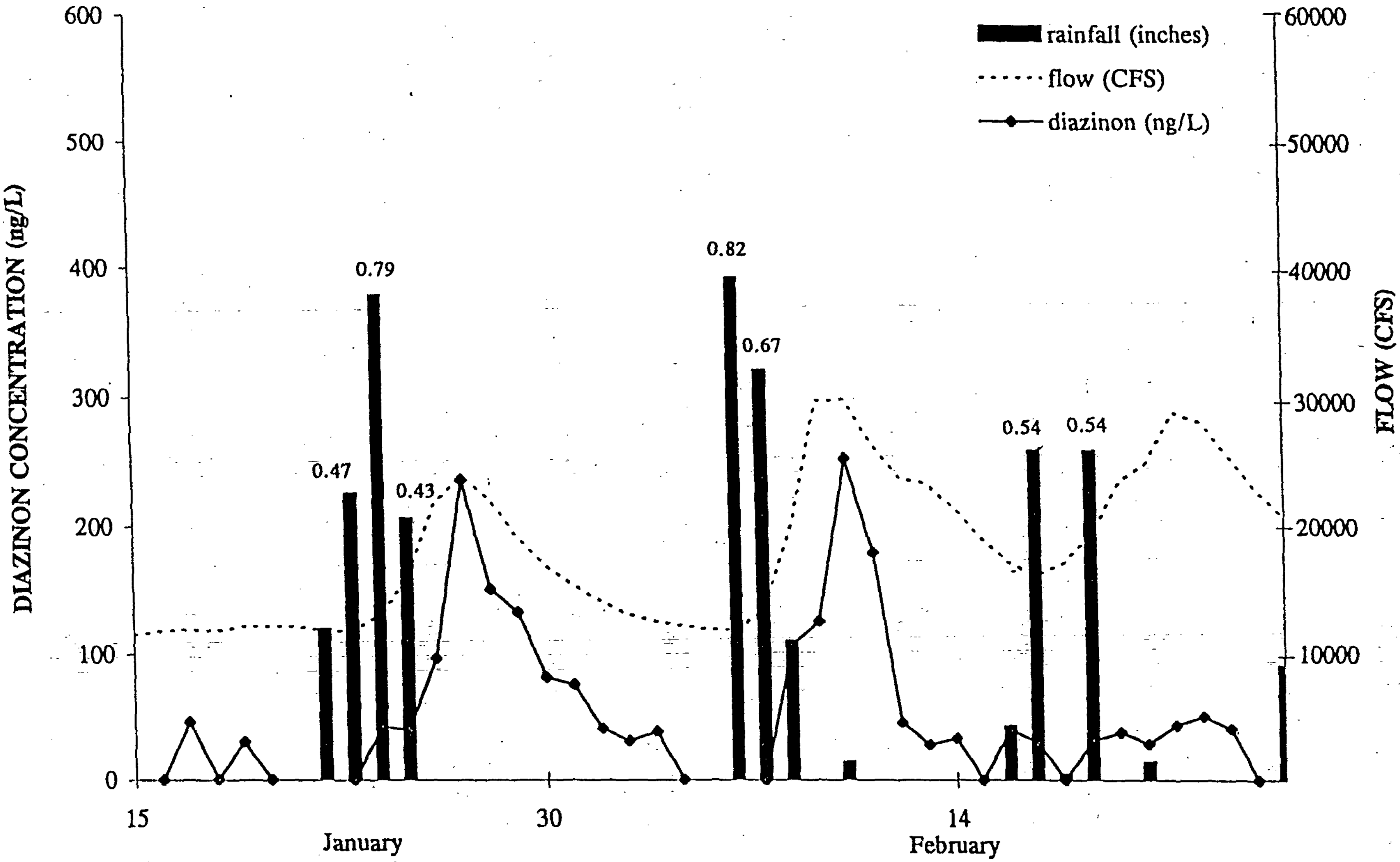


Figure 7. Rainfall (inches), flow (CFS), and diazinon concentration (ng/L) for the Sacramento River at Sacramento in January and February 1994.

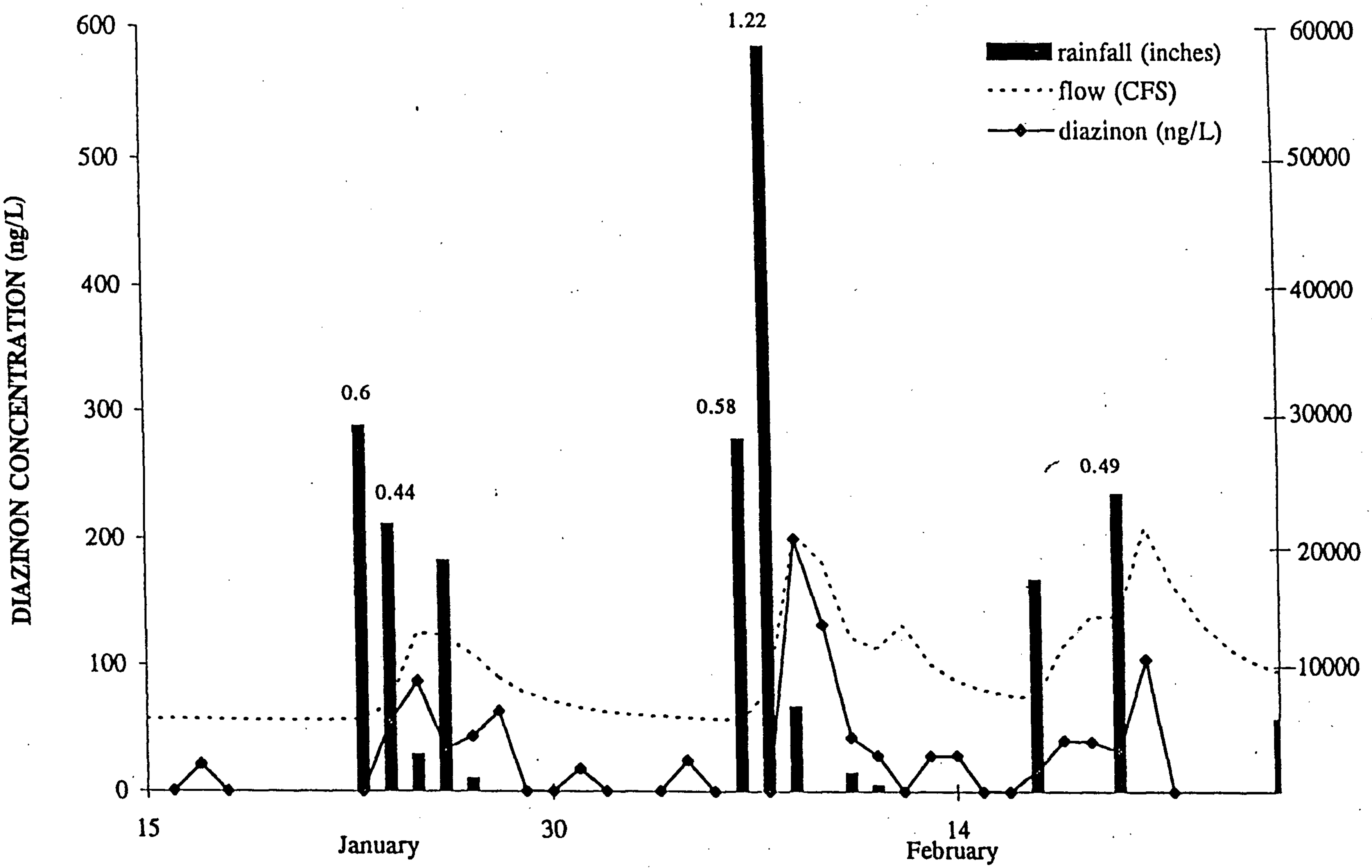


Figure 8. Rainfall (inches), flow (CFS), and diazinon concentration (ng/L) for the Sacramento River at Colusa in January and February 1994.

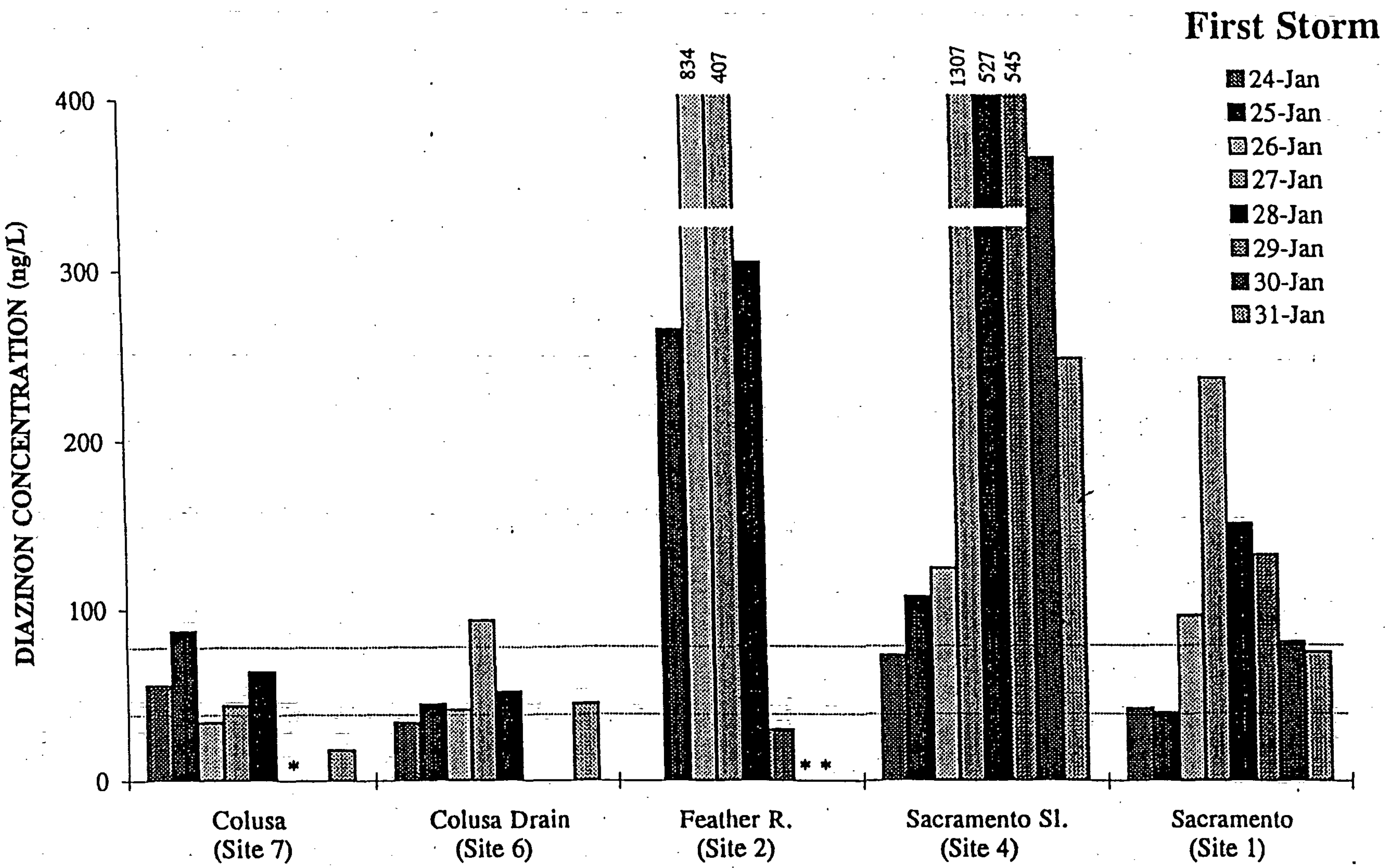


Figure 9. Diazinon concentration (ng/L) in the Sacramento River and in the principal orchard tributaries between the Colusa and Sacramento for the first storm (Janµary 24 - 28). Upstream sites are listed to the left. The two horizontal lines at 40 and 80 ng/L are the DFG acute and chronic diazinon water quality criteria for protecting aquatic life. Blanks indicate absence of data. Astericks are for values less than the ELISA detection limit (30 ng/L).

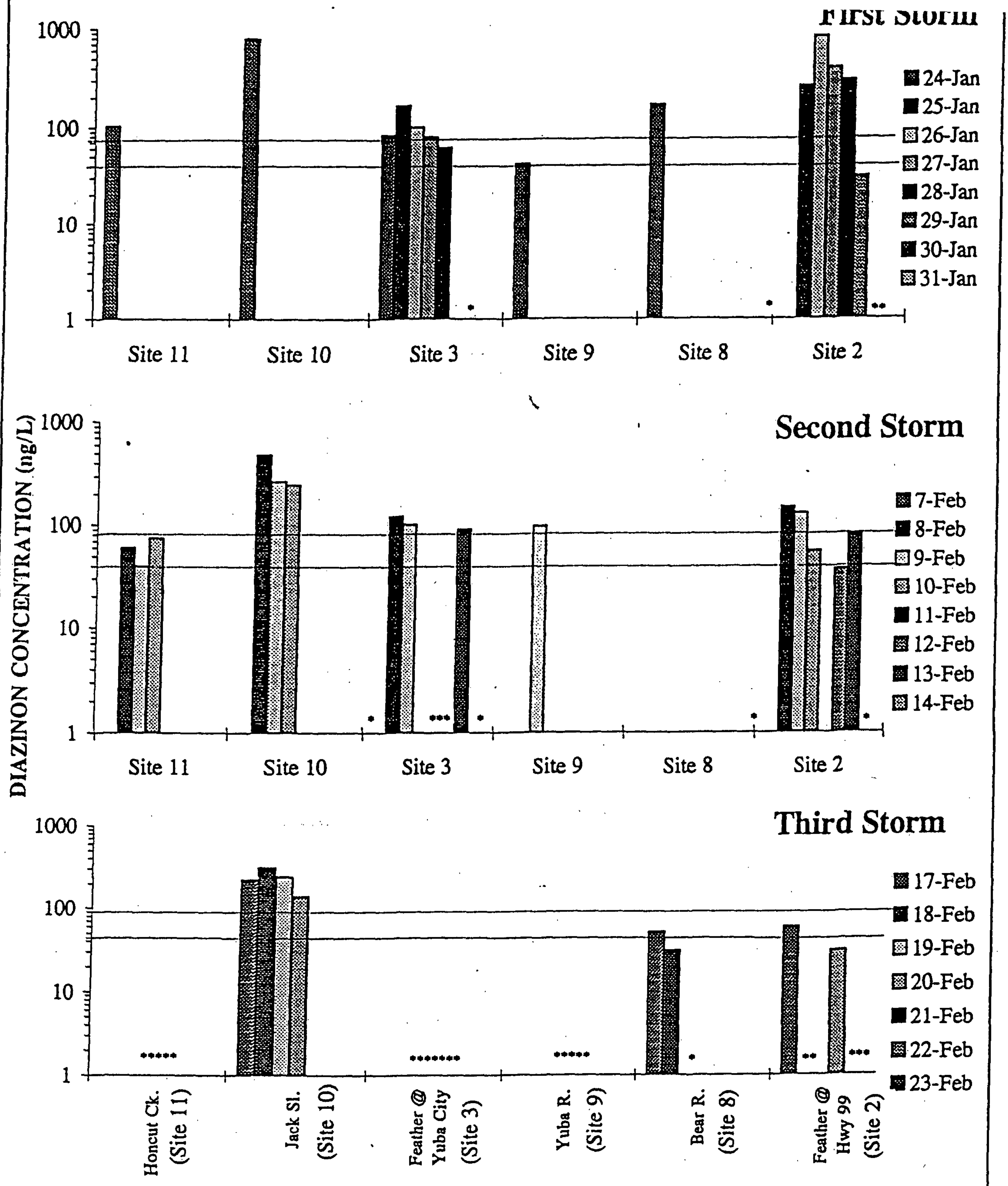


Figure 10. Diazinon concentration in Feather River watershed during each of three storms. Downstream sites are listed to the right. The two horizontal lines at 40 and 80 ng/L are the DFG acute and chronic diazinon water quality criteria for protecting aquatic life. Blanks indicate absence of data. Astericks indicate that diazinon concentration were below the ELISA detection limit (30 ng/L). Note that diazinon concentrations are on a log scale. See Figure 1 for site locations.

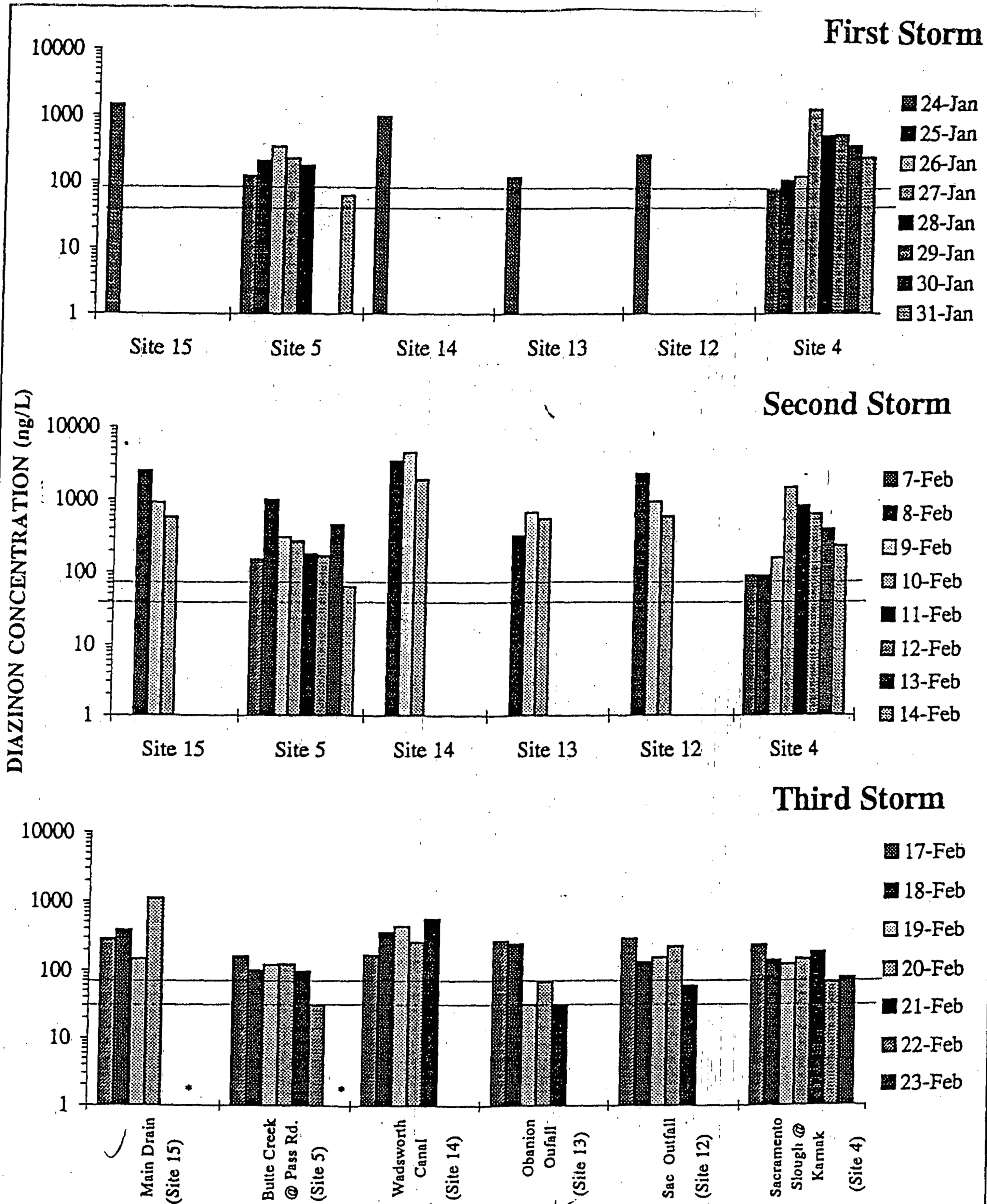


Figure 11. Diazinon concentration in Butte Creek, Sacramento Slough, and their tributaries during each of three storms. Downstream sites are listed to the right. The two horizontal lines at 40 and 80 ng/L are the DFG acute and chronic diazinon water quality criteria for protecting aquatic life. Blanks indicate absence of data. Astericks indicate that diazinon concentration were below the ELISA detection limit (30 ng/L). Note that diazinon concentrations are on a log scale. See Figure 1 for site locations.

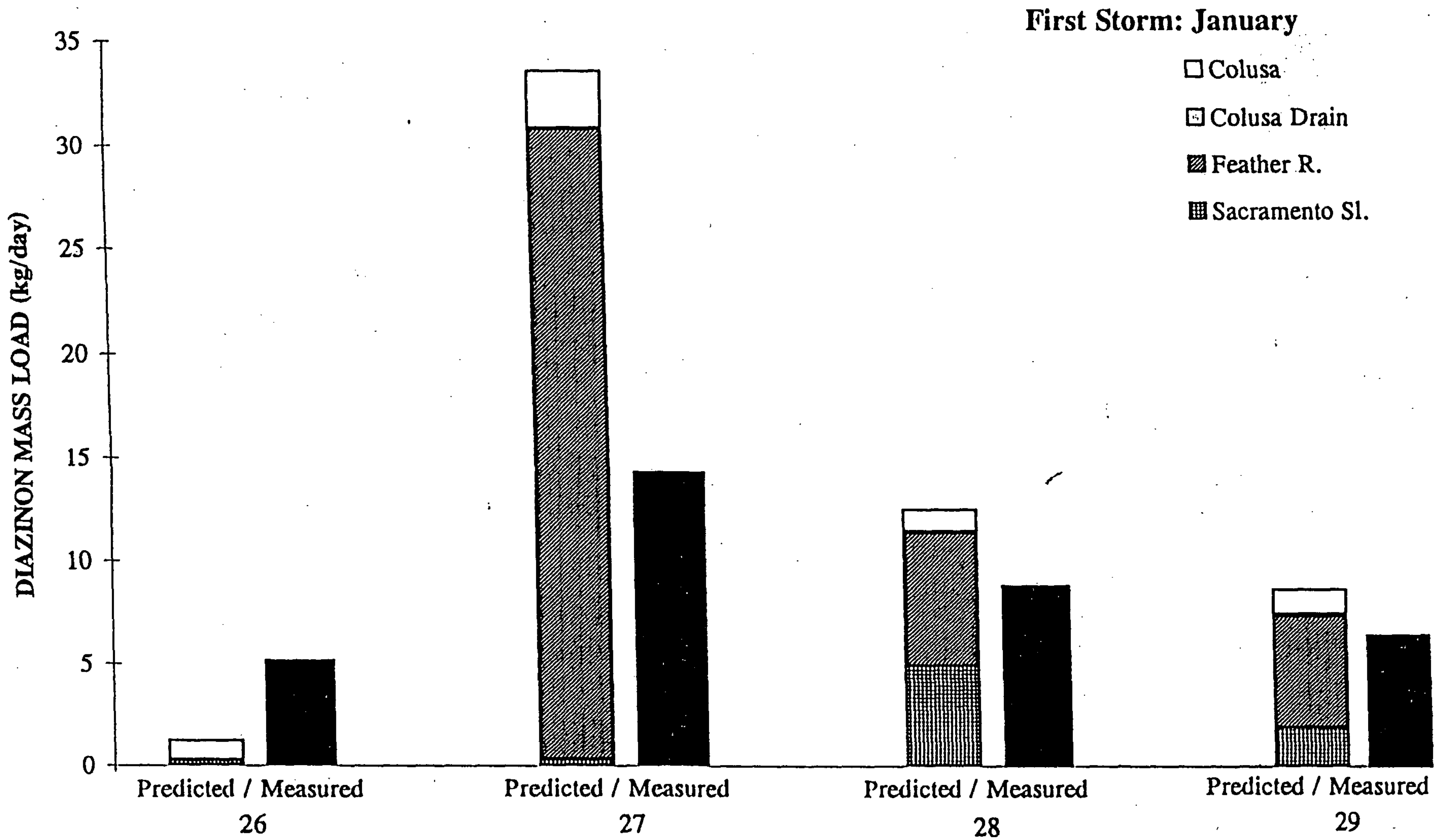


Figure 12. Predicted and measured diazinon mass load (kg/day) in the Sacramento River at Sacramento during January 24 to 28 rainfall event. Predicted values were estimated by summing the mass load from tributaries after accounting for travel times. Travel time estimates are presented in Table 4.

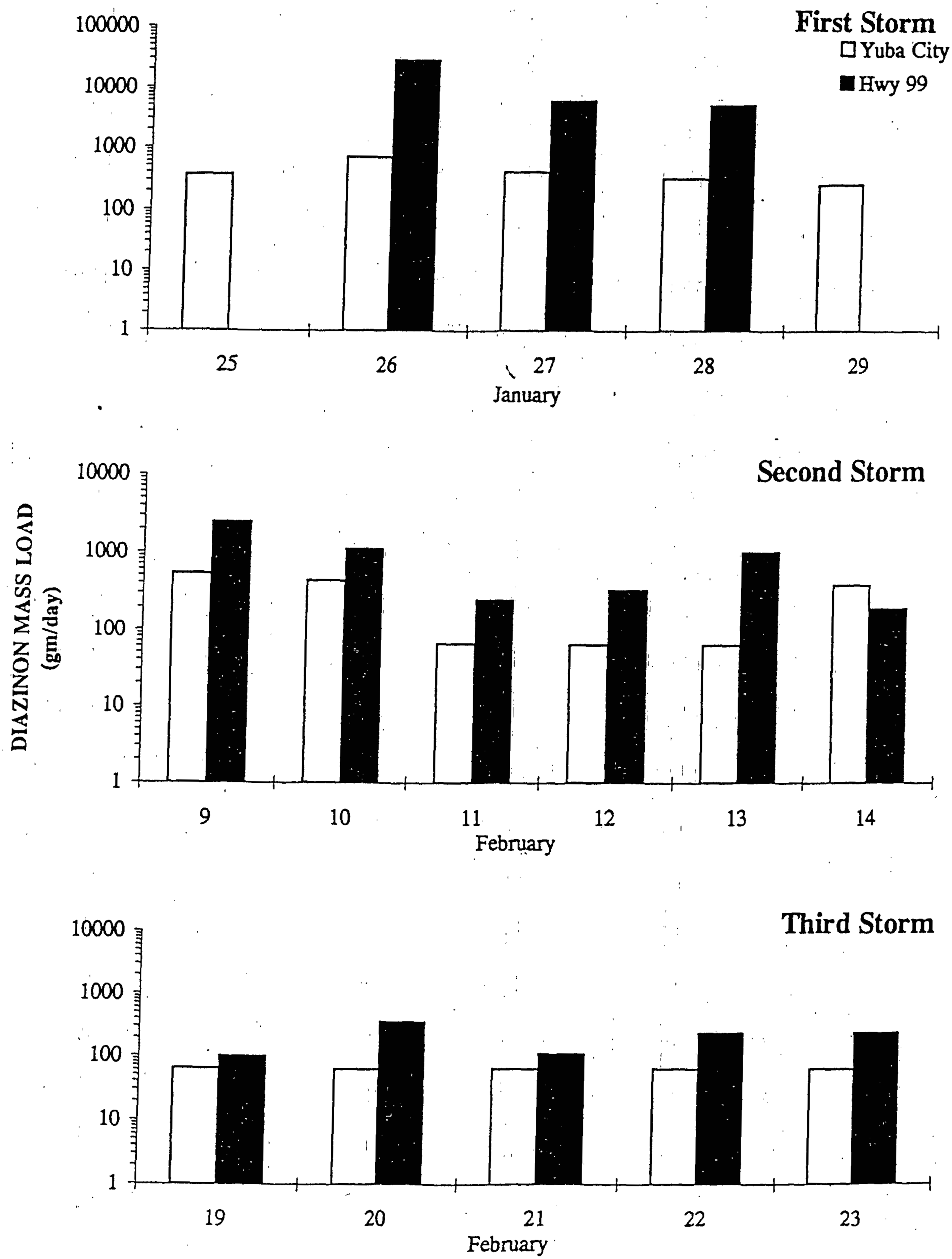


Figure 13. Comparison of Feather River diazinon loads at Yuba City and at Hwy 99 for each of three storms. The load estimate at Yuba City was lagged by a day to account for the travel time between the two locations. Note that diazinon loads are on a log scale.

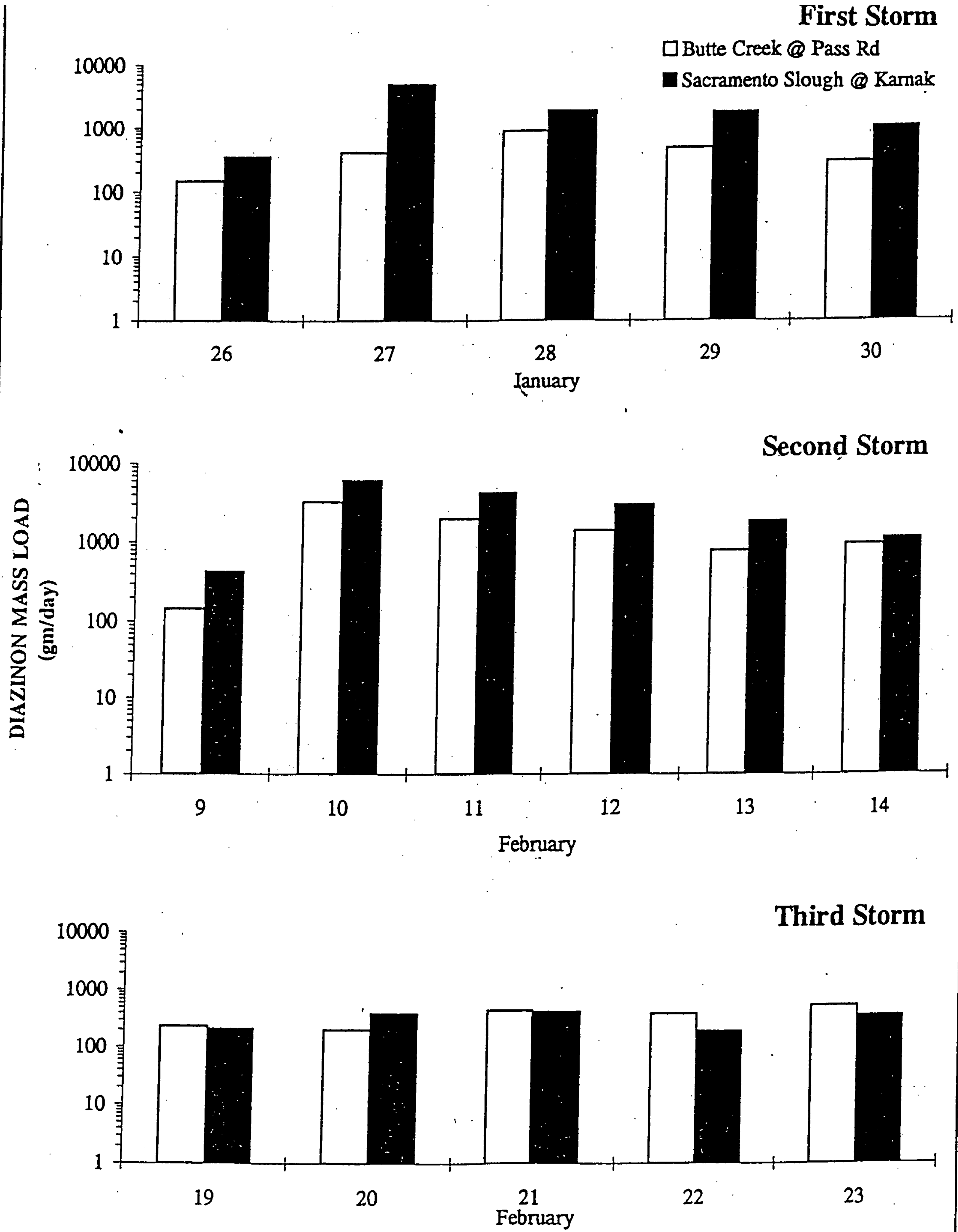


Figure 14. Comparison of diazinon loads at Pass Road and at Karnak in Sacramento Slough for each of three storms. The load estimate for Pass Road was lagged by two days to account for travel time between sites. Note that diazinon loads are on log scale.

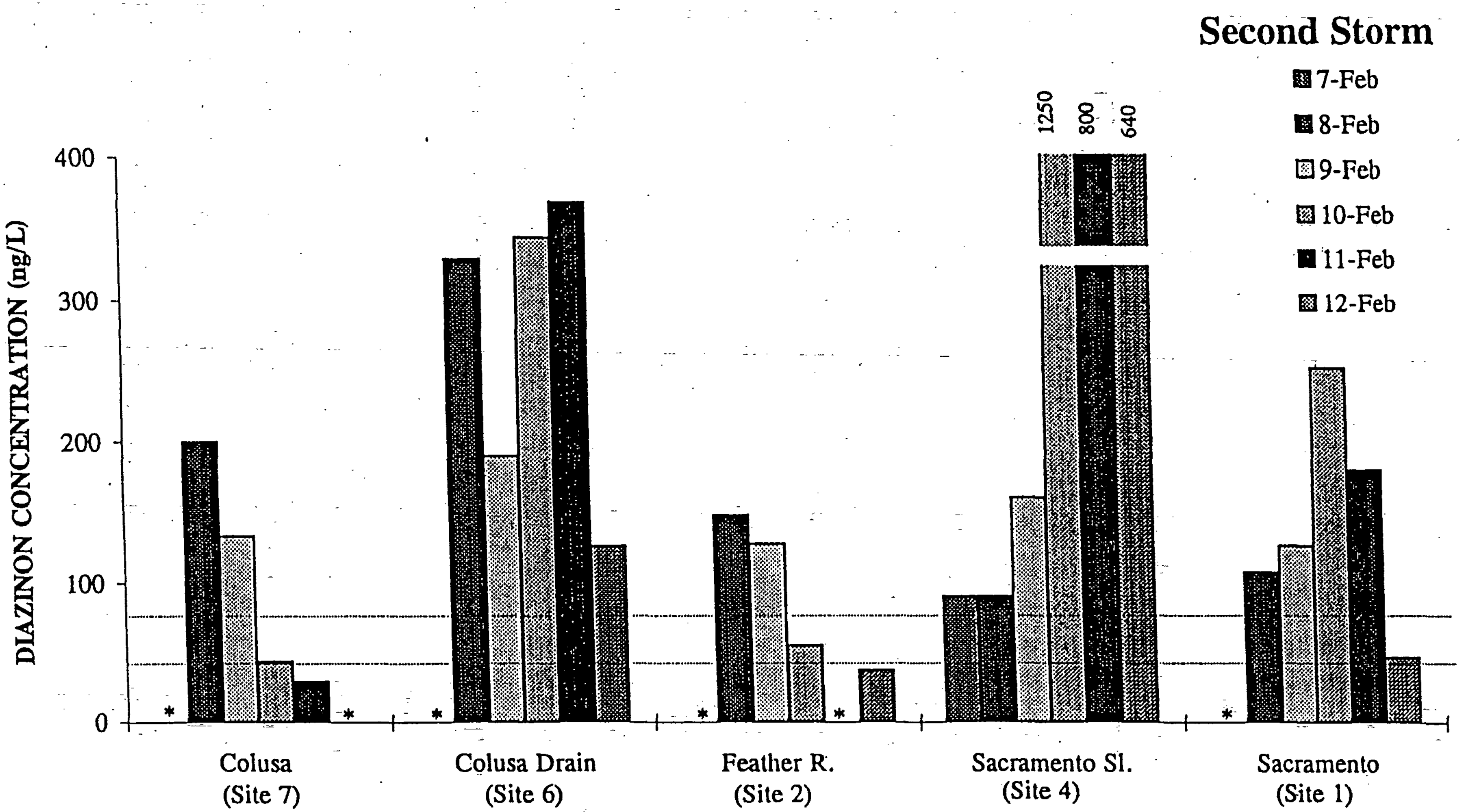


Figure 15. Diazinon concentration (ng/L) in the Sacramento River and in the principal orchard tributaries between Cities of Colusa and Sacramento for the second storm (February 6 to 11). Upstream sites are listed to the left. The two horizontal lines at 40 and 80 ng/L are the DFG acute and chronic diazinon water quality criteria for protecting aquatic life. Blanks indicate absence of data. Astericks are for values less than the ELISA detection limit (30 ng/L).

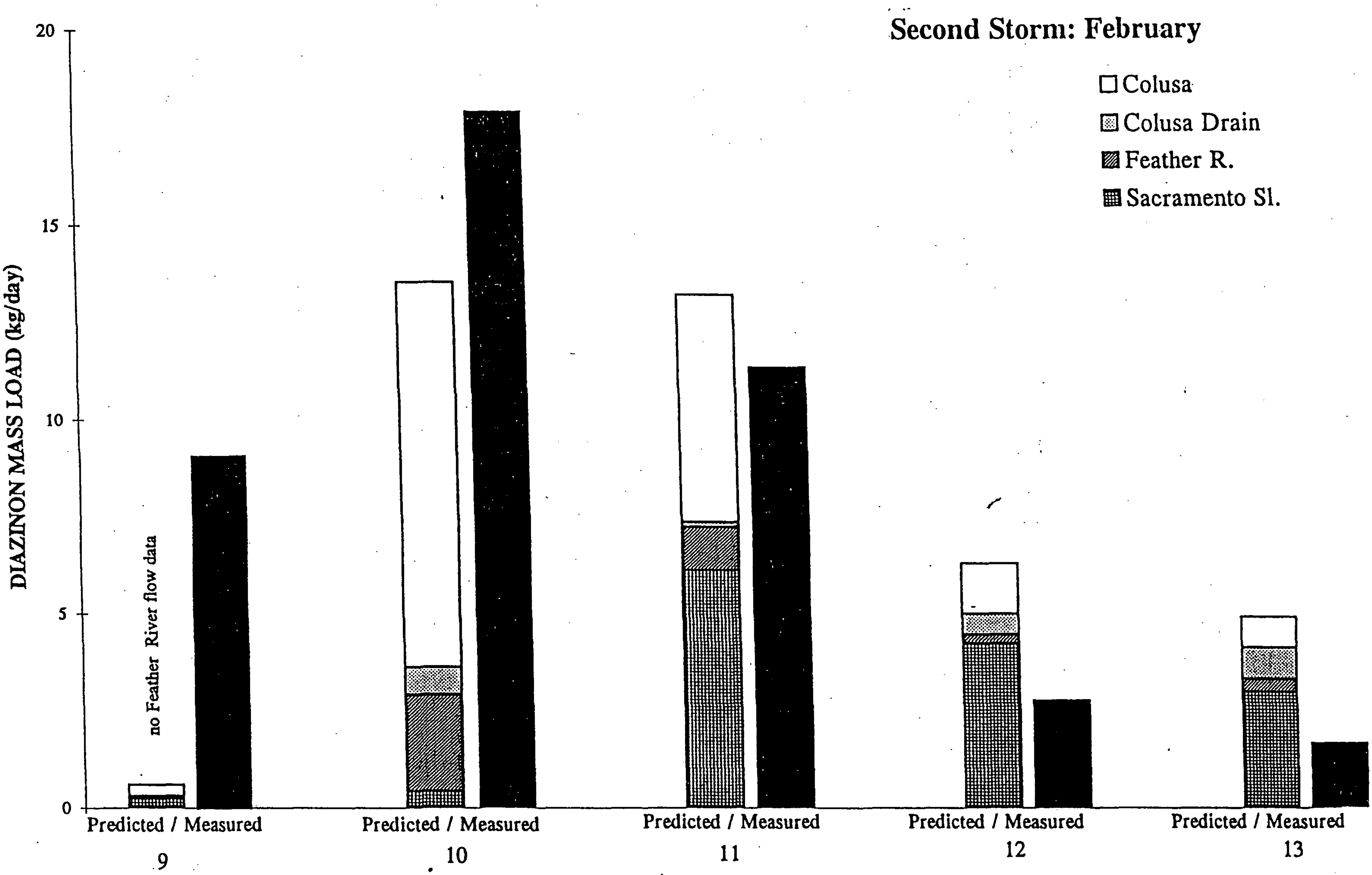


Figure 16. Predicted and measured diazinon mass load (kg/day) in Sacramento River at Sacramento during 9 to 13 February. Predicted values were estimated by summing the mass load from tributaries after accounting for travel times. Travel time estimates are presented in Table 4. The results suggest that the major source of diazinon in the Sacramento River at Sacramento originated from both Sacramento Slough and above Colusa. Flow data were not available for Feather River on 9 February.

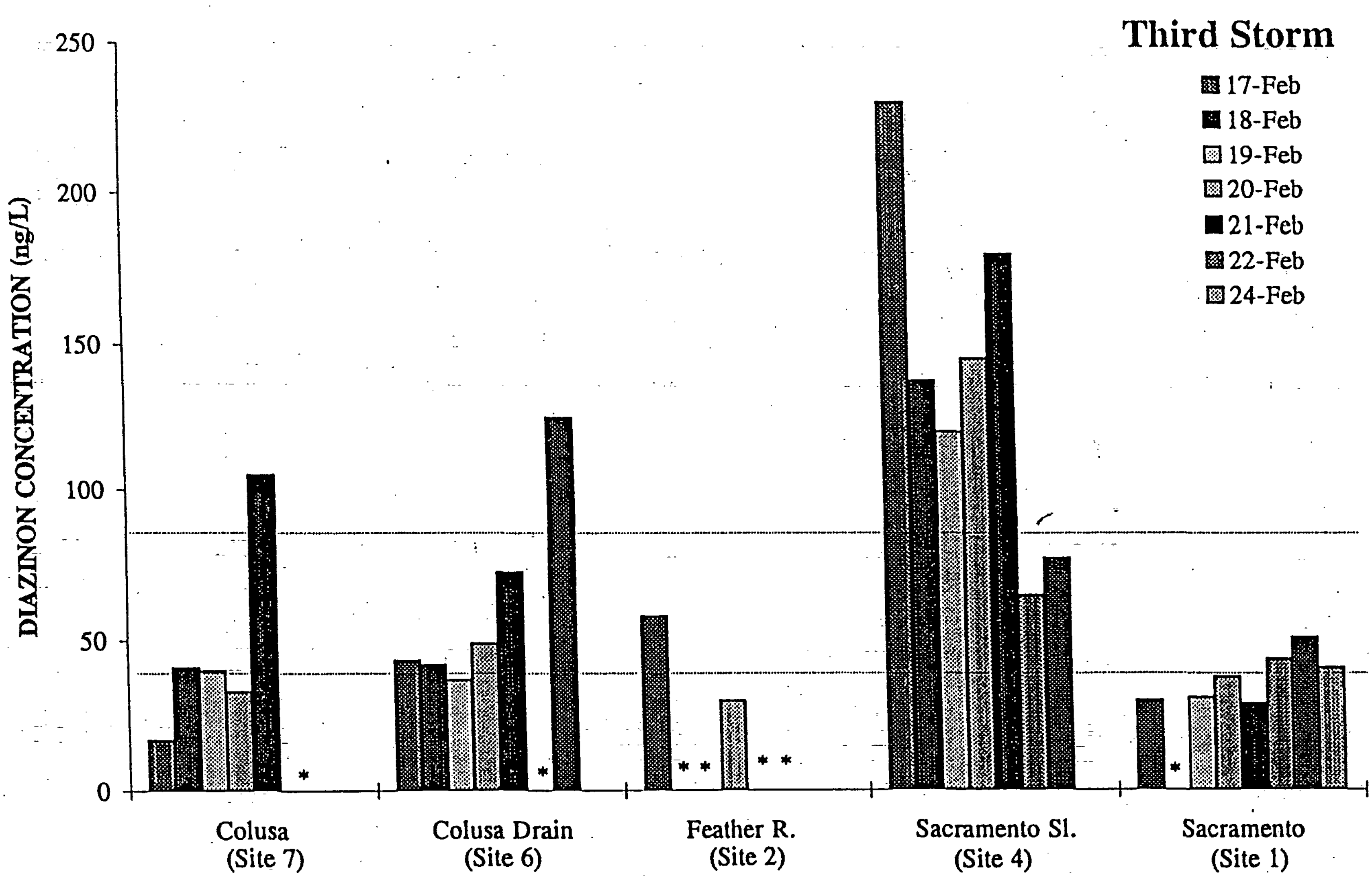


Figure 17. Diazinon concentrationS (ng/L) in the Sacramento River and principal orchard tributaries between Colusa and Sacramento for the third storm (February 17 to 24). Upstream sites are listed to the left. The two horizontal lines at 40 and 80 ng/L are the DFG acute and chronic diazinon water quality criteria for protecting aquatic life. Blanks indicate absence of data. Astericks are for values less than the ELISA detection limit (30 ng/L).

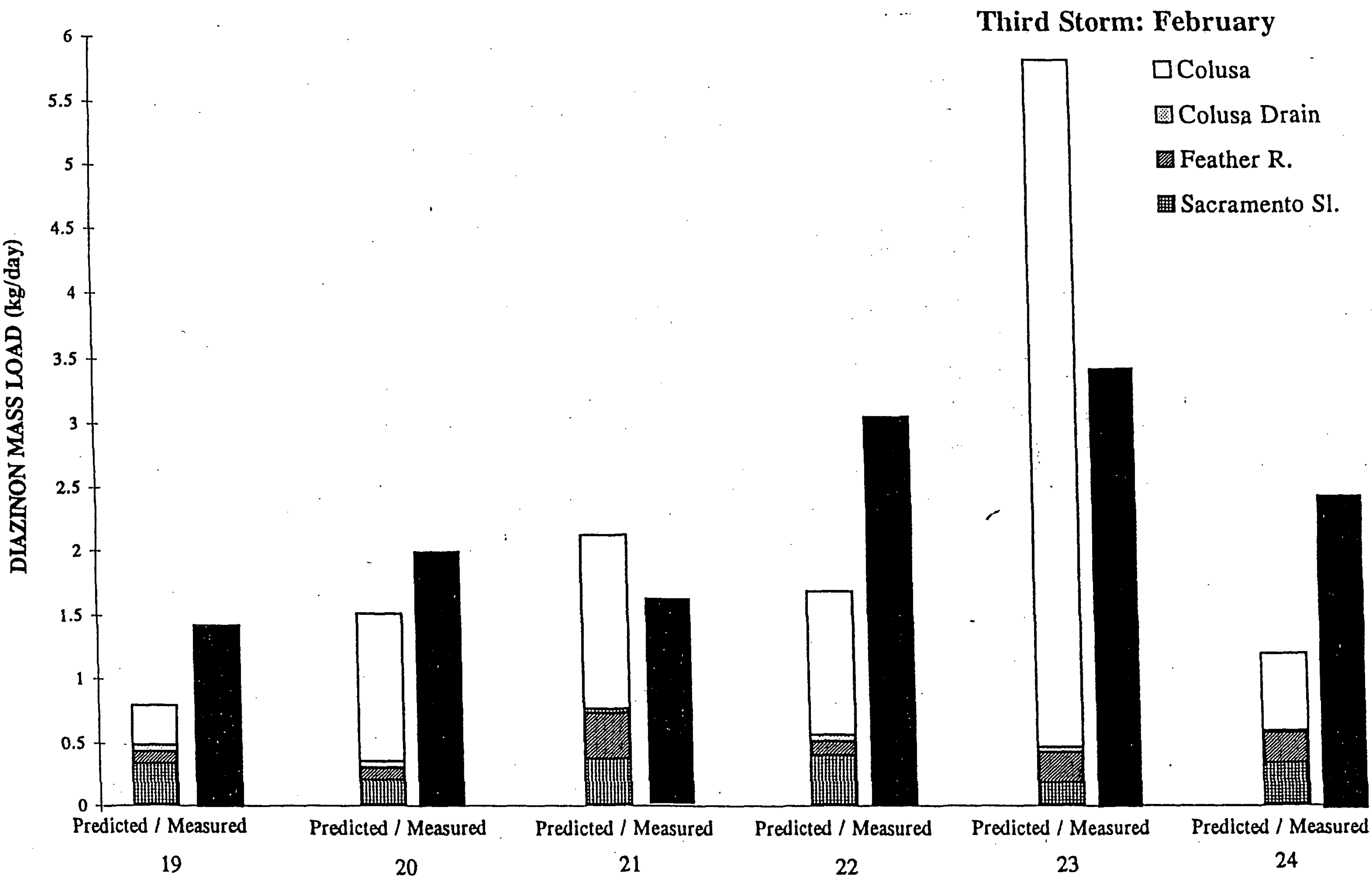


Figure 18. Predicted and measured diazinon mass load (kg/day) in Sacramento River at Sacramento during 19 to 24 February. Predicted values were estimated by summing the mass load from tributaries after accounting for travel times. Travel time estimates are presented in Table 4. The results suggest that the largest source of diazinon in the Sacramento River at Sacramento was from above Colusa.

Appendix A: Description of Sampling Locations

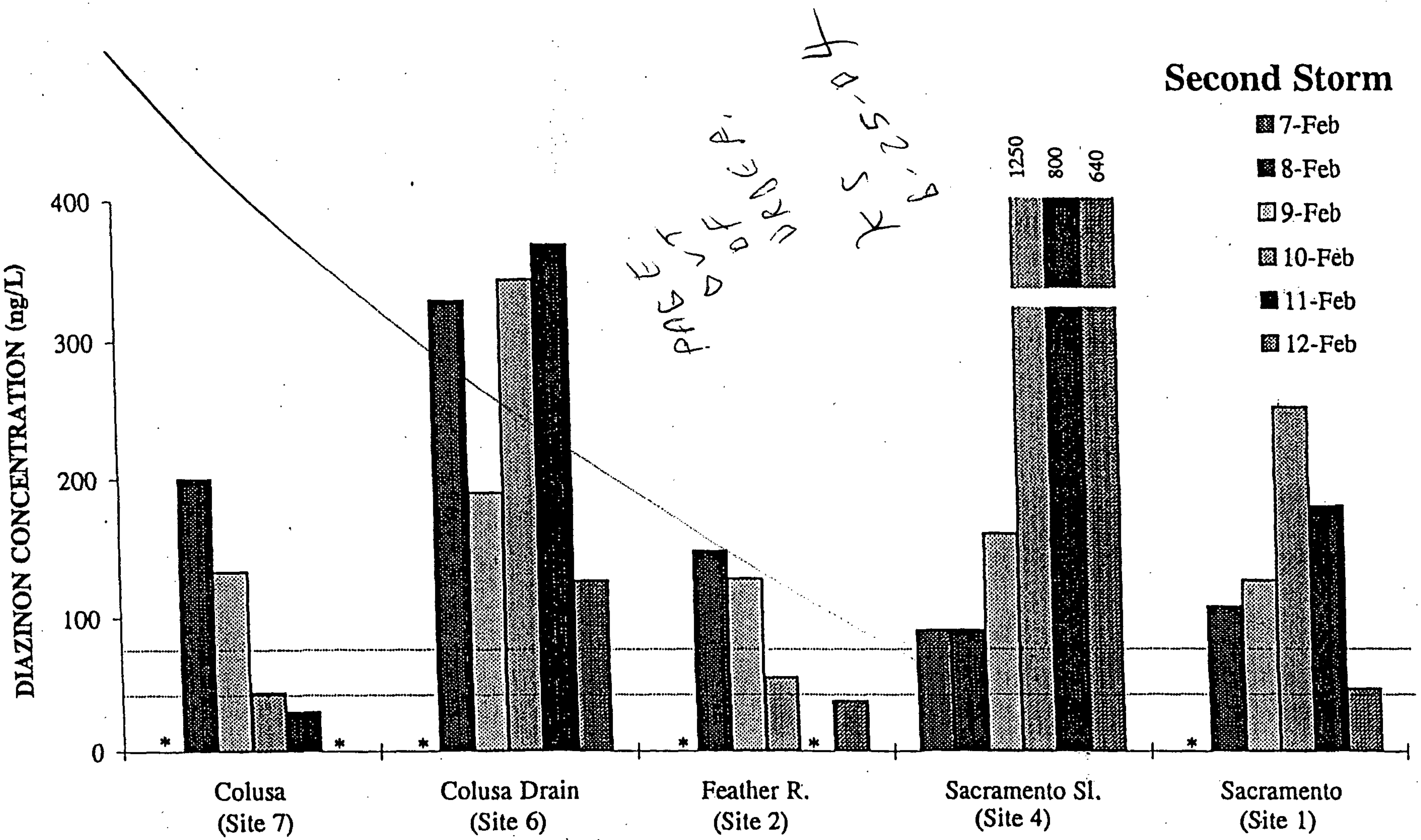


Figure 15. Diazinon concentration (ng/L) in the Sacramento River and in the principal orchard tributaries between Cities of Colusa and Sacramento for the second storm (February 6 to 11). Upstream sites are listed to the left. The two horizontal lines at 40 and 80 ng/L are the DFG acute and chronic diazinon water quality criteria for protecting aquatic life. Blanks indicate absence of data. Astericks are for values less than the ELISA detection limit (30 ng/L).

digitize I Street Bridge & Tower Bridge

Table 1. Primary sampling sites, description of their location, and rationale for selection.

Site No.	Location	Sampling Site Description	Sampling Rationale
site [illegible] 3414 (1)	Sacramento R. @ City of Sacramento 34M09N04E35 [illegible] section?	Tower Bridge at Capitol Mall I St. 34M09N04E35	Integrates all inputs from the Sacramento Basin.
on list 2	Feather R. @ Hwy 99 near Nicolaus 51M12N03E14	Hwy 99 Bridge	Integrates all upstream inputs to Feather River.
3	Feather R. @ Yuba City 58M15N03E23	West bank below Hwy 20 Bridge	Integrates all inputs from upper Feather River Basin except Jack Slough. Source of Yuba City drinking water.
on list 4 [illegible]	Sacramento Sl. @ Karnak 51M11N03E20	Bridge off Ely Rd.	Integrates all exports from Butte Slough.
(5)	Butte Creek @ Pass Rd (Slough Lower) 51M16N01E31	Pass Road Bridge	Inputs from Chico area carried down Butte Creek.
on list 6	Colusa Drain @ Knights Landing 38°48'45" 121°46'23" 57M11N02E08	Road 99 E Bridge	Inputs from orchards along Coastal range draining to Colusa Drain
(7)	Sacramento R. @ City of Colusa 39°12'51" 121°59'57" 06M16N01W29	Bridge on River Road at City of Colusa	Inputs from all orchards located along the upper River above Colusa including inputs from the Chico area.

Table 2. Secondary sampling sites.

Site No.	Location	Tributary to:
8	Placer Co? 13N 05E 03 Bear River @ Berry Rd.	Feather River
9	Yuba River @ Marysville USGS 39°08'40" 121°34'35"	Feather River
10	Jack Sl. @ 14th Street in Marysville	Feather River
11	Honcut Ck. @ Chandler Rd.	Feather River
12	Sacramento Outfall @ DWR pumping plant on Sacramento Rd. Sawtelle Rd?	Butte Slough
13	Obanion Outfall @ DWR pumping plant on Obanion Rd.	Butte Slough
14	Wadsworth Canal @ Franklin Rd.	Butte Slough
15	Main drainage canal to Cherokee Canal @ Colusa Hwy	Butte Slough
16	Butte City @ Hwy 162 Bridge	Mainstem Sacramento River
17 no samples	Ord Bend @ Ord Bend Road Bridge	Mainstem Sacramento River
18	Hamilton @ Hwy 32 Bridge	Mainstem Sacramento River
19	Vina @ South Avenue Bridge	Mainstem Sacramento River
20 no samples	Tehama @ Aramayo Way Bridge	Mainstem Sacramento River
21	Red Bluff @ Balls Ferry Bridge	Mainstem Sacramento River
22	Bend @ Bend Ferry Road Bridge	Mainstem Sacramento River

Appendix B: Quality Assurance and Quality Control Tables and Figures

GC/MS at both the USGS Central Laboratory and at Sacramento, and at UC Davis by ELISA. The mean percent difference was 30 percent.

Location	Site	Date	ELISA	GC(Sac)	GC(Colo)	% difference*
Feather River @ Hwy 99	2	01/04	30		40	25
		01/25	270/260	293		10
		01/26	960	782		19
		01/26	960		760	21
		01/27	420/460	379		14
		01/27	420/460		370	16
		01/28	440/450	150		66
		01/28	440/450		180	60
		02/08	155		140	10
		02/09	145		110	24
		02/13	140		21	85
Feather River @ Yuba City	3	01/04	16		36	55
		01/24	100		66	34
		01/25	160	171		6
		01/27	95	63		34
		01/28	85	38		55
		02/08	90		150	40
		02/09	100		100	0
Sacramento Slough @ Karnak	4	01/12	30		82	63
		01/12	30	86		65
		01/17	110		87	21
		01/21	60/65		93/83	29
		01/24	44	89		51
		01/24	44		89	51
		01/25	88	106		17
		01/25	88		130	32
		01/26	130	104		20
		01/26	130		140	7
		01/27	1400	1120		20
		01/27	1400		1400	0
		01/28	440	502		12
		01/28	440		640	31
		01/29	500		590	15
		01/30	320		410	22
		01/31	175		320	45
		02/04	80	86		7
		02/04	80		180	56
		02/11	850		800	6
		02/12	590		480	19
		02/13	500		290	42
		02/14	250/230		220	8
		02/17	290		170	41
		02/18	95		180	47
		02/19	90		150	40
		02/20	130		160	19
		02/21	190		170	11

* percent difference is (high-low)/highx100

Table 1. (continued)

Location	Site	Date	ELISA	GC(Sac)	GC(Colo)	% difference*
Butte Creek at Pass Rd.	5	01/04	28		57	51
		01/12	35	79		56
		01/24	145	105		28
		01/24	145		110	24
		01/25	180	226		20
		01/26	300		350	14
		01/26	300	353		15
		01/27	230	219		5
		01/28	190	161		15
		02/04	125	62		50
		02/08	1000		1000	0
		02/09	330		280	15
		02/10	300		240	20
		02/11	180		160	11
		02/12	170		150	12
		02/13	450		160	64
		02/17	180		140	22
		02/20	165		81	51
		02/21	80		110	27
Colusa Drain	6	01/24	30		36	17
		01/24	30	36		17
		01/26	30	42		29
		01/26	30		53	43
		01/27	42	60		30
		01/27	42		180	77
		01/28	48	55		13
		01/28	48		53	9
		01/31	42		49	14
		02/08	360		300	17
		02/09	210		170	19
		02/10	350		340	3
		02/11	380		360	5
		02/12	230		22	90
		02/13	420		120	71
		02/14	81		84	4
		02/17	38		49	22
		02/18	30		54	44
		02/19	30		44	32
		02/20	57		41	28
		02/21	65		80	19
Sac. River @ Colusa	7	01/24	60		52	13
		01/24	60	55		8
		01/27	42	46		9
		01/28	90	38		58
		02/04	48		20/17	61
		02/04	48	13		73
		02/08	180		220	18

* percent difference is (high-low)/highx100

Location	Site	Date	ELISA	GC(Sac)	GC(Colo)	% difference*
Sac. River @ Colusa	7	02/09	125		140	11
		02/10	30		57	47
		02/13	34		23	32
		02/20	41/30		28	21
		02/21	80		130	38
Bear River	8	01/24	135	203		33
		01/04	160		120	25
Yuba River @ Marysville	9	01/24	48	35		27
		02/09	190		2	99
Jack Slough	10	01/04	95		200	53
		01/24	1250	767		39
		01/24	1250		390	69
		02/08	330		640	48
		02/09	280		250	11
		02/10	300		190	37
		02/17	230		210	9
		02/18	400		220	45
		02/19	290		190	34
		02/20	220		32/160	56
Honcut Creek	11	01/04	200		150	25
		01/24	73/130	105		3
DWR Pump Plant @ Sac. Rd	12	01/04	200		420	52
		01/24	270	230		15
		01/24	270		290	7
		02/08	1800		2800	36
		02/09	940		1000	6
		02/10	700		500	29
		02/17	370		190	49
		02/18	110		150	27
		02/19	140		160	13
		02/20	290		150	48
DWR Pump Plant @ Obanion Rd.	13	01/04	280		130	54
		01/24	115	122		6
		02/08	350		300	14
		02/09	580		760	24
		02/10	580		530	8
		02/17	340/270		220/220	28
		02/18	210		270	22
Wadsworth Canal	14	01/04	700		170	76
		01/24	1250	569		54
		01/24	1250		740	41

* percent difference is (high-low)/highx100

Table 1. (continued)

Location	Site	Date	ELISA	GC(Sac)	GC(Colo)	% difference*
Wadsworth Canal	14	02/08	2000		4800	58
		02/10	1800		2000	10
		02/17	190		140	26
		02/18	310/330		360/380	14
		02/19	420		430	2
		02/20	290		220	24
		02/21	550		550	0
Main Drainage Canal	15	01/04	57		200	72
		01/24	1350	1342		1
		01/24	1350		1500	10
		02/08	2000		2900	31
		02/09	800		1000	20
		02/10	600		550	8
		02/17	340		230	32
		02/18	400		360	10
		02/19	95/165		180	28
Butte City	16	02/18	155		64	59
Hamilton	18	02/18	230		38	83
Vina	19	02/17	165		170	3
		02/18	210		29	86

* percent difference is (high-low)/highx100

Table 2. Difference in diazinon concentration (ng/L) of split surface water samples analyzed by GC/MS at both the USGS Central Laboratory and at Sacramento. The mean percent difference was 19 percent.

Location	site (#)	date	Arvada	Sacramento	% difference*
Feather R.@ Hwy 99	2	01/26	740	782	5
		01/27	370	379	2
		01/28	180	150	17
Sac Slough@ Karnak	4	01/12	82	86	5
		01/24	89	89	0
		01/25	130	106	17
		01/26	140	104	26
		01/27	1400	1120	20
		01/28	640	502	22
		02/04	180	86	52
Butte Creek	5	01/24	110	105	5
		01/26	350	353	1
Colusa Drain	6	01/12	18	20	10
		01/24	36	36	0
		01/25	60	30	50
		01/26	53	42	21
		01/27	180	60	67
		01/28	53	55	4
		02/04	29	25	14
Sac R.@Colusa	7	01/24	52	55	5
		02/04	20/17	13	30
Jack Slough	10	01/24	390	767	49
DWR Pump Plant@Sac Rd.	12	01/24	290	230	21
Wadsworth Canal	14	01/24	740	569	23
Main Drainage Canal	15	01/24	1500	1342	11

*percent difference is (high-low)/highx100

Table 3. Percent recoveries using GC/MS of 164 deuterated diazinon amendme into separate samples of laboratory water at USGS Central Laboratory. Mean 95 percent.

% Recovery	% Recovery	% Recovery	% Recovery
90	100	100	70
90	100	100	100
100	80	90	100
100	100	90	100
90	100	100	100
80	100	90	100
80	100	100	90
80	100	100	100
80	100	90	100
100	100	100	100
90	100	100	100
90	100	80	100
90	100	90	80
80	90	100	90
80	100	90	100
90	100	100	100
80	100	100	100
80	100	100	100
80	100	100	100
80	100	90	90
90	100	100	90
80	100	100	100
80	100	100	100
100	100	100	
100	100	100	
100	100	100	
100	100	100	
100	100	100	
100	100	100	
100	100	100	
100	100	100	
90	100	100	
80	100	100	
80	100	100	
80	100	100	
100	90	100	
90	100	100	
100	100	100	
90	100	100	
90	100	100	
80	100	100	
80	100	100	
100	100	100	
100	100	100	
80	100	90	
100	90	100	
70	80	100	

Table 4. Differences in diazinon concentration (ng/L) of the same field sample analyzed twice at UC Davis by ELISA. The mean percent difference was 20 percent.

location	site	date	split 1	split 2	% difference*
Sac R. @ Tower Bridge	1	01/19	28	33	18
		01/24	42	43	2
		02/02	32	30	6
		02/17	28	32	14
		02/23	53	49	8
Feather R.@Hwy 99	2	02/25	270	260	4
		02/27	420	460	10
		02/28	440	450	2
Sac Slough @Karnak	4	01/21	60	65	8
		02/14	250	300	20
Sac R.@Colusa	7	02/20	41	30	27
Honcut Creek	11	01/24	73	130	78
O'Banion	13	02/17	340	270	21
Wadsworth Canal	14	02/18	310	330	6
Main Drainage Canal	15	02/19	95	165	74

* percent difference is (high-low)/highx100

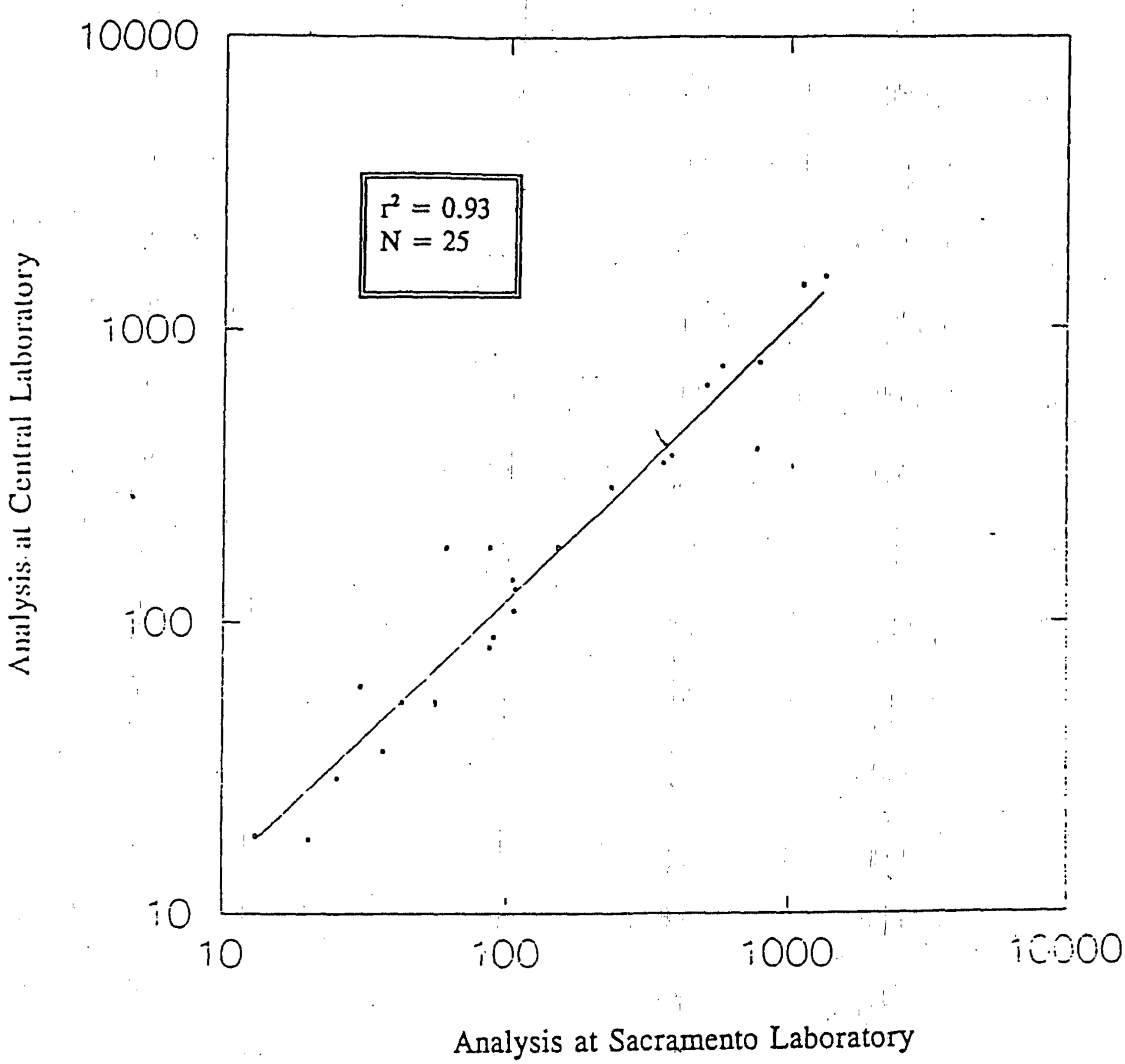


Figure 1. Correlation of diazinon concentration (ng/L) in surface water samples analyzed by GC/MS at the USGS Central Laboratory and at Sacramento. Data are presented in Table 2, Appendix B.

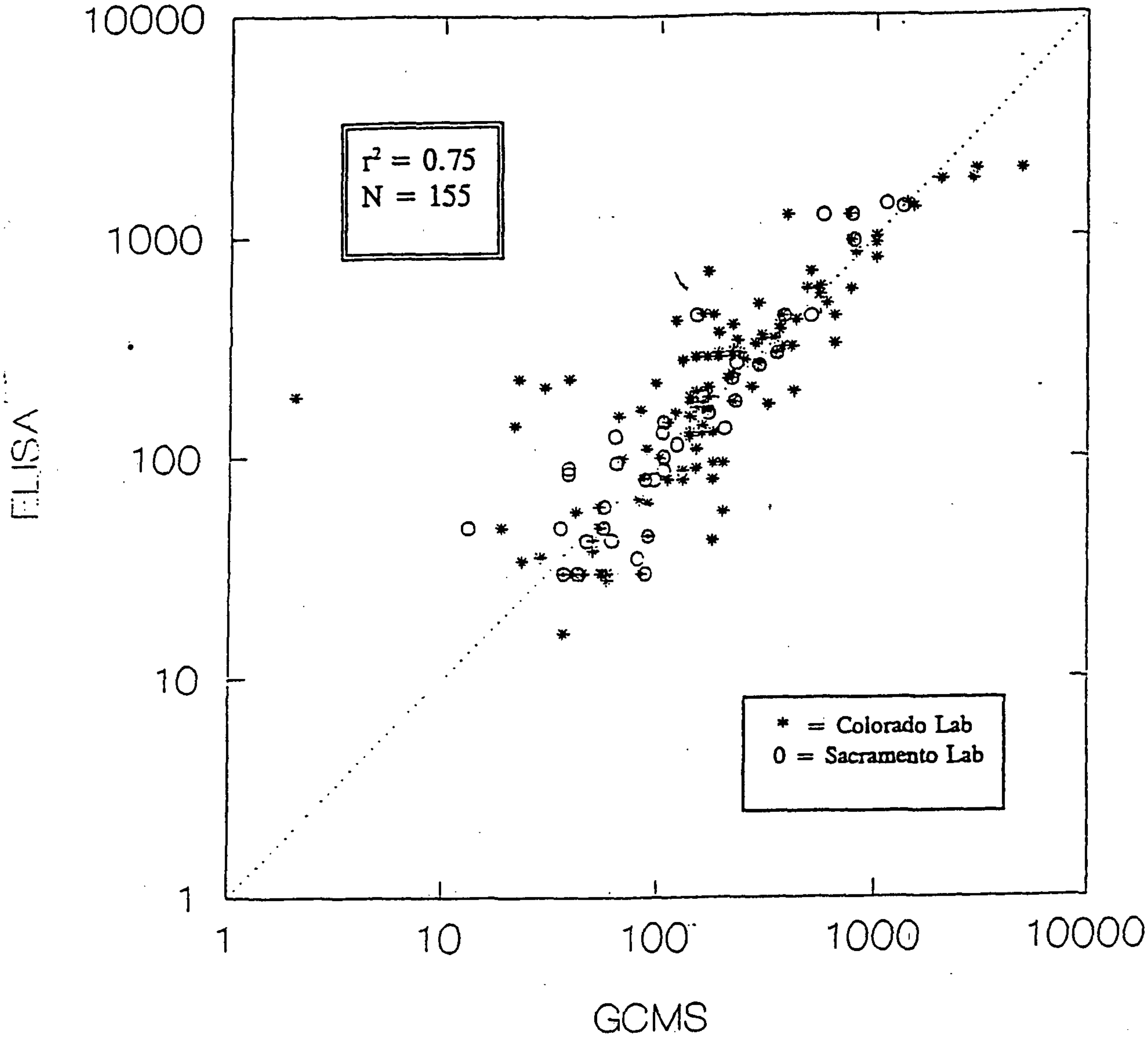


Figure 2. Correlation of diazinon concentration (ng/L) in surface water samples analyzed at the USGS Central Laboratory and at Sacramento by GC/MS, and at UC Davis by ELISA.

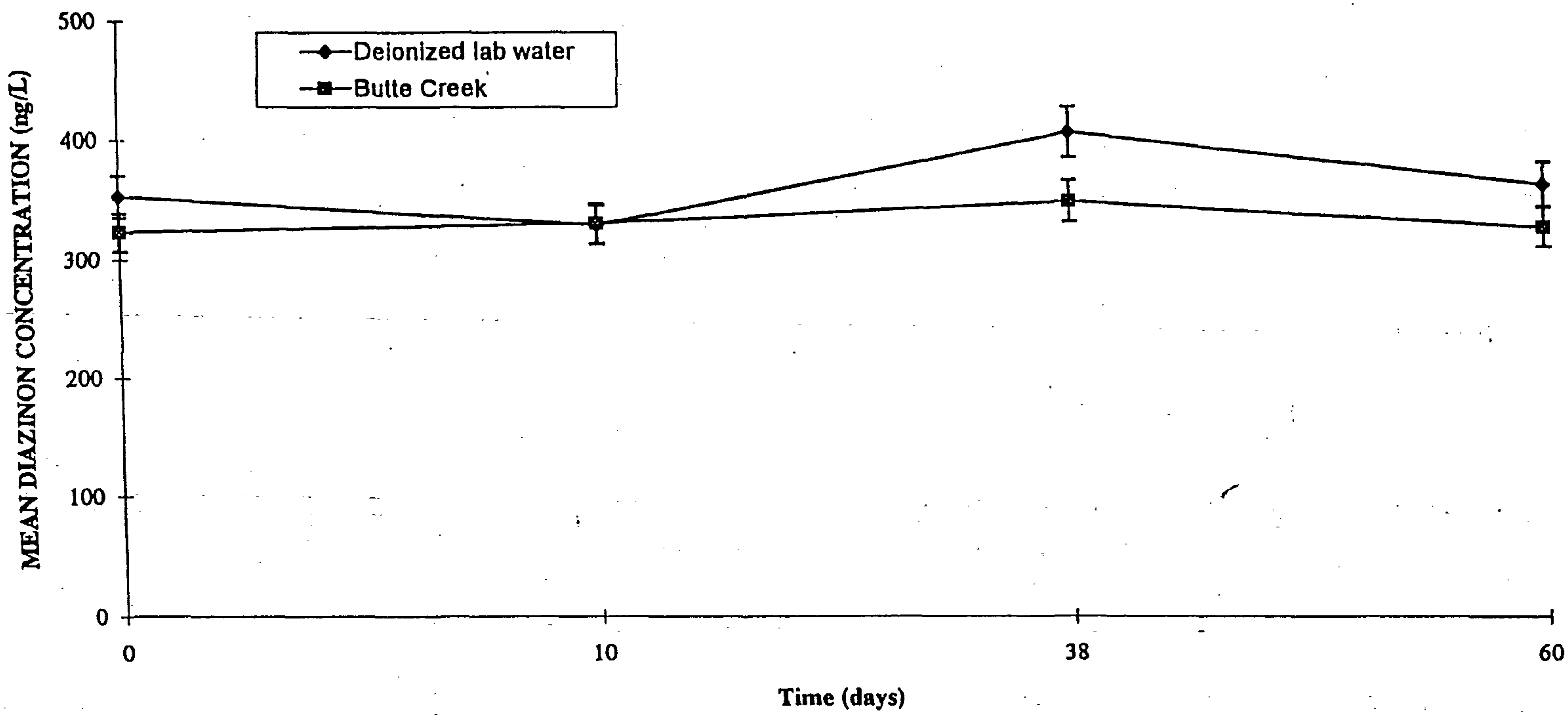


Figure 3. Mean change in concentration (ng/L) and +/- 1 SE of diazinon spiked into three replicate flasks of laboratory and Butte Creek surface water and held for up to a 60 day time period. Analysis by ELISA.

Appendix C: Summary of Diazinon Concentration and Loads

Site 1: Tower Bridge @ Sacramento	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3	bdt			bdt
4				
5	bdt			bdt
6				
7	bdt			bdt
8				
9				
10	bdt			bdt
11				
12	bdt			bdt
13				
14	bdt			bdt
15				
16				
17	46			46
18				
19	28/33			30.5
20				
21	bdt			
22				
23				
24	42/43			42.5
25	40			40
26	97			97
27	236			236
28	151			151
29	133			133
30	82			82
31	76			76
Feb 1	41			41
2	32/30			31
3	39			39
4	bdt			bdt
5				
6				
7	bdt			bdt
8	107			107
9	126			126
10	253			253
11	180			180
12	46			46
13	28			28
14	33			33
15	bdt			bdt
16	40			40
17	28/32			30
18	bdt			bdt
19	31			31
20	38			38
21	29			29
22	44			44
23	53/49			51
24	41			41
25	bdt			bdt
26	bdt			bdt
27				
28				
Mar 1				
2				
3				
4				

Site 2: Feather R. @ Hwy 99	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4	30	40		35
5				
6				
7				
8				
9				
10				
11				
12	bdt		44	44
13				
14				
15				
16				
17	36			36
18				
19				
20				
21	bdt			bdt
22				
23				
24	bdt			bdt
25	270/260		293	265
26	960	760	782	834
27	420/460	370	379	407.25
28	440/450	180	150	305
29	30			30
30	bdt			bdt
31	bdt			bdt
Feb 1				
2				
3				
4	bdt		12	
5				
6				
7	bdt			bdt
8	155	140		147.5
9	145	110		127.5
10	55			55
11	bdt			bdt
12	37			37
13	140	21		80.5
14	bdt			bdt
15				
16				
17	58			58
18	bdt			bdt
19	bdt			bdt
20	30			30
21	bdt			bdt
22	bdt			bdt
23	bdt			
24				
25				
26				
27				
28	bdt			bdt
Mar 1				
2				
3				
4	bdt			bdt

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

LMDL

Site 3: Feather R. @ Yuba City	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4	16	36		26
5				
6				
7				
8				
9				
10				
11				
12	bdt		33	33
13				
14				
15				
16				
17	bdt			bdt
18				
19				
20				
21	bdt			bdt
22				
23				
24	100	66		83
25	160		171	165.5
26	100			100
27	95		63	79
28	85		38	61.5
29				
30				
31	bdt			bdt
Feb 1				
2				
3				
4	bdt		12	12
5				
6				
7	bdt			bdt
8	90	150		120
9	100	100		100
10	bdt			bdt
11	bdt			bdt
12	bdt			bdt
13	90			90
14	bdt			bdt
15				
16				
17	bdt			bdt
18	bdt			bdt
19	bdt			bdt
20	bdt			bdt
21	bdt			bdt
22	bdt			bdt
23	bdt			bdt
24				
25				
26				
27				
28	bdt			bdt
Mar 1				
2				
3				
4	bdt			bdt

Site 4: Sacramento Slough @ Karnak	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4	180			180
5		100		100
6				
7				
8				
9				
10				
11				
12	30	82	86	66
13				
14				
15				
16				
17	110	87		98.5
18				
19				
20				
21	60/65	83/93		75.25
22				
23				
24	44	89	89	74
25	88	130	106	108
26	130	140	104	124.66
27	1400	1400	1120	1306.66
28	440	640	502	527.33
29	500	590		545
30	320	410		365
31	175	320		247.5
Feb 1				
2				
3				
4	80	180	86	115.33
5				
6				
7	90			90
8	90			90
9	160			160
10		1500		1500
11	800	850		825
12	590	480		640
13	500	290		395
14	250/230	220		233.33
15				
16				
17	290	170		230
18	95	180		137.5
19	90	150		120
20	130	160		145
21	190	170		180
22	65			65
23	77			77
24				
25				
26				
27				
28	90			90
Mar 1				
2				
3				
4	44			44

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Table 1. (continued)

Site 5: Butte Creek	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4	28	57		42.5
5				
6				
7				
8				
9				
10				
11				
12	35		79	57
13				
14				
15				
16				
17	48			48
18				
19				
20				
21	62			62
22				
23				
24	145	110	105	120
25	180		226	203
26	300	350	353	334.33
27	230		219	224.5
28	190		161	175.5
29				
30				
31	60			60
Feb 1				
2				
3				
4	125		62	93.5
5				
6				
7	150			150
8	1000	1000		1000
9	330	280		305
10	300	240		270
11	180	160		170
12	170	150		160
13	450	160		305
14	63			
15				
16				
17	180	140		160
18	100			100
19	120			120
20	165	81		123
21	80	110		95
22	30			30
23	bdt			bdt
24				
25				
26				
27				
28	60			60
Mar 1				
2				
3				
4	45			45

Site 6: Colusa Drain	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4	bdt			bdt
5		41		41
6				
7				
8				
9				
10				
11				
12	bdt	18	20	19
13				
14				
15				
16				
17	bdt	17		17
18				
19				
20				
21	bdt	36		36
22				
23				
24	30	36	36	34
25	bdt	60	30	45
26	30	53	42	41.66
27	42	180	60	94
28	48	53	55	52
29				
30				
31	42	49		45.5
Feb 1				
2				
3				
4	bdt	29	25	27
5				
6				
7	bdt			bdt
8	360	300		330
9	210	170		190
10	350	340		345
11	380	360		370
12	230	22		126
13	420	120		270
14	81	84		82.5
15				
16				
17	38	49		43.5
18	30	54		42
19	30	44		37
20	57	41		49
21	65	80		72.5
22	bdt			bdt
23	125			125
24				
25				
26				
27				
28	bdt			bdt
Mar 1				
2				
3				
4	bdt			bdt

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Table 1. (continued)

Site 7: Sac. River @ Colusa Date	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Jan 1				
2				
3				
4	bdt			bdt
5		25		25
6				
7				
8				
9				
10				
11				
12	bdt		10	10
13				
14				
15				
16				
17	bdt	21		21
18				
19				
20				
21	bdt			bdt
22				
23				
24	60	52	55	55.66
25	80		95	87.5
26	34			34
27	42		46	44
28	90		38	64
29				
30				
31	bdt	18		18
Feb 1				
2				
3				
4	48	20/17	13	24.5
5				
6				
7	bdt			bdt
8	180	220		200
9	125	140		132.5
10	30	57		43.5
11	bdt	29		29
12	bdt			bdt
13	34	23		28.5
14	bdt/bdt	29		29
15				
16				
17	bdt	17		17
18	bdt	41		41
19	bdt	40		40
20	41/30	28		33
21	80	130		105
22	bdt			bdt
23	bdt			bdt
24				
25				
26				
27				
28	bdt			bdt
Mar 1				
2				
3				
4	bdt			bdt

Site 8: Bear River Date	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Jan 1				
2				
3				
4	160	120		140
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	135		203	169
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	bdt			bdt
9	bdt			bdt
10	bdt			bdt
11				
12				
13				
14				
15				
16				
17	50			50
18	30			30
19	bdt			bdt
20				
21				
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Table 1. (continued)

Site 9: Yuba River @ Marysville Date	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Jan 1				
2				
3				
4	bdt			bdt
5		5		5
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	48		35	41.5
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	bdt			bdt
9	190	2		96
10	bdt			bdt
11				
12				
13				
14				
15				
16				
17	bdt			bdt
18	bdt			bdt
19	bdt			bdt
20	bdt			bdt
21	bdt			bdt
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Site 10: Jack Slough Date	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Jan 1				
2				
3				
4	95	200		147.5
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	1250	390	767	802.33
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	330	640		485
9	280	250		265
10	300	190		245
11				
12				
13				
14				
15				
16				
17	230	210		220
18	400	220		310
19	290	190		240
20	220	32/160		137.33
21				
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Site 11: Honcut Creek	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4	200	150		175
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	73/130		105	102.66
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	60			60
9	40			40
10	75			75
11				
12				
13				
14				
15				
16				
17	bdt			bdt
18	bdt			bdt
19	bdt			bdt
20	bdt			bdt
21				
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Site 12: DWR Pump Plant @ Sac. Rd.	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3	--			
4	200	420		310
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	270	290	230	263.33
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	1800	2800		2300
9	940	1000		970
10	700	500		600
11				
12				
13				
14				
15				
16				
17	370	190		280
18	110	150		130
19	140	160		150
20	290	150		220
21	57			57
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Table 1. (continued)

Site 13: DWR Pump Plant @ Obanion Rd. Date	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Jan 1				
2				
3				
4	280	130		205
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	115		122	118.5
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	350	300		325
9	580	760		670
10	580	530		555
11				
12				
13				
14				
15				
16				
17	340/270	220/220		262.5
18	210	270		240
19	30			30
20	66			66
21	30			30
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Site 14: Wadsworth Canal Date	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Jan 1				
2				
3				
4	700	170		435
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	1250	740	569	995
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	2000	4800		3400
9		4500		4500
10	1800	2000		1900
11				
12				
13				
14				
15				
16				
17	190	140		165
18	310/330	360/380		345
19	420	430		425
20	290	220		255
21	550	550		550
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Table 1. (continued)

Site 15: Main Drainage Canal	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4	57	200		128.5
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	1350	1500	1342	1425
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8	2000	2900		2450
9	800	1000		900
10	600	550		575
11				
12				
13				
14				
15				
16				
17	340	230		285
18	400	360		380
19	95/165	180		146.66
20		1100		1100
21	bdt			bdt
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Site 16: Butte City	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3	--			
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18	155	64		109.5
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Table 1. (continued)

Site 18: Hamilton	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17	50			50
18	230	38		134
19	30			30
20				
21	70			70
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Site 19: Vina	ELISA	GC/MS Arvada Colorado	GC/MS Sacramento California	Average
Date				
Jan 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17	165	170		167.5
18	210	29		119.5
19	bdt			bdt
20				
21	65			65
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

bdt = below ELISA (<30 ng/L) detection limit; blank = not sampled

Table 2. Diazinon mass loading calculation. One half the ELISA detection limit (30 ng/L) was used to estimate loads when the concentration was below detection.

Site 1: Tower Bridge @ Sacramento	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
*3	bdt	14200	213000	521
4				
*5	bdt	13600	204000	499
6				
*7	bdt	12800	192000	469
8				
9				
*10	bdt	12600	189000	462
11				
*12	bdt	12400	186000	455
13				
*14	bdt	11700	175500	429
15				
16				
17	46	11900	547400	1338
18				
19	30.5	12200	372100	910
20				
*21	bdt	12200	183000	447
22				
23				
24	42.5	13200	561000	1372
25	40	15900	636000	1555
26	97	21800	2114600	5170
27	236	24000	5664000	13848
28	151	22100	3337100	8159
29	133	19200	2553600	6244
30	82	17000	1394000	3408
31	76	15500	1178000	2880
Feb 1	41	14200	582200	1423
2	31	13200	409200	1000
3	39	12600	491400	1201
*4	bdt	12300	184500	451
5				
6				
*7	bdt	13400	201000	491
8	107	19900	2129300	5206
9	126	29800	3754800	9180
10	253	29900	7564700	18496
11	180	26400	4752000	11619
12	46	23800	1094800	2677
13	28	23400	655200	1602
14	33	21500	709500	1735
*15	bdt	19200	288000	704
16	40	17300	692000	1692
17	30	16200	486000	1188
*18	bdt	17100	256500	627
19	31	19400	601400	1470
20	38	23500	893000	2183
21	29	25000	725000	1773
22	44	28900	1271600	3109
23	51	28200	1438200	3516
24	41	25500	1045500	2556
*25	bdt	22900	343500	840
*26	bdt	20800	312000	763
27				
28				
Mar 1				
2				
3				
4				

Site 2: Feather R. @ Hwy 99	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
4	35	3618	126630	310
5				
6				
7				
8				
9				
10				
11				
12	44	3227	141988	347
13				
14				
15				
16				
17	36	3186	114696	280
18				
19				
20				
*21	bdt	3236	48540	119
22				
23				
*24	bdt	3074	46110	113
25	265			
26	834	14943	12462462	30471
27	407.25	6444	2624319	6416
28	305	7322	2233210	5460
29	30			
30	bdt			
*31	bdt	3739	56085	137
Feb 1				
2				
3				
4	12	3245	38940	95
5				
6				
*7	bdt	3354	50310	123
8	147.5			
9	127.5	8000	1020000	2494
10	55	8374	460570	1126
*11	bdt	6705	100575	246
12	37	3659	135383	331
13	80.5	5281	425120.5	1039
*14	bdt	5197	77955	191
15				
16				
17	58	4036	234088	572
*18	bdt	2650	39750	97
*19	bdt	2734	41010	100
20	30	4952	148560	363
*21	bdt	3112	46680	114
*22	bdt	6697	100455	246
*23	bdt	6673	100095	245
24				
25				
26				
27				
*28	bdt	3299	49485	121
Mar 1				
2				
3				
4	bdt			

Note: Diazinon concentration average derived from Table 1.
* = 1/2 the ELISA detection limit used for calculation when value found was below detection limit (bdt).

Site 3: Feather River @ Yuba City	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445×10^{-3} = Diazinon g/day
Date				
Jan 1				
2				
3				
*4	26	2000	52000	127
5				
6				
7				
8				
9				
10				
11				
*12	33	1730	57090	140
13				
14				
15				
16				
17	bdt	1730	25950	63
18				
19				
20				
21				
22				
23				
*24	83	1790	148570	363
*25	165.5	1760	291230	712
26	100	1740	174000	425
*27	79	1730	136670	334
*28	61.5	1730	106395	260
29				
30				
31	bdt	1720	25800	63
Feb 1				
2				
3				
4	12	1720	20640	50
5				
6				
7	bdt	1910	28650	70
*8	120	1820	218400	534
*9	100	1780	178000	435
10	bdt	1790	26850	66
11	bdt	1750	26250	64
12	bdt	1750	26250	64
13	90	1750	157500	385
14	bdt	1730	25950	63
15				
16				
17	bdt	1780	26700	65
18	bdt	1750	26250	64
19	bdt	1750	26250	64
20	bdt	1780	26700	65
21	bdt	1770	26550	65
22	bdt	1750	26250	64
23	bdt	1750	26250	64
24				
25				
26				
27				
28	bdt	1760	26400	65
Mar 1				
2				
3				
4	bdt			

Site 4: Sacramento Slough @ Karnak	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445×10^{-3} = Diazinon g/day
Date				
Jan 1				
2				
3				
4	180	570	102600	251
5	100	602	60200	147
6				
7				
8				
9				
10				
11				
12	66	654	43164	106
13				
14				
15				
16				
17	98.5	541	53288.5	130
18				
19				
20				
21	75.25	561	42215.25	103
22				
23				
24	74	731	54094	132
25	108	969	104652	256
26	124.66	1130	140865.8	344
27	1306.66	1550	2025323	4952
28	527.33	1500	790995	1934
29	545	1360	741200	1812
30	365	1180	430700	1053
31	247.5	964	238590	583
Feb 1				
2				
3				
4	115.33	648	74733.84	183
5				
6				
7	90	873	78570	192
8	90	1290	116100	284
9	160	1090	174400	426
10	1250	2000	2500000	6113
11	800	2160	1728000	4225
12	640	1890	1209600	2957
13	395	1870	738650	1806
14	233.33	1940	452660.2	1107
15				
16				
17	230	1200	276000	675
18	137.5	1000	137500	336
19	120	694	83280	204
20	145	1060	153700	376
21	180	923	166140	406
22	65	1160	75400	184
23	77	1810	139370	341
24				
25				
26				
27				
28	90	1150	103500	253
Mar 1				
2				
3				
4	44	828	36432	89

Note: Diazinon concentration average derived from Table 1.
* = 1/2 the ELISA detection limit used for calculation when value found was below detection limit (bdt).

Table 2. (continued)

Site 5: Butte Creek	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
4	42.5	266	11305	28
5				
6				
7				
8				
9				
10				
11				
12	57	278	15846	39
13				
14				
15				
16				
17	48	311	14928	37
18				
19				
20				
21	62	385	23870	58
22				
23				
24	120	496	59520	146
25	203	827	167881	410
26	334.33	1120	374449.6	916
27	224.5	890	199805	489
28	175.5	685	120217.5	294
29				
30				
31	60	409	24540	60
Feb 1				
2				
3				
4	93.5	446	41701	102
5				
6				
7	150	394	59100	145
8	1000	1320	1320000	3227
9	305	2620	799100	1954
10	270	2110	569700	1393
11	170	1860	316200	773
12	160	2400	384000	939
13	305	1740	530700	1298
14	63	1100	69300	169
15				
16				
17	160	588	94080	230
18	100	799	79900	195
19	120	1460	175200	428
20	123	1240	152520	373
21	95	2210	209950	513
22	30	2360	70800	173
23				
24				
25				
26				
27				
28	60	803	48180	118
Mar 1				
2				
3				
4	45	605	27225	67

Site 6: Colusa Drain	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
*4	bdt	185	2775	7
5	41	184	7544	18
6				
7				
8				
9				
10				
11				
12	19	181	3439	8
13				
14				
15				
16				
17	17	24	408	1
18				
19				
20				
21	36	391	14076	34
22				
23				
24	34	403	13702	34
25	45	433	19485	48
26	41.66	366	15247.56	37
27	94	454	42676	104
28	52	499	25948	63
29				
30				
31	45.5	333	15151.5	37
Feb 1				
2				
3				
4	27	231	6237	15
5				
6				
*7	bdt	548	8220	20
8	330	851	280830	687
9	190	249	47310	116
10	345	621	214245	524
11	370	897	331890	811
12	126	675	85050	208
13	270	655	176850	432
14	82.5	436	35970	88
15				
16				
17	43.5	480	20880	51
18	42	493	20706	51
19	37	337	12469	30
20	49	428	20972	51
21	72.5	241	17472.5	43
*22	bdt	279	4185	10
23	125	658	82250	201
24				
25				
26				
27				
*28	bdt	395	5925	14
Mar 1				
2				
3				
*4	bdt	571	8565	21

Note: Diazinon concentration average derived from Table 1.
* = 1/2 the ELISA detection limit used for calculation when value found was below detection limit (bdt).

Table 2. (continued)

Site 7: Sac. River @ Colusa	Diazinon concentration (ng/L) Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
*4	bdt	6660	99900	244
5	25	6620	165500	405
6				
7				
8				
9				
10				
11				
12	10	5740	57400	140
13				
14				
15				
16				
17	21	5740	120540	295
18				
19				
20				
*21	bdt	5680	85200	208
22				
23				
24	55.66	7020	390733.2	955
25	87.5	12600	1102500	2696
26	34	12300	418200	1022
27	44	10900	479600	1173
28	64	9040	578560	1415
29				
30				
31	18	6710	120780	295
Feb 1				
2				
3				
4	24.5	5890	144305	353
5				
6				
*7	bdt	8050	120750	295
8	200	20400	4080000	9976
9	132.5	18200	2411500	5896
10	43.5	12200	530700	1298
11	29	11400	330600	808
*12	bdt	13200	198000	484
13	28.5	10200	290700	711
14	29	8860	256940	628
15				
16				
17	17	7480	127160	311
18	41	11600	475600	1163
19	40	13900	556000	1359
20	33.00	13900	458700	1122
21	105	20900	2194500	5366
*22	bdt	16500	247500	605
*23	bdt	13500	202500	495
24				
25				
26				
27				
*28	bdt	10500	157500	385
Mar 1				
2				
3				
*4	bdt	8590	128850	315

Site 9: Yuba River @ Marysville	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
*4	bdt	1200	18000	44
5	5	1210	6050	15
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24	41.5	1400	58100	142
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
*8	bdt	1490	22350	55
9	96	1220	117120	286
*10	bdt	1160	17400	43
11				
12				
13				
14				
15				
16				
*17	bdt	1140	17100	42
*18	bdt	1570	23550	58
*19	bdt	1300	19500	48
*20	bdt	1450	21750	53
*21	bdt	1350	20250	50
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Note: Diazinon concentration average derived from Table 1.
* = 1/2 the ELISA detection limit used for calculation when value found was below detection limit (bdt).

Table 2.

Site 16: Butte City	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18	109.5	15400	1686300	4123
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Site 17: Ord Bend	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
*17	bdt	7579	113685	278
18	90	15692	1412280	3453
19	36	12004	432144	1057
20				
21	100	18105	1810500	4427
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Note: Diazinon concentration average derived from Table 1.
* = 1/2 the ELISA detection limit used for calculation when value found was below detection limit (bdt).

Site 19: Vina	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17	167.5	11038	1848865	4520
18	119.5	14559	1739800.5	4254
*19	bdt	11046	165690	405
20				
21	65	14325	931125	2277
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Site 21: Red Bluff	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17	80	9250	740000	1809
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Note: Diazinon concentration average derived from Table 1.
* = 1/2 the ELISA detection limit used for calculation when value found was below detection limit (bdt).

Table [illegible] (continued)

Site 22: Bend	Diazinon concentration (ng/L) *Average	Discharge (cfs)	Concentration x Discharge	Result x 2.445 x 10-3 = Diazinon g/day
Date				
Jan 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Feb 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
*18	bdt	9683	145245	355
*19	bdt	8690	130350	319
20				
*21	bdt	10563	158445	387
22				
23				
24				
25				
26				
27				
28				
Mar 1				
2				
3				
4				

Note: Diazinon concentration average derived from Table 1.
* = 1/2 the ELISA detection limit used for calculation when value found was below detection limit (bdt).

Appendix D: Summary of other chemicals detected in study

1/24/97 concentrations reported ... records were set to conc = Ø.

Table 1. Summary of all pesticide concentrations (ng/L) measured above the U.S. Geological Survey Arvada, Colorado detection limit.

	site	date	alachlor	alpha bhc	atrazine (MDL .017 ppb)	carbaryl	carbofuran	chlorpyrifos	cyanazine	dcpa	deethyl atrazine	diazinon	dimethoate	eptc	ethalfluralin	ethoprop	malathion	methyl parathion	metolachlor	metribuzin	molinate	napropamide	pendimethalin	phorate	prometon	pronamide	simazine (.008)	tebuthiuron (.015)	terbacil	terbufos	thiobencarb (.008)	trifluralin
Feather R.@Hwy 99	2	01/04										40															14					
		01/26			.007		27			2		760							3		22						200					
		01/27			.007		36			2		370							3		29						260					
		01/28			.006		32			2		180							3		33						170	5				
		02/08			.005		23			2		140							3		24						290					
		02/09			.010					2		110							2		24						280	52				
		02/13			.008		21			1		21									30						110					
Feather R.@Yuba City	3	01/04										36															4					
		01/24								2		66															22					
		02/08			.006	16				2		150													11		50					
		02/09			37					2		100													9		75					
Sac. Slough@Karnak	4	01/05					56					100		10					3		89										7	
		01/12					21					82		7					3		100										9	
		01/17					69					87									83						8					
		01/21					63					93									99						8				5	
		01/21					55					83									100						5				6	
		01/24					64					89									130						9				5	
		01/25					79					130									120						45	110			6	
		01/26					75					140							6		130						67	30			4	
		01/27	7				70					1400							4		130						57	25			5	
		01/28	9				83					640							4		120						140	9			5	
		01/29					81					590							4		110						200				6	
		01/30					70					410							4		100						140				5	
		01/31					71					320									100						130				5	
		02/04					65					180									80						70					
		02/10					58					1500		7					3		75						200	10				
		02/11					51					850							6		91						280					
		02/12					58					480							5		89						230					
		02/13				10	52			2		290		8					6		78						210					
		02/14					56					220		10					8		66						170				4	
		02/17			23		58					170							7		65						150					
		02/18			.014		64					180		4					5		59						160					
		02/19			20		61					150		4					4		62						180	12				
		02/20			.012		62					160							6		53						210					
		02/21					73					170							3		72					5	130					

[ ] = below MDL

* = intra laboratory split sample; blank = below detection limit

Table 1. (continued)

	site	date	alachlor	alpha bhc	atrazine	carbaryl	carbofuran	chlorpyrifos	cyanazine	dcpa	deethyl atrazine	diazinon	dimethoate	eptc	ethalfluralin	ethoprop	malathion	methyl parathion	metolachlor	metribuzin	molinate	napropamide	pendimethalin	phorate	prometon	pronamide	simazine	tebuthiuron	terbacil	terbufos	thiobencarb	trifluralin
Butte Creek	5	01/04		1			46			1		57		15					5		93						11				9	3
		01/24					60			1		110		2					3		130						11				5	1
		01/26			6	5	55			2		350							4		110						260	9	11		7	
		02/08			6		48			3		1000		2					2		84						440				5	
		02/09			6		44			3		280		2					2		120						270				4	
		02/10			5		42			3		240		3					4		76	7					300		7			2
		02/11			4		40			4		160		23					8		75					16	190				8	4
		02/12			3		48			3		150		18					7		81					18	170				7	3
		02/13			5		49			2		160		7					6		72					17	160				9	2
		02/17			4		66			2		140		2					3		87					17	150				4	3
		02/20			4		58			2		81							3		89					14	130				3	1
		02/21			52					2		110							2			7				17	260					
Colusa Drain	6	01/05			3		39			2		41		2					2		86	8					17	4			21	3
		01/12			4		25			1		18							2		73						22				12	
		01/17			4		27			1		17		1							72						11	6			14	
		01/21					29					36									85						14				15	
		01/24					35			2		36									130	8					13				10	3
		01/25			5		46			3		60		2					4		120	10					410	23			12	2
		01/26					27	19		3		53							2		81	76				68	68	4	34		21	3
		01/27			17		50		21	15		180		1					56	6	110	30			320	60	400	13			13	4
		01/28			6		49			3		53							6		140	7					430	70			13	3
		01/31			41		68			4		49		1					4		180					14	360	21			12	1
		02/04			8		39			2		29				8			2		120						97	13			10	
		02/08			5	7	31	5	42	17		300			41				7		75	440	3				900				10	23
		02/09			29		47	9	9	26		170		3					35		100	200	3			36	980	48			12	6
		02/10			77		56			6	3	340							310	8	100	85	2			250	840	30			10	6
		02/11			49		62		13	16		360		3					130	16	110	41			270	160	570	13			10	5
		02/12			3		30			1		22									71					64	18	6			14	
		02/13			11		48		16	13		120		2					36		100	19			260	36	390	13			11	4
		02/14			10		38		17	6		84							20		95	12		16	150	24	300	11			9	3
		02/17			5		26		20	7		49							8		75	7			94	18	220	9			9	3
		02/18			6		29		75	3		54							9		84				85	18	300				10	3
		02/19			6		23		34	6		44							8		83	57			67	17	290				11	3
		02/20			4		24		19	5		41							5		86	13			59	14	240	4			11	3
		02/21			* 14				32	3	1	80		10					33		81	110		18	58	17	780				7	8

* = intra laboratory split sample; blank = below detection limit

Table 1. (continued)

	site	date	alachlor	alpha bhc	atrazine	carbaryl	carbofuran	chlorpyrifos	cyanazine	dcpa	deethyl atrazine	diazinon	dimethoate	eptc	ethalfluralin	ethoprop	malathion	methyl parathion	metolachlor	metribuzin	molinate	napropamide	pendimethalin	phorate	prometon	pronamide	simazine	tebuthiuron	terbacil	terbufos	thiobencarb	trifluralin
Butte Creek	5	01/04		1			46			1		57		15					5		93						11				9	3
		01/24					60			1		110		2					3		130						11				5	1
		01/26			6	5	55			2		350							4		110						260	9	11		7	
		02/08			6		48			3		1000		2					2		84						440				5	
		02/09			6		44			3		280		2					2		120						270				4	
		02/10			5		42			3		240		3					4		76	7					300		7			2
		02/11			4		40			4		160		23					8		75					16	190				8	4
		02/12			3		48			3		150		18					7		81					18	170				7	3
		02/13			5		49			2		160		7					6		72					17	160				9	2
		02/17			4		66			2		140		2					3		87					17	150				4	3
		02/20			4		58			2		81							3		89					14	130				3	1
		02/21			52					2		110							2			7				17	260					
Colusa Drain	6	01/05			3		39			2		41		2					2		86	8					17	4			21	3
		01/12			4		25			1		18							2		73						22				12	
		01/17			4		27			1		17		1							72						11	6			14	
		01/21					29					36									85						14				15	
		01/24					35			2		36									130	8					13				10	3
		01/25			5		46			3		60		2					4		120	10					410	23			12	2
		01/26					27	19		3		53							2		81	76				68	68	4	34		21	3
		01/27			17		50		21	15		180		1					56	6	110	30			320	60	400	13			13	4
		01/28			6		49			3		53							6		140	7					430	70			13	3
		01/31			41		68			4		49		1					4		180					14	360	21			12	1
		02/04			8		39			2		29				8			2		120						97	13			10	
		02/08			5	7	31	5	42	17		300			41				7		75	440	3				900				10	23
		02/09			29		47	9	9	26		170		3					35		100	200	3			36	980	48			12	6
		02/10			77		56			6	3	340							310	8	100	85	2			250	840	30			10	6
		02/11			49		62		13	16		360		3					130	16	110	41			270	160	570	13			10	5
		02/12			3		30			1		22									71					64	18	6			14	
		02/13			11		48		16	13		120		2					36		100	19			260	36	390	13			11	4
		02/14			10		38		17	6		84							20		95	12		16	150	24	300	11			9	3
		02/17			5		26		20	7		49							8		75	7			94	18	220	9			9	3
		02/18			6		29		75	3		54							9		84				85	18	300				10	3
		02/19			6		23		34	6		44							8		83	57			67	17	290				11	3
		02/20			4		24		19	5		41							5		86	13			59	14	240	4			11	3
		02/21			* 14				32	3	1	80		10					33		81	110		18	58	17	780				7	8

* = intra laboratory split sample; blank = below detection limit

Table 1. (continued)

	site	date	alachlor	alpha bhc	atrazine	carbaryl	carbofuran	chlorpyrifos	cyanazine	dcpa	deethyl atrazine	diazinon	dimethoate	eptc	ethalfluralin	ethoprop	malathion	methyl parathion	metolachlor	metribuzin	molinate	napropamide	pendimethalin	phorate	prometon	pronamide	simazine	tebuthiuron	terbacil	terbufos	thiobencarb	trifluralin
Sac R.@Colusa	7	01/05								1		25																				
		01/17										21																				
		01/24										52																				
		01/31			5							18										4					28					
		02/04			3							20															10					
		02/04										17																				
		02/08			85					3		220							2			9				17	440					
		02/09			28					2		140							1								280					
		02/10			17					1		57							1			17					170		14	40		
		02/11			13					1		29							2								100					
		02/13			20					1		23	18													14	89					
		02/14			11							29															56		11			
		02/17			5	5				1		17															29					
		02/18			16					3		41															320					2
		02/19			35					2		40															110					
		02/20			26					2		28							1								97					
		02/21			82					2	2	130							3							16	470					
Bear R.@Berry Rd.	8	01/04					110					120							3		55						66					
Yuba R.@Marysville	9	01/05										5															9					
		02/09										2															55					
Jack Slough@14th St.	10	01/04					160					200									220						19					
		01/24					210					390									270						460					
		02/08					120			4		640						8			160						590	9			2	
		02/09					220					250									330						200					
		02/10					310					190									420						140					
		02/17					340					210									360						470					
		02/18					340					220									360						240					
		02/19					370					190									340						150	10				
		02/20					68					32									46						500					
		02/20					290					160									260						940	11				
Honcut Creek@Chandler Rd.	11	01/04					94					150									38						21					
DWR Pump Plant@Sac. Rd.	12	01/04					220					420		5							400						33	170			32	
		01/24					290					290		5							420						740	1000			42	

* = intra laboratory split sample; blank = below detection limit

Table 1. (continued)

	site	date	alachlor	alpha bhc	atrazine	carbaryl	carbofuran	chlorpyrifos	cyanazine	dcpa	desethyl atrazine	diazinon	dimethoate	eptc	ethalfluralin	ethoprop	malathion	methyl parathion	metolachlor	metribuzin	molinate	napropamide	pendimethalin	phorate	prometon	pronamide	simazine	tebuthiuron	terbacil	terbufos	thiobencarb	trifluralin
DWR Pump Plant@Sac. Rd.	12	02/08	22				130	10		4		2800		13							350						270	100			11	9
		02/09	34				140			4		1000		5							280						160	93			14	
		02/10	37				170			3		500		8				23		11	380						110	46			15	
		02/17			5300		180			2	12	190		5							300						760				16	
		02/18			5100		260			2	9	150		4							310						1200	9			29	
		02/19			3100		260				7	160									260						610	25			29	
		02/20			1400		260				5	150									290						620	47			28	
DWR Pump Plant@Obanion Rd.	13	01/04					55					130									96											
		02/08					66			3		300									140						490					
		02/09					48			17		760		5			20				79				9		720				3	
		02/10					69			6		530									120						220					
		02/17					29			8		220									55						170					
		02/17					31			7		220									59						160					
		02/18					28			6		270									53						160					
Wadsworth Canal@Franklin Rd.	14	01/04					24					170									54											
		01/24					30					740									47						47				4	
		02/08					42			3		4800		3							54						460				3	
		02/09				16	62					4500									79						430					
		02/10				28	56					2000									90						370				3	
		02/17					29					140		3							44						220					
		02/18			5	8	50					360		4							70						170				5	
		02/18					51					380		4							72						170				7	
		02/19			3		40					430									62						300					
		02/20					32					220									41						150					
		02/21					41					550		8					3		50						640					
Main Drainage Canal to Cherokee Canal@Colusa Hwy	15	01/04					88					200									170											
		01/24					81					1500									170						21				5	
		02/08					85			4		2900					9				160						210				6	
		02/09					83					1000									170						68				3	
		02/10					94					550									150						40					

* = intra laboratory split sample; blank = below detection limit

	site	date	alachlor	alpha bhc	atrazine	carbaryl	carbofuran	chlorpyrifos	cyanazine	dcpa	deethyl atrazine	diazinon	dimethoate	eptc	ethalfluralin	ethoprop	malathion	methyl parathion	metolachlor	metribuzin	molinate	napropamide	pendimethalin	phorate	prometon	pronamide	simazine	tebuthiuron	terbacil	terbufos	thiobencarb	trifluralin
Main Drainage Canal to Cherokee Canal@Colusa Hwy	15	02/17					160					230									240						11					
		02/18					120					360									200						34					
		02/19					94					180									150						16					
		02/20					91			3		1100					26				160						48				4	
Butte City	16	02/18			51							64															110					
Hamilton	18	02/18			26							38															78					
Vina	19	02/17			140							170															130					
		02/18			29	5				2		29															75					

* = Intra laboratory split sample; blank = below detection limit

Table 2. Pesticides identified in scan at USGS Sacramento Laboratory. Values are ng/L.

	site	date	diazinon	molinate	carbofuran	simazine	methidathion
Feather R.@Hwy 99	2	01/12	44	11	.013.		
		01/25	293			329	143
		01/26	782	37		251	26
		01/27	379			279	
		01/28	150			172	
		02/04	12				
Feather R.@Yuba City	3	01/12	33				56
		01/25	171				
		01/27	63			62	
		01/28	38				
		02/04	12				
Sac. Slough@Karnak	4	01/12	86	113	35		
		01/24	89	121	38		
		01/25	106	132	42		
		01/26	104	165	37	48	
		01/27	1120	134	52	142	104
		01/28	502	168	55	215	75
		02/04	86	113	28	110	
Butte Creek@ Pass Road	5	01/12	79	140	49	8	
		01/24	105	128	50		
		01/25	226	150	36	85	
		01/26	353	142	30	263	
		01/27	219	127	44	154	
		01/28	161	147	64	125	
		02/04	62	84	13		
Colusa Drain	6	01/12	20	98	27		
		01/24	36	131	31		
		01/25	30	108	26		
		01/26	42	109	20	117	665
		01/27	60	165	49	523	
		01/28	55	166	55	613	
		02/04	25	168	25.4	120	
Sac R.@Colusa	7	01/12	10				
		01/24	55				
		01/25	95			750	
		01/27	46			322	
		01/28	38			151	
		02/04	13			22	
Bear R.@Berry Rd.	8	01/24	203	91	82	132	57
Yuba R.@Marysville	9	01/24	35			36	
Jack Slough	10	01/24	767	264	135	1348	1102
Honcut Creek@Chandler Rd.	11	01/24	105		21		

Table 2. (continued).

	site	date	diazinon	molinate	carbofuran	simazine	methidathion
DWR Pump Plant@Sac. Rd.	12	01/24	230	475	157	803	49
DWR Pump Plant@Obanion Rd.	13	01/24	122	272	41	30	
Wadsworth Canal	14	01/24	569	57	15	86	58
Main Drainage Canal to Cherokee Canal@Colusa Hwy	15	01/24	1342	200	45		55