Characterization of Propanil Prune Foliage Residues as related to Propanil Use Patterns in the Sacramento Valley, California

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Abstract

Propanil, a broad-spectrum, post-emergent rice herbicide, has seen significantly increased use in the Sacramento Valley. Propanil is a California restricted material due to a history of significant damage to prune orchards. Prune foliage compliance monitoring is required as a condition of use. Recently, prune foliage concentrations exceeding the 0.1ppm threshold have been commonly observed. Continued use of propanil requires a set of use conditions implemented valley-wide that minimize the probability of significant adverse impacts to off-target sites. The objective of this analysis is to characterize the patterns of propanil use relative to the observed propanil residues at compliance monitoring sites located throughout the Sacramento Valley.

These results suggest that aerial applications within approximately 10 miles contribute a low but measurable level of residues to compliance monitoring orchards. This appears to be true in both the West Side where only helicopters are allowed to operate, and in the Butte County Study Area where only fixed wing application were allowed in the 2001 season. This "background" level of residues is the base upon which residue contributions from more proximate activities are added. More proximate activities alone appear to produce observed propanil concentration peaks. Important proximate activities are aerial applications (helicopter or fixed wing) within about 6 miles and/or ground applications within 1 or 2 miles. There is no measurable distinction between helicopter and fixed wing. In fact, the two compliance monitoring sites primarily influenced by helicopter applications show the highest peak residues. Compliance monitoring sites influenced primarily by ground applications show peak concentrations of approximately 0.12 ppm. However, ground applications alone can produce very high peak concentrations. In 1999, a single 120 acre ground application was directly associated with a peak concentration of 1.07 ppm and in 2000, a single ground application of 154 acres was associated with a residue level of 1.20 ppm. These are the highest residues observed in compliance monitoring results since the inception of the program.

There are six broad observations to be made from this data and analysis: 1) both ground and aerial applications have the potential for long range drift to occur but this potential is greatest for aerial applications, 2) closer applications have more influence on observed residue levels than applications farther away, 3) larger applications have more influence on observed residue levels than smaller applications, 4) drift from aerial applications is probably relatively transient due to the short application time; therefore, is highly dependent upon wind direction during and immediately following (1 to 2 hours) a particular aerial application, 5) there does not appear to be any evidence to support the concept of regional atmospheric loading, and 6) these compliance monitoring results do not support a distinction between fixed wing and helicopter applications.

Clearly, both air and ground applications must be considered when designing and implementing a mitigation plan. The appropriate mix of air and ground controls will depend upon the desired mitigation goal. These results can aid risk managers in selected that mix of air and ground controls.

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I. Background

Propanil is a broad-spectrum, post-emergent rice herbicide that since 1997 has seen significantly increased use in the Sacramento Valley. Propanil is a California restricted material because it has a history of off-target problems. For example, propanil use was suspended in 1969 following damage to prune orchards associated with aerial application of the emulsifiable concentrate formulation of propanil in 1967 and 1968. In 1982, based upon the introduction of drift reduction technology, the Westside Propanil Use Area was formed to allow limited propanil use in Colusa and Glenn Counties. Strict control on the number of acres and applications methods was required. Propanil use did not exceed 12,000 acres per year between 1982 and 1996. Based upon work by Akesson (1986) a prune foliage threshold level of 0.1 ppm was set and prune foliage monitoring (compliance monitoring) has been required as a condition of use. Through 1997 no prune foliage monitoring results exceeded 0.1 ppm.

In 1997 the Expanded Use Area was formed through emergency regulation, allowing ground applications throughout the Sacramento Valley and aerial applications under certain conditions in a Butte County Study Area (BCSA). Applications continue to be allowed in the Westside Propanil Use Area. Following the formation of the Expanded Use Area, the use of propanil has increased significantly each year (Figure 1). Beginning in 1998, prune foliage concentrations exceeding the 0.1ppm threshold have been commonly observed. In 2001 a total of 496,463 acres of rice were planted in the Sacramento Valley and propanil was applied to 297,736 acres. Assuming a typical application rate of 4-lbs active ingredient per acre, approximately 1,191,000 lbs of propanil were applied between the middle of May and the middle of July. The total acreage of propanil applied has increased 10-fold relative to 1997. The growth in acres applied has been driven primarily by a growth in ground applications. The acreage by ground has increased almost 20 fold (18.8 fold) relative to 1997. The growth in aerial applications has been between 2 and 3 fold, depending upon the year. The growth in ground applications is far larger than the growth in aerial applications because of the strict geographic restrictions associated with aerial propanil applications.

In 1998 the California Propanil Task Force (CPTF) was formed as a cooperative research organization of rice growers, pesticide applicators, the two registrants of propanil (Dow AgroSciences and RiceCo), the Rice Research Board, and the California Rice Commission. Beginning in 1999 Compliance Monitoring has been coordinated by the CPTF. In addition, the CPTF has completed research studies with the objective of developing a database appropriate for designing mitigation measures to reduce the risk of propanil use to prune orchards in the Sacramento Valley (CRRB, 2001).

Continued use of propanil will depend upon development of a set of use conditions implemented valley-wide that minimize the probability of significant adverse impacts to off-target sites. Compliance monitoring results provide a unique opportunity to examine valley wide the general link between use patterns and the residues observed off-site.

II. Objective

The report presents analysis of the 2001 Compliance Monitoring Results. The objective of this analysis is to characterize the patterns of propanil use relative to the observed propanil residues at compliance monitoring sites located throughout the Sacramento Valley.

III. Methods

A. Residue and Use Data.

This analysis examines patterns in the 2001 Compliance Monitoring Propanil prune foliage levels (Table 1) and the Propanil prune foliage levels measured at additional orchards included in the 2001 Butte County Aerial Study (CRRB, 2001) (Table 2). Details of the prune foliage sample collection and analytical procedures are available in the Compliance Monitoring Protocol (CPTF, 2002) and in the 2001 Butte County Aerial Study (CRRB, 2001).

In the Enforcement Branch letter ENF 01-17 to the County Agricultural Commissioners (DPR, 2001) DPR requested that the seven rice counties (Butte, Colusa, Glenn, Placer, Sutter, Yolo, Yuba) "…maintain a record of propanil use on a daily basis using the Propanil Application Log…" During the 2001 Propanil Use Season, DPR received a total of 4590 records of propanil ground (3896 records) and aerial (694 records) applications from the seven county propanil use area. As requested, the records from each county's Propanil Application Log (PAL) were submitted directly to the DPR Pesticide Enforcement Branch on Tuesday of each week. The PAL was to "…reflect daily use data for the previous Tuesday through Monday report period…" Therefore, it is assumed for this analysis that the PAL records are identical to those that will eventually appear in the 2001 Pesticide Use Report (PUR). This is because, per the request in ENF 01-17, only applications actually made during a particular week were to be reported to DPR. The objective of the weekly reporting request during the 2001 Propanil Use Season was the have accurate "real time" records of actual use in the event that Propanil residues in any of the compliance monitoring sites were above levels of concern. Since the PAL records were to be accurate "real time" use records, analysis of these records should yield identical results to those that would be obtained using the official 2001 PUR when it becomes available.

In Butte county aerial applications were allowed only as part of the 2001 Butte County Aerial Study conducted in the Butte Country Study Area (BCSA). Aerial applicators were required to submit Aerial Application logs as a condition of being included in the study. The aerial applicator logs were available for this analysis. Since completing an accurate aerial applicator log was a requirement of participating in the Butte County study (and being allowed to perform aerial applications in the Expanded Use Area), ideally, the aerial applicator logs would be accurate records of all the aerial applications that occurred in the BCSA. The PAL records have a resolution down the to section in which the application was made. The aerial applicator log records in the BCSA have a resolution down to the parcel level, and the time of application within the day the application occurred. However, 16 aerial applications were reported in the PAL records but were not recorded in the aerial applicator log. Therefore, while the date and section location of the applications, the parcel and the exact time of those 16 applications is unknown. Because these applications are missing, the aerial applicator log is not totally accurate.

B. Weather Data Sources.

The CRRB maintained a weather station in the BCSA as part of the 2001 study protocol. The data from this weather station allows more detailed analysis of the residue results observed during the Butte County Study. The BCSA weather station measured wind speed and wind direction at 10 meters. Hardcopy and electronic records of 15-minute averaged weather data for the duration for the study was submitted with the study (CRRB, 2001).

C. GIS methods.

A database containing information from the PAL records was developed to include records from the seven Sacramento Valley rice counties (Butte, Glenn, Colusa, Yuba, Sutter, Yolo, and Placer). Database fields included county name, application date, total acres, acres air, acres ground, section, township, range, and COMTRS (county, meridian, township, range, section). A query was performed on the table to sum acreage totals by COMTRS for each application date. This query summed the total acres applied, acres applied by air, and acres applies by ground. This query was then used to create the daily summed-by-section tables that were used to create propanil acreage maps.

Propanil acreage maps were created using ArcView 3.2. Data themes included the Public Land Survey (PLS) system grid for the seven counties and digitized points for the monitoring locations. Monitoring locations were digitized using GPS coordinates along with visual identification using satellite imagery and roads. The daily acreage tables previously created were imported into ArcView and were individually joined to the PLS attribute table based on the COMTRS field. The PLS theme was then selected to show only sections with total acres greater than zero. The resulting sections were then added as a new theme to the project. This was done for each day during the study period. Circular buffers were created around each monitoring location at distances of 0.5, 1, 2, 4, 6, 8, and 10 miles. The daily acreage totals were made active on an individual basis to determine acreage totals within the buffer distances. The acreage totals for air and ground were calculated separately and were reported as totals for each buffer distance. In some instances sections with propanil use fell across the boundary between two buffers. To resolve this, the centroid of the PLS theme was made active and the acreage of that section was included in the totals for the buffer distance in which the centroid was located.

D. Statistical Analysis

Statistical analysis in this memorandum was conducted using MINITAB V12.1 (Minitab Inc., 1997), SigmaPlot V7.0 (SPSS Inc., 2000), and MicroSoft Excel 2000. Analysis techniques include simple correlation and multiple regression. The analysis is focused on 1) the first week of the compliance monitoring because it represents the baseline residues and use patterns without carryover from the previous week's applications, and 2) the peak week concentrations and the use patterns present during the monitoring week that produced the peak at each compliance monitoring site. By focusing on use patterns present during the peak week, conditions of use can be identified that should be modified to mitigate the magnitude of the peak to the desired risk management level. Specific use patterns present during the non-peak monitoring weeks, while interesting, do not contribute to the mitigation effort because they do not represent "worst case."

IV. Results

A. Regional Trends

Figure 2 shows the rice growing region of the Sacramento Valley with the 2001 compliance monitoring orchard sites are labeled. Results of the weekly compliance monitoring and PAL submissions were analyzed for patterns of use that might be major contributors to the off-site deposition observed.

1. Use Season Summary. Figure 3 shows the compliance monitoring results for the 2001 use season presented in an order that reflects the locations of the compliance monitoring orchards. The "West Side" area is comprised of five compliance monitoring orchards: Spurlock, Meyers, Weems, Zumwalt, and Strains, located along western side of the Sacramento Valley. The two orchards shown at the left side of the West Side group of orchards (Spurlock and Meyers) are at the base of the Coastal Mountain Range. Spurlock is the farther north of the two orchards. These two orchards sit on low hills just above the rice fields in Glenn and Colusa counties. The remaining West Side compliance monitoring orchards are on the valley floor, in Glenn and Colusa counties. These compliance monitoring orchards are shown in north to south order in Figure 3, beginning with Weems and ending with Strains. The "East Side" areas includes one compliance monitoring site in eastern Colusa County (Argo), the compliance monitoring sites in Butte, Sutter, Yuba, and Placer Counties, and the southern most compliance monitoring orchard in Yolo County (Figure 2). The "East Side" compliance monitoring orchards are shown in Figure 3 in a circular north to south order beginning with the western most site, Argo. Those orchards, in the sequence shown in Figure 3, are Argo, Gorrill, North Island, Ramada, Kullar, Sundial, Thiara, Dale, Farmland, Bains, and Faye.

The orchards at the extreme western edge of the rice growing region (Spurlock and Meyers) show the highest concentrations throughout the season. These two orchards are located in areas of heavy local use by both ground and air (helicopter only). The remaining West Side orchards show a discernable pattern of residues from north to south, reflecting the geographic distribution of propanil applications. Weems is surrounded by a high density of ground applications. In contrast, Zumwalt, on the eastern edge of the Westside rice acreage has no rice cultivation for several miles to the east. However, some aerial applications were made between 8 and 10 miles away from the Zumwalt orchard. The Strains site is in an area of very light propanil use compared to other areas of the valley. In fact, there is no rice in the immediate area of the Strains orchard. The "East Side" orchards also show a generalized north to south pattern that is likely influenced by the density of local ground applications and the proximity to aerial applications. Six compliance monitoring sites, Argo, Gorrill, North Island, Ramada, Kullar, and Sundial, surround the BCSA where, in 2001, only fixed wing aerial applications were allowed. The remaining orchards in the "East Side" area had no aerial applications within approximately 10 miles.

Based on the patterns of use and monitoring data, there are two mechanisms potentially contributing to the propanil residues observed in compliance monitoring orchard samples. The first contributing mechanism is long-range (miles), low-level drift deposition from many applications in the general area surrounding the compliance monitoring orchards. This long-range drift deposition may originate from both air and ground applications. However, as will be discussed below, measurable long-range drift is more likely to originate from aerial applications. This mechanism amounts to a background level and may constitute a sort of baseline to which residue contribution from more proximate ground applications is then added at Spurlock, Meyers, Zumwalt, Argo, Gorrill, North Island, Ramada, Kullar, and Sundial.

The second mechanism is relatively large deposition from single or a few relatively nearby applications. Nearby applications are likely responsible for the highest residues observed. In general, drift from nearby applications is more likely to have originated from ground applications since the propanil regulations dictate that unless expressly authorized by the Agricultural Commissioner, aerial applications cannot be made within four miles of prunes, grapes, or pistachios. During the 2001 use season, the propanil use data obtained directly from the counties on a weekly basis confirmed that no aerial applications occurred closer than four miles from any of the Compliance Monitoring sites, with the exception of Colusa County where aerial applications by helicopter were allowed between 2 and 4 miles from Meyers.

Based on the above discussion, the Compliance Monitoring Sites can be broadly separated into four groups: West Side #1, West Side #2, BCSA, and East Side. Two of the groups, West Side #1 and BCSA, have both air and ground applications in relatively close proximity (air/ground). The two remaining groups, West Side #2 and East Side, are most heavily influence by ground applications (ground). Table 3 shows the Compliance Monitoring sites included in each group. Tables 4-7 give summaries of the compliance monitoring results and the applications that occurred near each Compliance Monitoring Site during the first week of compliance monitoring and during the week in which the peak concentration was observed.

2. Compliance Monitoring Week 1. The first week of compliance monitoring (5/29/01 – 6/03/01) allows examination of baseline conditions. Background samples taken on 5/22/01 showed no detections at any of the compliance monitoring sites. With the exception of Glenn and Colusa Counties, no use occurred in the compliance monitoring area prior to 5/29/01. In Glenn County, except for a 28-acre ground application between ½ mile and 1 mile from Weems on May 28, no applications were close to the compliance monitoring sites. In Colusa County, during the week of 5/22/01 – 5/28/01 there were 2533 acres applied by air in Colusa County. It is possible that these earlier aerial applications contributed to the higher residues observed in the 6/3/01 sample from Meyers. However, the half-life of propanil in prune foliage is approximately 7 days (Barry, 2001a) thus it is more likely that activities during the sampling week of 5/29/01-6/03/01 were the major influence on residues observed in the 6/03/01 samples.

Tables 4 and 5 and Figures 4 and 5 present the compliance monitoring results from the first week of compliance monitoring sampling. Figure 4 suggests higher residue levels on average at the West Side #1 and BCSA sites (air/ground sites) relative to the West Side #2 and East Side sites (ground sites). However, the West Side #1 and BCSA sites are also in the areas where more individual applications and therefore more absolute acres were applied by both ground and air during Week 1. Only one of the 8 air influence sites showed a non-detect result. That site, Gorrill Ranch, had a very low volume of applied acres nearby. Only 70 acres of ground applications occurred between 2 and 4 miles away and only 179 acres of air application occurred between 6 and 10 miles away (the BCSA is 6 miles away from Gorrill).

The remaining BCSA sites, Spurlock, North Island, Ramada, Argo, and Sundial had ground applications made no closer than 2 miles and aerial applications of at least 100 acres between 4 and 6 miles away (Table 4). Kullar had ground applications made between 1 and 2 miles away and aerial applications made 4 to 6 miles away. Meyers had 590 acres of ground applications made between 2 and 4 miles away and 553 acres of aerial applications made between 2 and 4 miles away. Spurlock had 174 acres of ground applied between 2 and 4 miles away and 585 acres applied by air between 4 and 6 miles away. The higher residue levels at Meyers and Spurlock may be partially related to the large volume of both air and ground applications made relatively close. Aside from Gorrill and Sundial, however, the range of concentrations (0.1ppm – 0.15ppm) was relatively narrow (Table 4 and Figure 4).

In contrast, only 2 of the 8 no air influence sites showed detections during the first week. Those two sites were Weems and Zumwalt, in West Side#2 where ground applications were made between ½ mile and 1 mile away and substantial acreage was applied by ground within 4 miles of these compliance monitoring sites (2294 acres for Weems and 850 acres for Zumwalt). Weems had 75 acres applied by ground between ½ mile and 1 mile. Zumwalt had 80 acres applied by ground between ½ mile and 1 mile. With reference to these sites, it should be noted that DPR (2001) issued a letter to the CAC's providing guidance in issuing propanil application permits. The guidance states that applications may be allowed between ½ mile and 1 mile provided there is positive wind flow away from sensitive sites for the entire period of the application. If the applications between ½ mile and 1 mile away were indeed the source of the residues, then these results indicate that the guidance was not followed. If the applications made between ½ mile and 1 mile adhered to the guidance, then the residues observed at these two compliance monitoring sites for week 1 originated from applications 1 mile or more from the site (either ground beyond 1 mile or air beyond 4 miles). As stated above, significant ground acreage were applied within 4 miles of both sites. In addition, Zumwalt had 13 aerial applications (10 helicopter, 3 fixed wing) made between 8 and 10 miles away. It is possible those aerial applications contributed to the residues. However, Weems had no aerial applications made within 12 miles, suggesting that ground applications were the primary source of the residues.

The remaining sites, all in the East Side grouping, had little or no acres applied by ground within 4 miles during the week (Table 5). With the exception of Thiara, no ground applications were made closer than 2 miles.

The first week results suggest that some of these low level concentrations (~0.1 ppm) may be largely the result of relatively long range transport of propanil from aerial applications (within approximately 10 miles). The half-life of propanil in prune foliage is estimated at 7 days (Barry, 2001a). As a result, under the use patterns observed last season, propanil levels in the 0.1 ppm–0.2 ppm range (or even as high as 0.32 ppm at Gorrill as will be discussed later) might be expected all season at some sites due to constant, relatively long range transport of low levels of propanil drift from aerial applications alone. Figure 5 shows that some of the highest Week 1 concentrations were at compliance monitoring sites that did not have any ground applications closer than 2 miles. The two largest concentration observations with the closest ground applications no closer than 0.5 miles are Weems and Zumwalt, the two sites in West Side #2 (Figure 5). The residues measured at these two sites are likely the result of the close ground applications.

Figures 6 through 8 show the Week 1foliage concentrations observed versus the number of ground acres applied within 1, 2, and 4 miles of the compliance monitoring sites. Week 1 is early in the season and the density of ground applications is relatively low. There is no significant correlation between the ground acres applied within 1 or 2 miles and the concentration (r=0.139; p=0.607 and r=0.342; p=0.195, respectively). However, there is a marginally significant correlation between the ground acres applied within 4 miles and the concentration (r=0.456; p=0.076).

Figures 9 through 11 show the Week 1 foliage concentrations observed versus the number of air acres applied within 6, 8, and 10 miles. The concentration observed is significantly correlated with the air acres applied within 6, 8, and 10 miles (r=0.623; p=0.01, r=0.627; p=0.009, and r=0.749; p=0.001, respectively).

Relative to ground applications, there are three potential factors that could produce a greater contribution of measurable low-level, long range propanil drift from aerial applications: 1) Aerial applications are typically made at approximately 10 feet above the crop canopy compared to ground applications made at approximately 3 feet above the crop canopy, 2) aerial applications tend to have, on average, a larger volume of small droplets (fines or driftable fraction) released during the application because of the faster application speed, and 3) aerial applications can be made to large acreage over a relatively short period of time, the larger volume of small droplets may form cohesive "clouds" during the applications that are then available for off-site transport. Thus the larger volume of small droplets coupled with the higher release height may facilitate the long-range transport of low levels of propanil miles to the compliance monitoring sites. If this is not the case, then the Week 1 residues detected at the Air/Ground sites originated solely from ground applications at least 2 miles away.

In fact, it is most likely that the residues detected originated in part from both aerial and ground applications, even though, with the exception of Kullar, neither type of application was made closer than 2 miles from any of the Air/Ground sites. Figure 12 shows the relationship between Week 1 concentration, ground acres applied within 4 miles and air acres applied within 10 miles. Figure 12 indicates that the East Side sites (all non-detects), Strains (non-detect, West Side #2), and Gorrill (non-detect, BCSA) all had low concentrations, and low acreage of both ground 4 miles and air within 10 miles. The Weems site (0.11 ppm, West Side #2) had no air acres within 10 miles but well over

2000 acres of ground applied within 4 miles. The remainder of the sites, Spurlock (0.15 ppm, West Side #1), Meyers (0.12 ppm, West Side #1), Zumwalt (0.12 ppm, West Side #2), North Island (0.11 ppm, BCSA), Ramada (0.10 ppm, BCSA), Argo (0.10 ppm, BCSA), Kullar (0.11 ppm, BCSA), and Sundial (0.08 ppm, BCSA) all had either a large number of air acres applied within 10 miles, or a large number of ground acres applied within 4 miles, or both. Multiple linear regression was used to estimate the relative importance of the air and ground acres to describe the concentration patterns observed in the baseline Week 1 (Figure 12). The selection method used was Stepwise Regression. The dependent variable was the Week 1 propanil foliage concentration (week 1 conc (ppm)). The independent variables available for selection were: air acres applied within 4 miles (air4), air acres applied within 6 miles (air6), air acres applied within 8 miles (air8), air acres applied within 10 miles (air10), ground acres applied within 1 mile (ground1), ground acres applied within 2 miles (ground2), and ground acres applied within 4 miles (ground4). The resulting multiple regression equation is:

week 1 conc (ppm) = 0.0031 +0.000083 air10 +0.000048 ground4

$R^2 = 78\%$

The intercept is not significantly different from zero, indicating that, for a particular compliance monitoring orchard, if there were no aerial applications within 10 miles or ground applications within 4 miles that there should be no residues detected this early in the season. This is consistent with the compliance monitoring results for Week 1. The acres of air applied within 10 miles (air10) explained the largest proportion of the variation (56%) followed by acres of ground applied within 4 miles (ground4) (22%). In addition, the coefficient for air10 was about twice the size of the coefficient for ground 4. This was true on both the unstandardized and standardized scale. These results support the theory that aerial applications potentially contribute a measurable level of residues to prune orchards within a wide area (within 10 miles). However, ground applications no closer than 2 miles but within a 4 mile radius also appear to contribute significantly to these low level residues.

These results suggest that, although the residues levels are low, relatively long-range drift is occurring in the Sacramento Valley. This regression equation is not intended to predict for other weeks the concentrations expected given patterns of acres applied. Instead, it is intended to illustrate the relative importance of the aerial applications and ground applications in the levels of propanil residues observed at the compliance monitoring orchards during Week 1.

Figures 13 through 15 show the concentrations measured versus the minimum distance to air and ground applications. Figure 13 shows that the compliance monitoring sites with the highest Week 1 concentration also had aerial applications within approximately 10 miles. However, during Week 1 there is a wide range of concentrations (non-detect to 0.15 ppm) even among those sites. Figure 14 shows a wide range of residue values for sites with varying distances to the nearest ground applications. However, the sites that had smaller minimum distances to ground applications tend to have higher Week 1 residue levels. With the exception of Gorrill (non-detect), all sites had ground applications in the section that was at the minimum of 2 miles. At Gorrill the closest section with a ground application was three miles away. Figure 15 shows that as either air or ground applications (or both) get closer, the Week 1 residues increase at the orchards.

3. BCSA (Air/Ground) Week 1 Detailed Analysis. Closer examination of Week 1 results (Table 4) from the BCSA only, together with the weather data collected during the study from a site within the BCSA indicates that residues detected at any particular BSCA monitoring site is potentially related to certain days and a few relatively close applications (within approximately 8 miles) made on those days by both air and ground. Appendix A contains daily use and weather data patterns in and around the BSCA for Week 1.

a. ***North Island and Ramada.*** These data indicate that June 2 is probably the most critical day during Week 1 with respect to residues detected on foliage from North Island and Ramada (Appendix A, Figure A4). June 2 was the day before sample collection so residues deposited on this day would not have degraded appreciably (Barry, 2001a). In addition, wind conditions coupled with application patterns appear to suggest this was the most influential day during Week 1. The 100-acre aerial application made in the northeast corner of the BSCA and the 188 acre and 91 acre ground applications south of North Island and Ramada Ranch probably contributed some of the detected residues. According to the pilot's log, the 100-acre aerial application was conducted from 0830-0930. The 15-minute average winds speed ranged from approximately 8 mph at the beginning to 5 mph at the end of the application. Propanil from this application would require a travel time following release of approximately 30 minutes to 1-hour to reach North Island or Ramada. The hour following the application had wind speeds of 4.5 to 1.5 mph (Appendix A, Figure A9). The from wind direction during the application ranged between 125 degrees and 149 degrees (to direction between 305 degrees and 320 degrees). One hour after completion of the application the wind shifted so that the wind was from approximately 300 degrees (to 120 degrees). This wind shift would carry any small propanil droplets still airborne across the path of North Island and Ramada as the wind shifted. This may ultimately have deposited much of the propanil measured at those orchards because the shift occurred at approximately the time the propanil from the second half of the 100-acre aerial application would have reached those orchards. In addition, the large ground applications south of North Island (188 acres) and Ramada (91 and 97 acres) may have also contributed some residues. Exact time of these ground applications is unknown but the wind direction most of the day was from the general direction of those applications to the monitoring sites. Barry (2002) discusses the potential for large ground applications to contribute measurable residues considerable distances downwind.

b. ***Kullar and Sundial.*** Contrary to the idea of aerial application influence, it appears unlikely that any aerial applications were significant contributors at these two sites during Week 1. Ground applications likely to have contributed to Kullar and Sundial occurred on May 31, June 2 and June 3 (Appendix A, Figures A2, A4, and A5). On May 31 early in the day the general wind direction, relative to the ground applications, was away from Kullar and Sundial, however, just before noon the wind shifted toward these sites (Appendix A, Figure A7). The aerial application of 145 acres had been completed hours earlier (by 0800) and following that application the wind remained away from Kullar and Sundial until the shift at noon. However, the three ground applications of 28, 26, and 139 acres may have been contributors. On June 2 the wind direction patterns from 1030 until 0200 indicate it is possible that the large ground application of 150 acres near Kullar and Sundial contributed residues to both sites. It should be noted that it is unknown whether this large application was completed in a single day. Based upon known application times, wind direction and wind speed data, it is unlikely that any of the aerial applications made on June 2 were significant contributors to the residues at Kullar and Sundial (Appendix A, Figure A9). The 199-acre aerial application made approximately five miles from Kullar was made between 0730 hrs and 0950 hrs. During the entire application time the wind direction was approximately 135 degrees (from the Southeast to the Northwest). Between 1030 hrs and 1145 hrs the wind speed dropped and the direction shifted to approximately 270 degrees to 315 degrees (from the Northwest to the Southeast). This shift did not occur until roughly 30 minutes after the completion of the application. Therefore it is unlikely, but theoretically possible, that residue from the end 199-acre application was deposited at Kullar. On June 3 a 50 acre ground application was made within 2 miles of both Kullar and Sundial. The wind direction on June 3 indicates it is unlikely that propanil residues from this application would have reached Kullar (Appendix A, Figure A10). Sundial was consistently downwind of this application but the day was quite breezy, likely leading to some dilution of residues relative to calmer days.

c. ***Argo.*** The Argo site of the BSCA appears to be influenced by two large ground applications made on May 30 (117 and 118 acres), and a series of aerial applications made in the same section between 0900 and 1115 on May 31 (333 acres), and two aerial applications June 2 (20 and 82 acres) (Appendix A, Figures A1, A2, and A4). The ground applications were at least two miles away. The aerial applications were between 4 and 6 miles away.

d. ***Summary.*** In summary, prune foliage from five of the six monitoring sites surrounding the BCSA showed detection of propanil at or close to the 0.1 ppm regulatory threshold during Week 1. No damage of prune foliage is expected at this residue level (Barry, 2001b). Aerial applications between 4 and 6 miles away reasonably appear to be sources of some of the residues at three of the sites. Ground applications reasonably appear to be sources of some of the residues at all five sites. Two of the five sites, Kullar and Sundial, potentially appear to have received residues only from ground applications. At four of the five sites ground applications occurred no closer than two miles. At one site, Kullar, 200 acres were applied by ground between 1 and 2 miles away.

4. Compliance Monitoring Peak Week. Peak week analysis examines application events associated with the peak concentrations observed (Tables 6 and 7). Note that the peak week dates vary by site. For example, the peak week for Meyers, Gorrill, and Kullar is Week 2, while the peak week for the remainder of the Air/Ground sites is Week 4. In Tables 6 and 7, the peak week is shown in parentheses next to the site name. Figure 16 suggests continued separation between the Air/Ground and Ground sites. However, aerial applications alone do not account for the higher residues observed. Confounding this pattern is the overall greater density of both ground and aerial applications in the general vicinity of the air influence sites.

Figures 17 through 19 show the observed concentrations versus the air acres applied within 6, 8,and 10 miles. The peak concentrations are significantly correlated with air acres applied within 6 miles ($r=0.725$, $p=0.001$) and air acres applied within 8 miles ($r=0.628$, $p=0.009$). However, the correlation of concentration with air acres applied within 10 miles is marginally significant ($r=0.47$, $p=0.066$). These results suggest that more proximate aerial applications are associated with the peak concentrations. The two highest peak concentrations were observed at Meyers and Spurlock of the West Side #1 group. The concentration observations from these sites appear to be associated most closely with aerial applications within 6 miles. In particular, Meyers had 11 aerial applications made within 4 miles, the largest of which was 102 acres. Spurlock had 6 aerial applications within 6 miles, the largest of which was 176 acres.

Figures 20 through 22 show the observed concentrations versus the ground acres applied within 1, 2, and 4 miles. There were no statistically significant correlations between the concentration and the acres of ground applied within 1, 2, and 4 miles. The two West Side #1 sites (Meyers and Spurlock) appear to not follow the general trend of increased residue levels as close ground acres increase evident in Figures 20 through 22. This may be because of local effects due to terrain (these sites are on low hills slightly above the rice growing areas), individual influential ground applications, their proximity to helicopter applications, or the sum of all these factors.

Multiple linear regression analysis was used to rank the importance of the contributions from ground and aerial applications for the set of Peak Week Compliance Monitoring results. Stepwise regression method was used to select the regression equation. The dependent variable was the Peak Week propanil foliage concentration (ppm) (Peak conc. (ppm)). The independent variables available for selection were: air acres applied within 4 miles (air4), air acres applied within 6 miles (air6), air acres applied within 8 miles (air8), air acres applied within 10 miles (air10), ground acres applied within 1 mile (ground1), ground acres applied within 2 miles (ground2), and ground acres applied within 4 miles (ground4). The resulting equation is:

$$\text{Peak conc. (ppm)} = 0.146 + 0.000384\ \text{air6} + 0.000408\ \text{ground1}$$

$$R^2 = 60\%$$

The intercept is significantly different from zero, indicating a high probability for compliance monitoring sites to show residues above the detection limit independent of use patterns during the peak week. The percent variation explained by the air acres applied within 6 miles is 52% and the percent variation explained by the ground acres applied within 1 mile is 8%. The unstandardized regression coefficients for air6 and ground1 are about the same size. However, the standardized regression coefficient for air6 is approximately 3 times the size of the standardized regression coefficient for ground1. This indicates that for the data set as a whole, the number of air acres applied tends to have about 3 times the influence on the residues levels relative to the number of ground acres applied within 1 mile.

Figure 23 shows the peak concentration versus the ground acres applied within 1 mile and the air acres applied within 6 miles. Figure 23 suggests that, with respect to peak concentrations, the compliance monitoring sites split into three groups: 1) sites with peaks that appear to be associated with nearby aerial applications (Spurlock, Meyers, North Island, Kullar, and Argo), 2) sites with peaks that appear to be associated with nearby ground applications (Ramada, Sundial, Weems, and Dale), and 3) sites with peaks that appear to be associated with further away activities, either air or ground (Gorrill, Zumwalt, Strains, Thiara, Farmland, Bains, and Faye).

With the exception of Meyers, the sites with peaks that appear to be associated with nearby aerial applications did not have ground applications closer than 1 mile. The sites that did not have ground applications closer than 1 mile showed peak concentrations between 0.54 ppm and 0.22 ppm. Those sites were Spurlock (0.54 ppm), North Island (0.34 ppm), Kullar (0.34 ppm), and Argo (0.22 ppm). Argo may show a lower peak because, although this site is approximately 4 miles west of the BCSA, there is a large riparian area that likely is a partial filter between the BCSA and Argo. Meyers (0.61 ppm) had both close aerial applications (2-4 miles) and close ground applications (less than ½ mile). Therefore, in the case of this site it is difficult to separate the relative contributions of close ground and close aerial applications.

The sites with peak concentrations that appear to be associated with nearby ground applications (Ramada, Sundial, Weems, and Dale) all had ground applications between 0.5 miles and 1 mile away (Tables 6 and 7). Ramada (0.44 ppm) and Sundial (0.17 ppm) had 334 acres and 194 acre of ground applied within 1 mile, respectively. In addition, these two sites also had 307 acres and 80 acres of air applied within 4 to 6 miles, respectively. However, the peak concentrations appear to be associated with the close ground applications. These sites will be discussed in more detail in the BCSA section below. Weems (0.28) and Dale (0.11 ppm) had no aerial applications closer than 12 miles and 24 miles, respectively. The peak residues at these two sites are most likely the result of ground applications.

The sites with peaks that appear to be associated with further away activities (Gorrill, Zumwalt, Strains, Thiara, Farmland, Bains, and Faye), in general, have lower residue levels. The highest residue level in this group is at Gorrill (0.32 ppm). It does appear that these residues are associated with aerial applications between 6 and 8 miles away (see discussion in BCSA section below). Of the remaining sites, Zumwalt (0.18 ppm) and Strains (0.06 ppm) had aerial applications of 1487 acres and 37 acres between 8 and 10 miles away, respectively. Meteorological data indicate that it is possible in the case of Zumwalt that aerial applications in the BCSA (fixed wing) on June 6 (324 acres) and on the West Side (helicopter) on June 9 (197 acres) contributed some residues to the peak concentration. However, Zumwalt also had 2901 acres of ground applied during the peak week, 188 acres of which were applied between 1 and 2 miles away. Therefore, it is most likely that contributions from both ground and air are important at Zumwalt, the aerial applications contributing the low level "background" and the closer ground applications contributing the additional residues to comprise the actual peak. Thiara (0.12 ppm), Farmland (0.11 ppm), Bains (0.18 ppm), and Faye (0.09 ppm) had no aerial application closer than 16 miles, 17 miles, 12 miles, and 11 miles, respectively. Due to the large separation between aerial applications and these sites, it is most likely that the residues at these sites originated largely from ground applications.

5. BCSA Peak Week Detailed Analysis. Closer examination of Peak Week results from the BCSA only, together with the weather data collected from a site within the BCSA during the study indicates that residues detected at any particular BSCA monitoring site can be related to certain days and a few relatively close applications (within approximately 8 miles) made on those days by both air and ground. Appendix B and Appendix C show use daily patterns and weather data in the vicinity of the BSCA for the Peak Weeks of Week 2 and Week 4, respectively.

a. Gorrill and Kullar. The season peak occurred during Week 2 (June 4–June 10) at Gorrill and Kullar (Appendix B). On June 4 between 1159 and 1300 hours 104 acres was applied by air between 4 and 5 miles from Kullar (Appendix B, Figure B1). The wind direction during and immediately following the application was in the general direction towards Kullar. Two additional aerial applications of 105 acres and 52 acres were made later in the afternoon (1307 – 1423 hours). However, wind shifts occurred that may have reduced the likelihood of deposition from those applications (Appendix B, Figure B8). On June 5 an aerial application of 111 acres was conducted between 0905 and 1010 hours approximately 7 miles southeast of Gorrill (Appendix B, Figure B2). The wind direction during this application, and for several hours after, was towards the Gorrill monitoring site (Appendix B, Figure B9). In addition, a 154-acre ground application was recorded that day in the section direction north of the 111-acre aerial application. It is unlikely that Gorrill received any residues on June 6 (Appendix B, Figure B3). However, it is possible Kullar received residues from a 114-acre ground application to the northwest, and an aerial application of 61 acres directly to the west. On June 7 a total of 386 acres was applied by air in the section 19N01E23 (Appendix B, Figure B4). Unfortunately, since this series of 5 applications was not recorded in the study pilot's log, so it is not known what time these applications occurred or how long the applications lasted. It can probably be assumed that they were made as one unit. If these applications were made in the morning, it is unlikely that residues from these applications reached Gorrill. However, if they were made in the afternoon (as some aerial applications were during the season) then residues from these applications may have contributed to the peak concentration observed at Gorrill. A 111 acre ground application made between 1 and 2 miles from Kullar likely contributed residues to Kullar. On June 8, between 8 and 9 miles southwest of Gorrill, a series of 3 applications totaling 253 acres were applied by air (Appendix B, Figure B5). Since these applications were not entered into the pilot's log, the time and duration of the applications is unknown. However, the wind direction was consistently from the southeast (from the applications) to the northwest (to Gorrill) the entire day (Appendix B, Figure B12). It is likely that some residues from these applications reached Gorrill. On June 9 it is possible that Kullar received some residues from a 150-acre ground application between 1 and 2 miles to the southwest

(Appendix B, Figure B6). However, this likelihood depends upon when the ground application occurred during the day since significant wind shifts occurred several times (Appendix B, Figure B13). June 10 may be the most important day in terms of the residues detected at Gorrill (Appendix B, Figure B7). The foliage is collected in the morning and Gorrill was at the north end of the collection sequence. Between 0715 and 0850 hours an aerial application of 143 acres was made between 6 and 7 miles due south of Gorrill. The wind direction during and for two hour immediately following that application was generally to the north (Appendix B, Figure B14). If the samples were collected after the residues from this application reached Gorrill, this would be fresh deposition with no degradation. Thus explaining the peak in the Gorrill residues when no applications were made by with ground or air close to this monitoring site. Wind direction in the morning of June 10 was away from Kullar so it is unlikely that this monitoring site received any residues before collection.

In summary, the peak at Gorrill appears to be associated with specific aerial applications. The aerial application that occurred early in the day on June 10 (collection day) was probably the most important. The regression analysis and Figure 25 suggest that peak at Kullar is most closely associated with aerial applications. Kullar was directly downwind of large aerial applications several days during the peak week. However, ground applications were also made in the vicinity of Kullar during the peak week. Therefore, it is likely that ground applications contributed a measurable portion of the peak residues observed at this orchard.

b. ***North Island, Ramada, Sundial, and Argo.*** The peak week for these four sites was Week 4 (June 19-June 25) (Appendix C). June 19 Sundial was likely downwind of a 122-acre ground application (Appendix C, Figures C1 and C8). It is also possible, depending upon the timing, that North Island was downwind of at least some of a total of 210 acres of ground applications. However, this is only possible if the applications were made in the afternoon. This is also true of a series of ground applications to the south and west of Argo. The morning of June 20 Sundial was generally downwind of both ground and air applications (Appendix C, Figures C2 and

C9). On June 20 Ramada may have received residues from a 50-acre ground application within the same section (within 1 mile). On June 21 both North Island and Ramada were downwind of a significant volume of applications by both ground and air (Appendix C, Figures C3 and C10). The wind direction was variable but starting at 0700 was generally to the north, northwest, and northeast, depending upon the time of day. Ground applications were made close to Argo on June 21, but the wind direction was generally directly not towards. On June 22, three aerial applications were made in the northern portion of the BCSA (Appendix C, Figure C4). A 175-acre application was made from 0530-0640 hrs. The wind was to the south/southwest during this application, however, shortly after completions of the application the wind shifted to the north/northeast (towards North Island) (Appendix C, Figure C11). Therefore, it is possible that some propanil from this application reached North Island. Two other aerial applications were made in the northern portion of BCSA, 68 acres and 62 acres in two separate sections. These applications were not recorded in the study pilot's log so the times of the applications are not known. However, the general wind direction from 0730 to noon was to the north/northeast. Therefore, it is possible some residues from these applications were deposited at North Island and/or Ramada. In addition, that day Ramada had significant ground acres applied within either the same, or adjacent sections. June 23 showed steady wind to the northwest (Appendix C, Figure C12). The distribution of both ground and aerial applications on that day indicates that any drift probably did not contact the compliance monitoring orchards.

On June 24 a total of 158 acres were applied by ground in the sections immediately south and east of Ramada (Appendix C, Figure C6). These applications were ½ mile to 1 away. In addition, the wind direction was consistently to the Ramada orchard from the sections where the applications took place (Appendix C, Figure C13). North Island had 99 acres applied by ground within approximately 1 mile. North Island was generally downwind of this section. Any applications that took place on June 25 (collection day) would have had to be early in the day to have affected the residues detected for this week (Appendix C, Figure 7). In the morning the wind direction was between to the northwest, north, and west (Appendix C, Figure C14). Therefore, North Island and Ramada would not have received residues from the BCSA. However, Ramada did have ground applications immediately to the southeast. If these applications were early, they could have significantly influenced the residue levels.

In summary, ground applications appear to be the most plausible explanation for the peak concentrations observed at Ramada and Sundial. In particular, the high peak observed at Ramada may be the result of ground applications made nearby on June 24, the day before collection may. The source of residues detect at North Island and Argo is less clear. The regression analysis and Figure 23 suggest that aerial applications within 6 miles were the major source of residues at these two orchards. However, a significant number of ground acres were also applied during the week in the general vicinity of these two orchards. Aerial applications most likely did contribute to the residues but specific aerial applications cannot be conclusively linked to the peaks.

c. BCSA *Summary.* The detailed BCSA analysis generally supports the patterns observed in Figure 23. The BCSA sites with peaks appearing to be associated primarily with nearby aerial applications (generally within 8 miles) are North Island, Kullar, Argo, and Gorrill. However, ground applications likely contributed some residues. The detailed analysis suggests the sites with peaks appearing to be associated primarily with nearby ground applications are Ramada and Sundial.

6. County Daily Acreage Cap Proposal. The phenomenon of "atmospheric loading" of propanil during the use season has been theorized for some time. There has been little actual data demonstrating the phenomenon. The half-life of propanil in the atmosphere is unknown. Nonetheless, the current propanil regulations (CCR Title 3, 6462) includes daily county acreage caps intended control any potential atmospheric loading. Atmospheric loading is perceived as a persistent regional build-up of residues in the atmosphere from many applications (Akesson, 1999). This atmospheric loading is then assumed to produce the peaks in compliance monitoring concentrations.

Whether or not atmospheric loading exists, daily acreage caps on aerial applications are probably prudent because of long range drift potential due to the ability to complete large applications over a short period of time on a single day. As discussed above, the levels of aerial applications over the last few seasons appear to lead to a "background" prune foliage residue level in the neighborhood of 0.1 ppm to 0.2 ppm. In the BCSA a daily aerial acreage cap of 720 acres was followed. In addition, in 2001 the BCSA study allowed fixed wing applications only, the assumed worst-case drift scenario for aerial applications. In Glenn and Colusa Counties the regulations stipulate helicopter applications only and daily aerial application limits of 300 and 500 acre limits per day, respectively. Fixed-wind aircraft travel over 100 mph, rotary aircraft over 50 mph. For example, during the 2001 CPTF study, a fixed-wing application of 251 acres was made over a two-hour period. Numerous aerial applications in the neighborhood of 100 – 200 acres were made. These applications took no more than two hours each. Also as discussed above, the short application time coupled with the release height of 10 feet creates the potential for cohesive clouds of small droplets (fines) originating from single field applications to travel long distances. In addition, because of the scale of the process, there is the potential for long-range drift (miles) from multiple aerial applications in the same general area on the same day to contact a single orchard. Therefore, an increase in the number of acres applied by air relative to the current use patterns could lead to higher off-site residues valley-wide. It is likely that limiting daily aerial acreage to the levels practiced in the BSCA for the past two years together with a strict 4-mile buffer will maintain the application density and thus aerial application residue contributions reasonably similar those observed in during the last few seasons.

Ground applications require much more time to complete than aerial applications of comparable size. Ground rigs travel approximately 6 mph and have a release height of approximately 3 feet. A 200-acre ground application would take all day to complete (Tom Anderson, per. comm.). Analysis of CPTF ground application data (Barry, 2002) suggests it is unlikely that a single ground application contributes a substantial level of deposition beyond about 2 miles.

One method to ascertain whether a significant level of atmospheric loading exists is to examine the season long compliance monitoring concentrations at individual monitoring sites together with the daily acreage totals in the counties. If atmospheric loading is indeed a significant contributor to residues observed at compliance monitoring sites, then the residues measured each week should at least approximately follow the patterns of application volume (acreage) because atmospheric loading as it is presented is a large scale phenomenon. Therefore, application events in the county at large should be reflected in the residue concentration patterns. In addition, compliance monitoring locations in the same general region (e.g., the north Sacramento Valley) should show approximately similar patterns of concentrations. Figures 24 through 26 show for Colusa, Glenn, and Butte counties both the daily acreage applied within each compliance monitoring week throughout the season and the compliance monitoring prune foliage results. A proposed cap of 3% per day of the rice acres by air and ground combined (CRRB, 2001) in each county is shown. These three counties are shown because the highest observed prune foliage concentrations were recorded at compliance monitoring sites in those counties. All graphs are on the same scale to allow direct comparison between counties and sites.

An examination of all nine graphs does not show a consistent regional pattern. Peak concentrations at the various sites occur during different weeks and at significantly differing magnitudes. These graphs suggest local effects (within a few miles) are driving the residue levels measured at a particular orchard on a particular date rather than a larger regional phenomenon (air basin scale). With the exception of North Island in Butte County, there is no general trend of residues with the range of daily acreage applied each week. And there is a wide range of residue levels observed for sites even within the same county where the use level is necessarily the same. It appears that the residues detected at a particular orchard are the result of activities in the relatively immediate area of that orchard for a particular week.

The effectiveness of a daily acreage cap, at least at the level proposed, is questionable. A 3% per day per county acreage cap would reduce the daily applications substantially only in Glenn County. In Colusa County the daily acreage was only above the proposed daily cap on two days all season. The level of daily use would not change substantially under a 3% per day acreage cap. In Butte County there was only one day slightly above the proposed cap. Therefore, virtually no change in the observed daily use level would be necessary to meet the cap.

V. Discussion

These results suggest that aerial applications in a relatively broad area (within approximately 10 miles) contribute throughout the season a low but measurable level of residues to compliance monitoring orchards. This appears to be true in both the West Side where since 1980 only helicopters are allowed to operate, and in the BCSA where only fixed wing application were allowed in the 2001 season. This "background" level of residues is the base upon which residue contributions from more proximate activities are added. The more proximate activities appear to produce the observed peaks during the season.

The important proximate activities appear to be aerial applications (helicopter or fixed wing) within about 6 miles and/or ground applications within 1 or 2 miles. There does not appear to be a measurable distinction between helicopter and fixed wing. In fact, the two compliance monitoring sites primarily influenced by helicopter applications (Meyers and Spurlock) show the highest peak residues in the compliance monitoring results. For Meyers it is impossible to separate the effect of close ground applications (within 1 mile) from the effect of close helicopter applications (within 2–4 miles). However, it is likely both types of applications were important in producing the 0.61 ppm observed at Meyers. At Spurlock the case for the helicopter applications as the primary source of the peak residues is more compelling. Spurlock showed a peak concentration of 0.54 ppm and had no ground applications closer than 1 mile during the peak week. Other sites with similar ground application patterns but no aerial applications showed peak concentrations no higher than 0.18 ppm. The compliance monitoring sites surrounding the BCSA would have received residues from fixed wing aerial applications only. In addition, no fixed wing aerial applications were made closer than 4 miles from those monitoring sites. Several sites appear to have aerial applications at the primary source of peak residues, Gorrill (0.32 ppm), North Island (0.34 ppm), Kullar (0.34 ppm) and Argo (0.22 ppm).

The highest peak among the BCSA compliance monitoring sites, at Ramada (0.44 ppm), appears to be most closely linked to close ground applications. The peak at Sundial (0.17 ppm) also appears to be primarily related to close ground applications. The potential for close ground applications alone to produce a relatively high peak concentration is most clearly demonstrated at the Weems site (0.28 ppm). This peak concentration is consistent with the ground application drift modeling results that indicate a persistent wind direction towards a sensitive site 1 mile away during a single 40 acre ground application would results in a propanil residue level of 0.11 ppm (Barry, 2002). Weems had 348 acres of ground applications made within 1 mile during its Peak Week.

In general, during the 2001 compliance monitoring season the peak concentrations observed at sites influenced primarily by ground applications were low, ranging from 0.06 ppm at Strains to 0.28 ppm at Weems. Most ground influence compliance monitoring sites had peak concentrations in the neighborhood of 0.12 ppm. However, there is clear indication that ground applications alone can produce very high peak concentrations. Two events in previous monitoring years, one in Butte County in 1999 and one in Glenn County in 2000, confirm the potential for a single ground application to produce a high residue level. In 1999 a single 120 acre ground application made just across a dirt road from the Butte #1 compliance monitoring orchard (Fenn) was directly associated with a peak concentration of 1.07 ppm. In 2000, Glenn County filed a civil penalty after a residue level of 1.20 ppm was measured at Spurlock prunes. A ground application of 154 acres had been made adjacent (within 50 ft) of the Spurlock compliance monitoring orchard.

In Summary, there are six broad observations to be made from this data and analysis: 1) both ground and aerial applications have the potential for long range drift to occur but this potential is greatest for aerial applications, 2) applications closer to sensitive sites (e.g. compliance monitoring orchards) have more influence on observed residue levels than applications farther away, 3) larger applications have more influence on observed residue levels than smaller applications, 4) drift from aerial applications is probably relatively transient due to the short application time and, therefore, is highly dependent upon wind direction during and immediately following (1 to 2 hours) a particular aerial application, 5) there does not appear to be any evidence to support the concept of regional atmospheric loading, and 6) these compliance monitoring results do not support a distinction between fixed wing and helicopter applications.

Clearly, both air and ground applications must be considered when designing and implementing a mitigation plan. The appropriate mix of air and ground controls will depend upon the desired mitigation goal. These results can aid risk managers in selecting that mix of air and ground controls.

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Table 1. Compliance monitoring results for the 2001 Propanil Use Season. Propanil prune foliage residue levels (ppm) by site and collection date.

County	Site	Collection Date							
		5/22	6/3	6/11	6/18	6/25	7/2	7/9	7/16
Butte	Gorrill	ND†	ND	0.32	0.20	0.18	0.11	0.08	0.10
Colusa	Zumwalt	ND	0.12	0.18	0.14	0.14	0.09	0.11	0.08
Colusa	Meyers	ND	0.12	0.61	0.24	0.16	0.08	0.06	0.06
Colusa	Strains	ND	ND	ND	0.06	0.05	0.04	ND	ND
Glenn	Weems	ND	0.11	0.17	0.17	0.28	0.29	0.15	0.08
Glenn	Argo	ND	0.10	0.12	0.18	0.22	0.17	0.11	0.08
Glenn	Spurlock	ND	0.15	0.23	0.20	0.54	0.31	0.27	0.14
Placer	Farmland	ND	ND	0.08	0.11	0.09	0.05	0.05	0.08
Sutter	Bains	ND	ND	0.07	0.11	0.18	0.07	0.09	0.09
Sutter	Dale	ND	ND	0.08	0.11	0.11	0.08	0.07	0.09
Yolo	Faye	ND	ND	ND	0.06	0.06	0.09	0.07	0.09
Yuba	Thiara	ND	ND	0.12	0.06	0.07	0.04	0.06	0.06

† ND = non-detect. Detection Limit = 0.01ppm

Table 2. 2001 Butte County Study Area (BCSA) results. Prune foliage Propanil residues (ppm) at collection sites. Note: Gorrill and Argo served as both Compliance Monitoring sites and BCSA sites. Therefore, prune foliage results for those sites are reported in both Table 1 and Table 2.

Site	**May 22**	**Week1** 5/29–6/3	**Week2** 6/4–6/10	**Week 3** 6/11–6/18	**Week 4** 6/19-6/25	**Week 5** 6/26-7/2
Gorrill	ND†	ND	0.32	0.20	0.18	0.11
North Is.	ND	0.11	0.17	0.23	0.34	0.15
Ramada	ND	0.10	0.20	0.13	0.44	0.13
Argo	ND	0.10	0.12	0.18	0.22	0.17
Kullar	ND	0.11	0.34	0.25	0.24	0.12
Sundial	ND	0.08	0.16	0.15	0.17	0.15

† ND = non-detect. Detection Limit = 0.01ppm

Table 3. Grouping of Compliance Monitoring Sites. Note that Argo has been grouped with the Butte County Study Area (BCSA) sites because samples were collected there as part of the Butte County Study. Argo is approximately 4 miles from the BCSA.

Air/Ground	**Ground**
West side #1	**West Side #2**
Spurlock	Weems
Meyers	Zumwalt
	Strains
East Side/BCSA	**East Side**
Gorrill	Thiara
North Island	Dale
Ramada	Farmland
Argo	Bains
Kullar	Faye
Sundial	

Table 4. Compliance Monitoring and use at Air/Ground site during baseline Week #1 (5/29/01 – 6/3/01).

Week 1 Concentration Results

West Side #1						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total Acres**	
Spurlock	0.15	2 – 4 miles	174	4 – 6 miles	585	877
Meyers	0.12	2 – 4miles	590	2 – 4 miles	553	1092
Butte County Study Area						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total |Acres**	
Gorrill[†]	0.00(ND*)	2 – 4 miles	70	6 – 8 miles	179	280
North Island	0.11	2 – 4 miles	238	4 – 6 miles	100	633
Ramada	0.10	2 – 4 miles	340	4 – 6 miles	100	479
Argo	0.10	2 – 4 miles	375	4 – 6 miles	660	1384
Kullar	0.11	1 – 2 miles	200	4 – 6 miles	199	1284
Sundial	0.08	2 - 4 miles	226	4 – 6 miles	199	1205

[†] The north boundary of the Butte County Study Area is 6 miles from Gorrill

[*] ND = no detection, Detection Limit = 0.01ppm. For analysis purposes 0.0 has been substituted for ND.

Table 5. Compliance Monitoring and use at Ground sites during baseline Week #1 (5/29/01 – 6/3/01).

First Week Results

West Side #2				
Site	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres ground ½ – 4 miles**
		Distance Range	**Total Acres**	
Weems	0.11	½ - 1 mile	75	2294
Zumwalt	0.12	½ - 1 mile	80	850
Strains	0.00 (ND*)	> 4 miles	-	0
East Side				
Site	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres ground ½ – 4 miles**
		Distance Range	**Total Acres**	
Thiara	0.00 (ND)	½ – 1 miles	71	249
Dale	0.00 (ND)	> 4 miles	0	0
Farmland	0.00 (ND)	2 – 4 miles	80	80
Bains	0.00 (ND)	> 4 miles	-	0
Faye	0.00 (ND)	2 – 4 miles	0	0

* ND = no detection, Detection Limit = 0.01ppm. For analysis purposes 0.0 has been substituted for ND.

Table 6. Peak concentration week Compliance Monitoring and use at Air/Ground sites. Number in parentheses following the site name is Peak Week number.

Peak Concentration Week Results

West Side #1						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total Acres**	
Spurlock (4)	0.54	1 – 2 mile	435	4 – 6 miles	507	1196
Meyers (2)	0.61	< ½ mile	59	2 – 4 miles	378	2397
Butte County Study Area						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total |Acres**	
Gorrill† (2)	0.32	2 – 4 miles	158	6 – 8 miles	425	1671
North Island (4)	0.34	1 - 2 miles	987	4 – 6 miles	508	2862
Ramada (4)	0.44	½ - 1 mile	334	4 – 6 miles	307	2972
Argo (4)	0.22	1 – 2 miles	477	4 – 6 miles	809	3887
Kullar (2)	0.34	1 – 2 miles	802	4 – 6 miles	451	4196
Sundial (4)	0.17	½ - 1 mile	194	4 – 6 miles	80	3597

† Closest Aerial Application to Gorrill is 6 miles

Table 7. Peak concentration week Compliance Monitoring and use at Ground sites. Number in parentheses following the site name is Peak Week number.

Peak Concentration Week

West Side #2				
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres of ground ½ mile – 4 miles**
		Distance Range	**Total Acres**	
Weems (4)	0.28	½ - 1 mile	348	1700
Zumwalt (2)	0.18	1 - 2 miles	188	2901
Strains (3)	0.06	1 – 2 miles	180	1119
East Side				
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres of ground ½ mile – 4 miles**
		Distance Range	**Total Acres**	
Thiara (2)	0.12	2 – 4 miles	672	672
Dale (3)	0.11	½ - 1 mile	99	2293
Farmland (3)	0.11	1 - 2 miles	95	870
Bains (4)	0.18	1 - 2 miles	150	981
Faye (5)	0.09	1 – 2 miles	93	338

Figure 1. Increase in total number of acres applied with propanil between 1996 and 2001. Also shown is a breakdown of total number of acres into acres of aerial and ground applications.

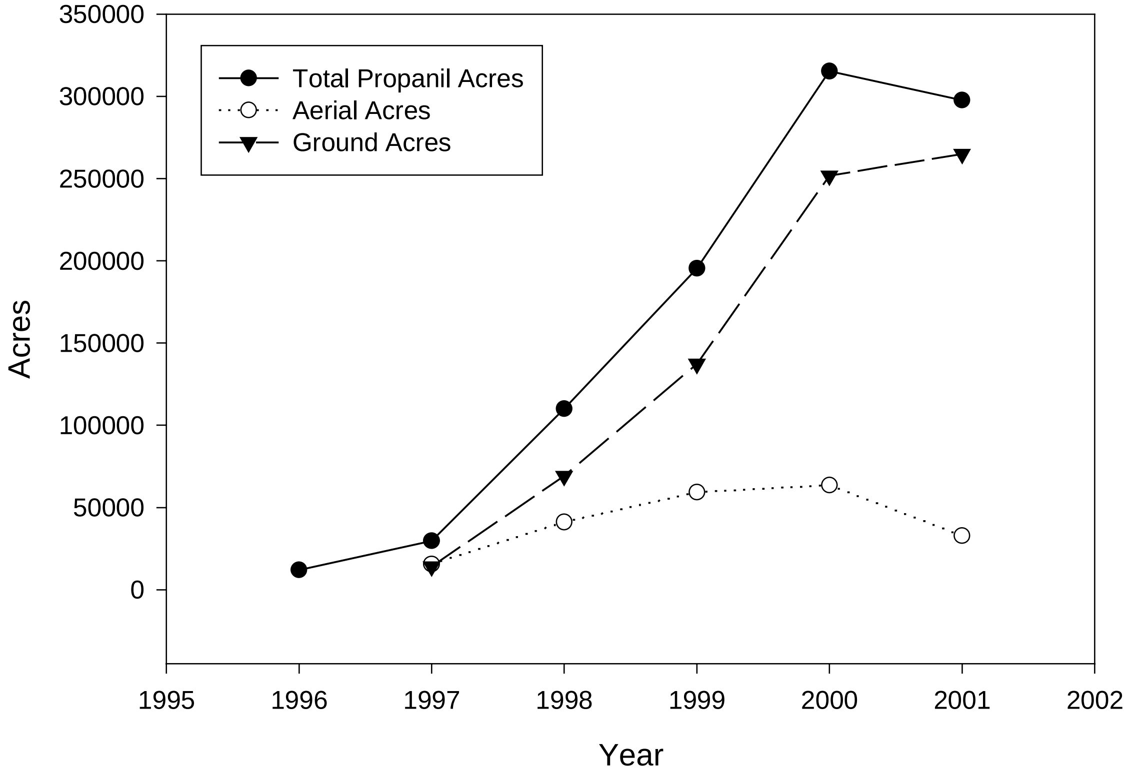

Figure 2. GIS map of rice region of the Sacramento Valley

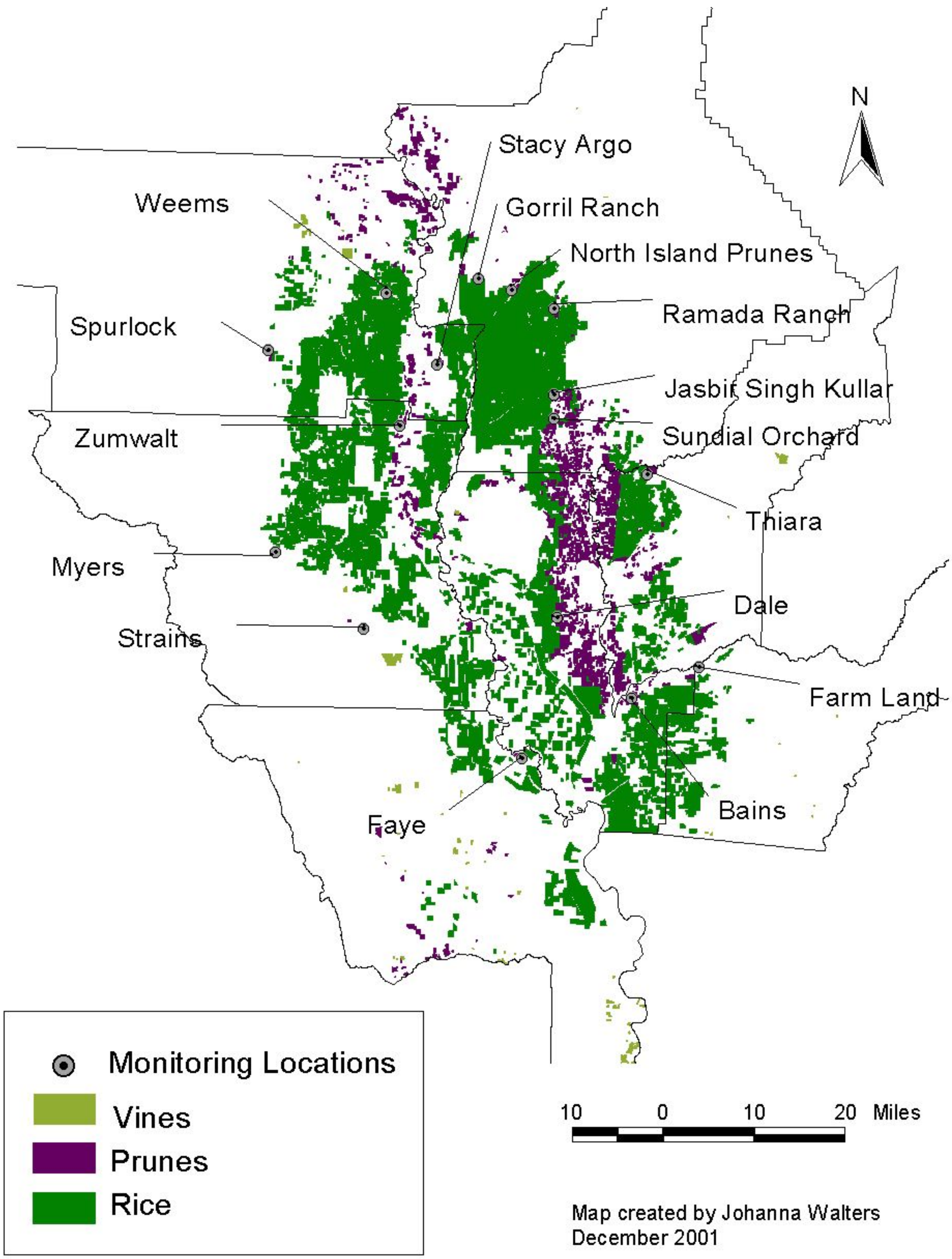

Figure 3. Propanil compliance monitoring results for the 2001 use season presented in an order that reflects the locations of the compliance monitoring orchards. The curve for each site shows compliance monitoring orchard foliage concentration results for each of the seven weeks from May 29, 2001 to July 9, 2001. For tabular presentation of the compliance monitoring orchard foliage concentration results see Table 1.

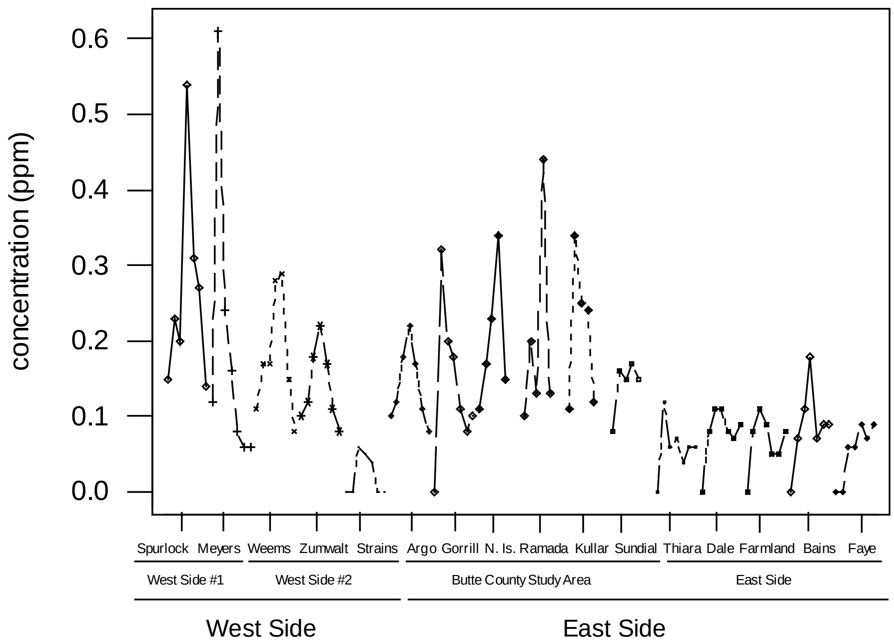

Figure 4. Week 1 Compliance Monitoring results. Sites separated according to four groups: West Side #1 (air/ground), West Side #2 (ground), Butte County Study Area (air/ground), and East Side (ground).

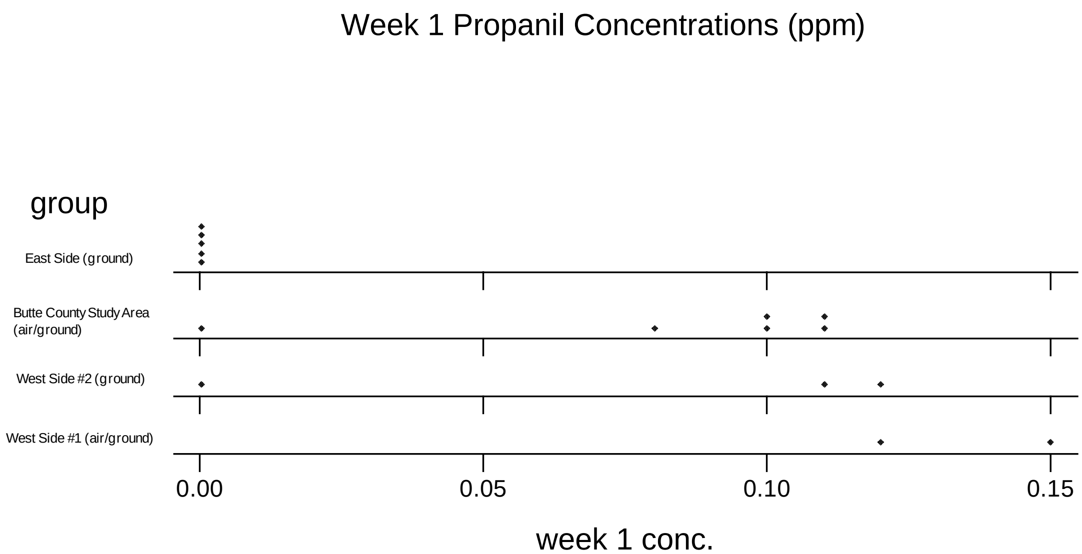

Figure 5. Week 1 compliance monitoring propanil concentration (ppm) separated according to the nearest ground applications (miles).

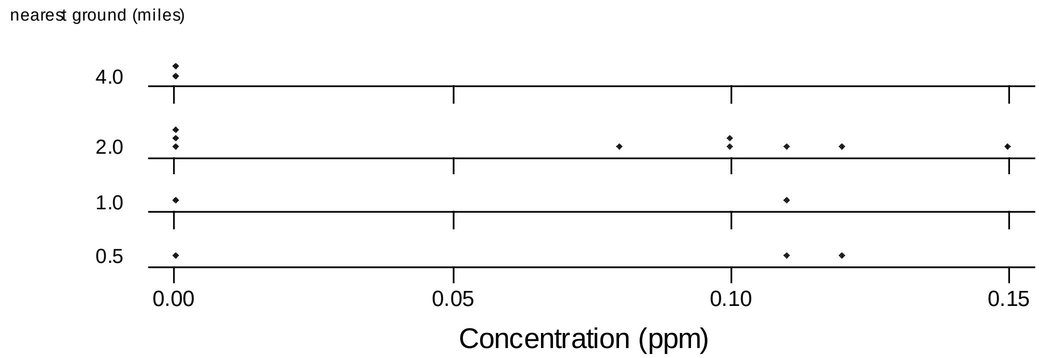

Figure 6. Week 1 compliance monitoring orchard propanil concentration (ppm) versus the number of acres applied by ground within 1 mile.

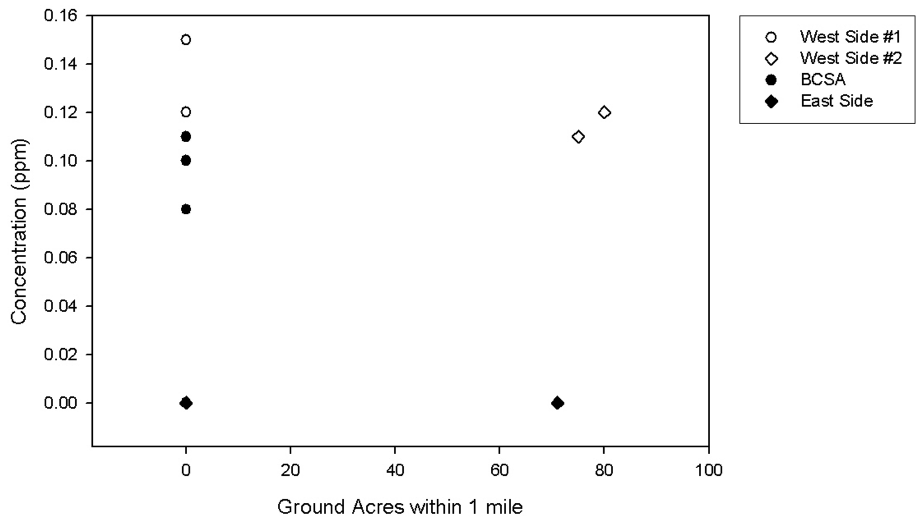

Figure 7. Week 1 compliance monitoring orchard propanil concentration (ppm) versus the number of acres applied by ground within 2 miles.

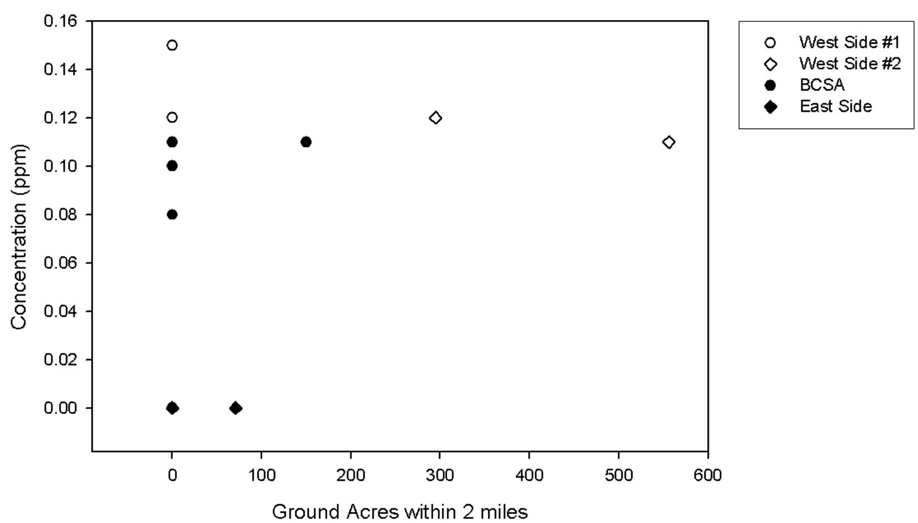

Figure 8. Week 1 compliance monitoring orchard propanil concentration (ppm) versus the number of acres applied by ground within 4 miles.

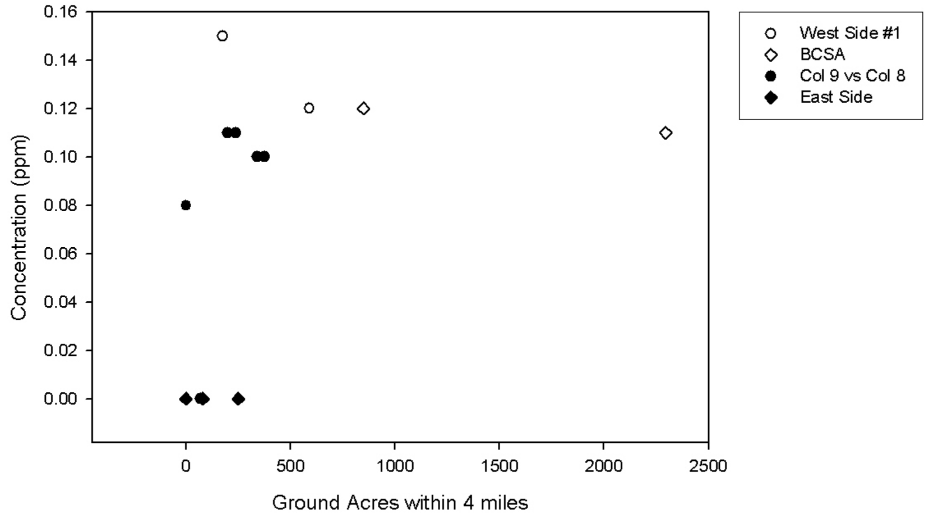

Figure 9. Week 1 compliance monitoring orchard propanil concentration (ppm) versus the number of acres applied by air within 6 miles.

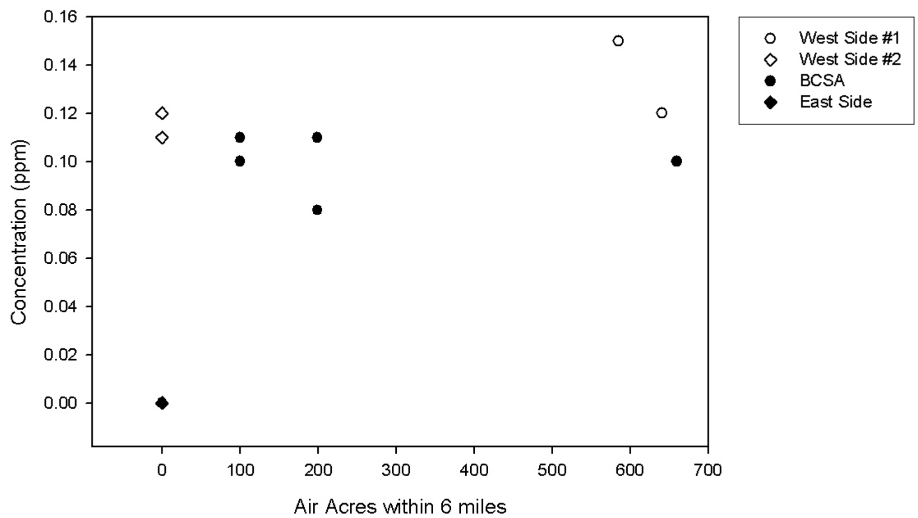

Figure 10. Week 1 compliance monitoring orchard propanil concentration (ppm) versus the number of acres applied by air within 8 miles.

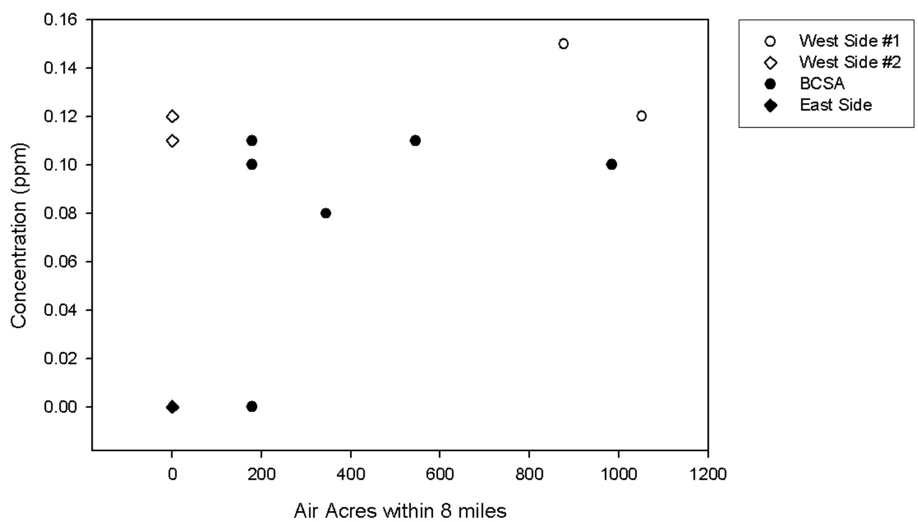

Figure 11. Week 1 compliance monitoring orchard propanil concentration (ppm) versus the number of acres applied by air within 10 miles.

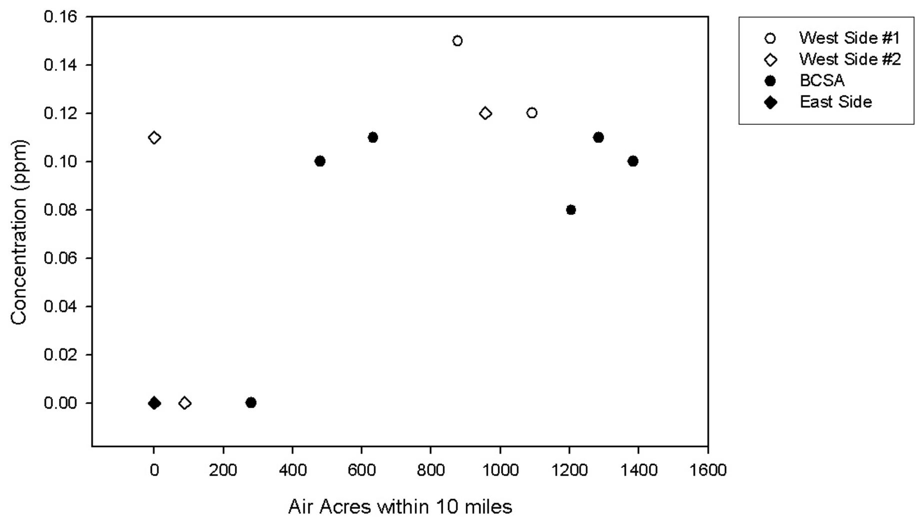

Figure 12. Week 1 propanil concentration (ppm) versus air acres applied within 10 miles and ground acres applied within 4 miles.

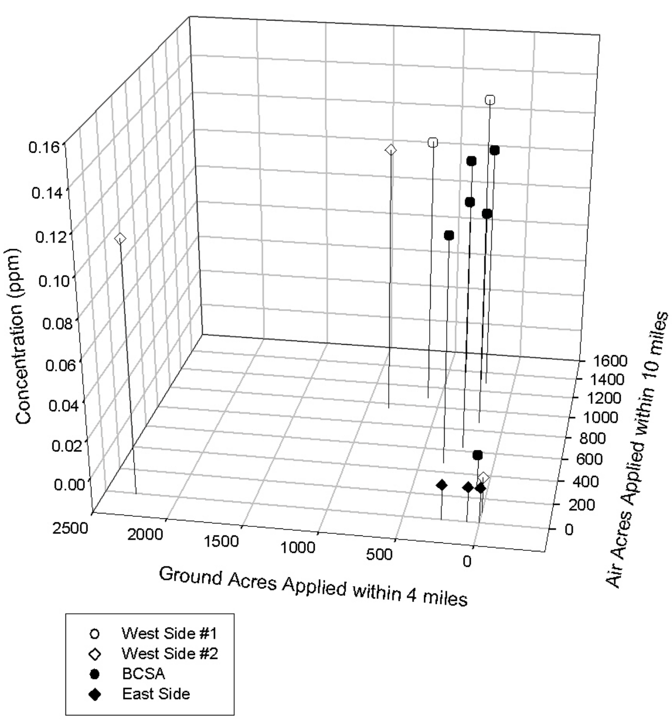

Figure 13. Week 1 propanil concentration (ppm) versus distance to the nearest aerial application (miles).

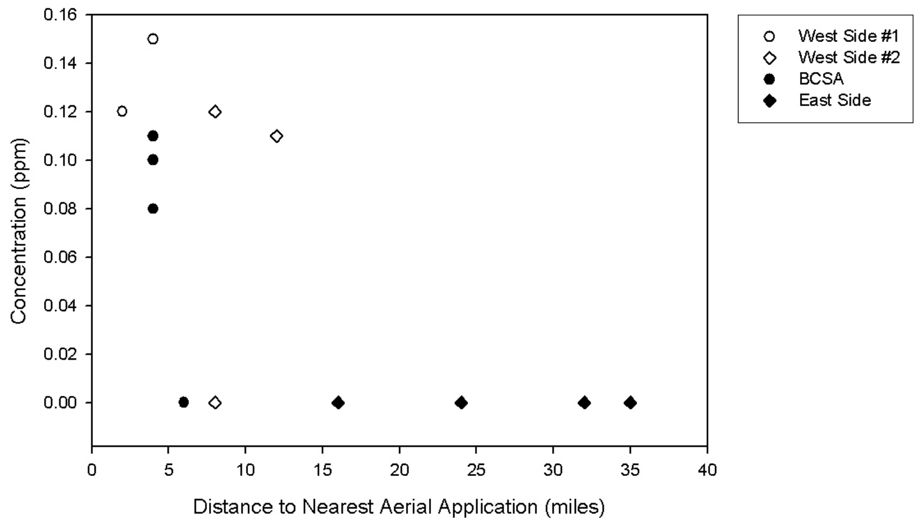

Figure 14. Week 1 propanil concentration (ppm) versus distance to the nearest ground application (miles).

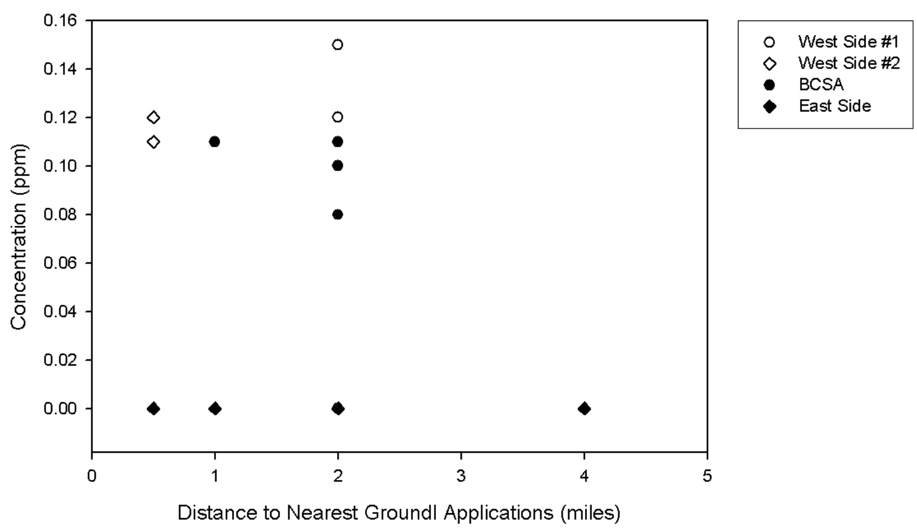

Figure 15. Week 1 propanil concentration (ppm) versus distance to the nearest aerial application (miles) and distance to nearest ground application (miles).

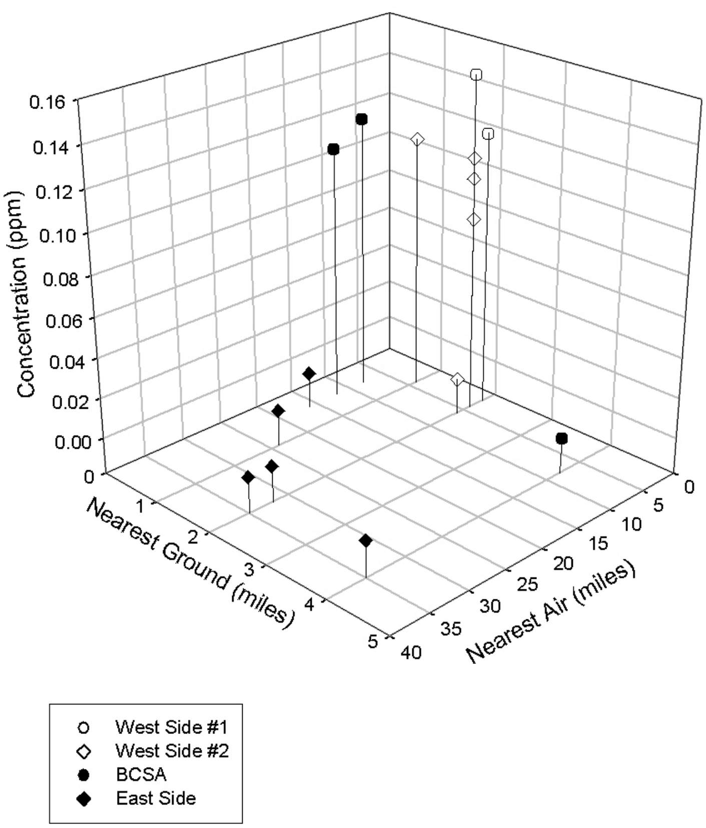

Figure 16. Peak Week Compliance Monitoring results. Note that the peak week varies according to site. See text for further discussion. Sites separated according to influence of aerial applications and geographic area within the air influence groups.

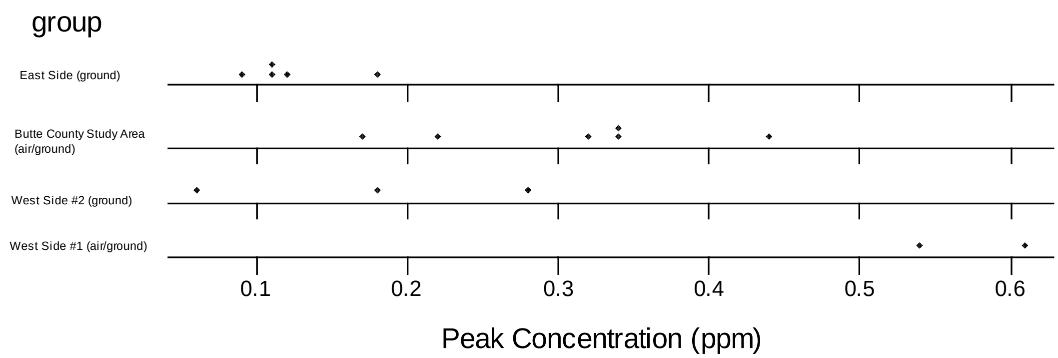

Figure 17. Peak Week propanil concentration (ppm) versus acres applied by air within 6 miles. Note that the peak week varies according to site. See text for further discussion.

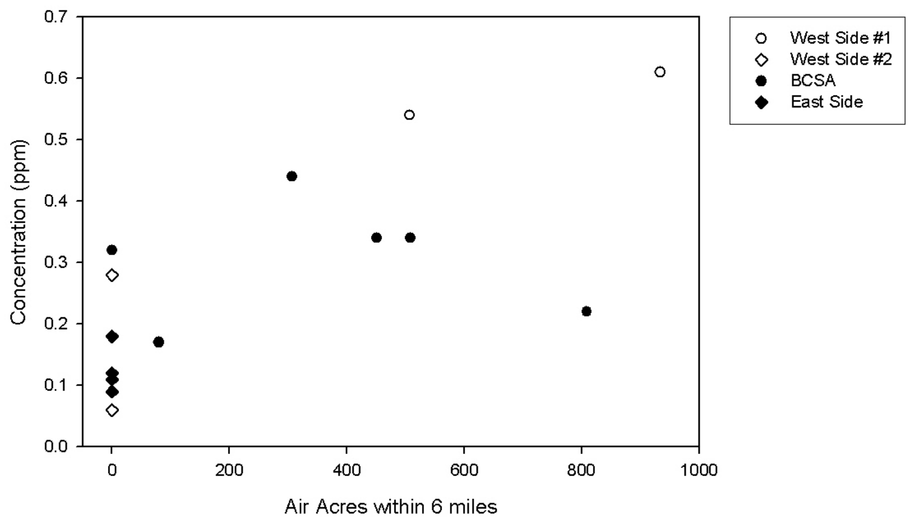

Figure 18. Peak Week propanil concentration (ppm) versus acres applied by air within 8 miles. Note that the peak week varies according to site. See text for further discussion.

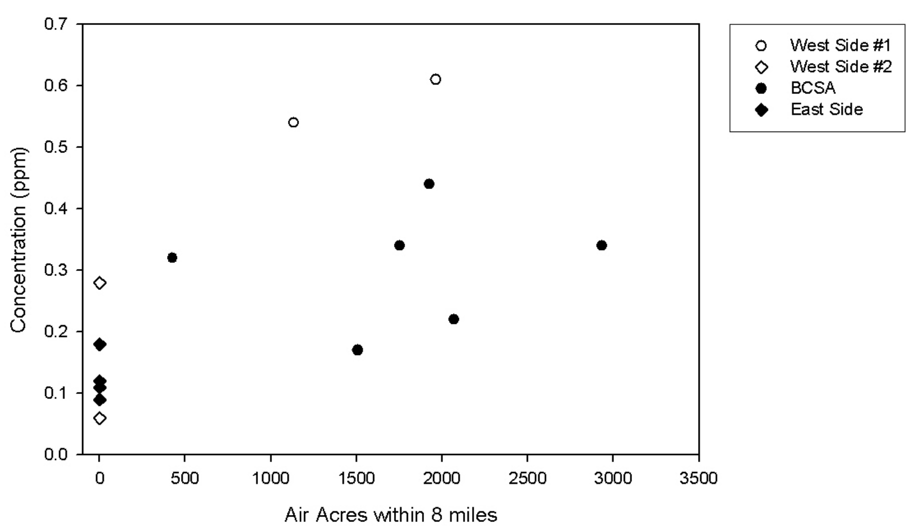

Figure 19. Peak Week propanil concentration (ppm) versus acres applied by air within 10 miles. Note that the peak week varies according to site. See text for further discussion.

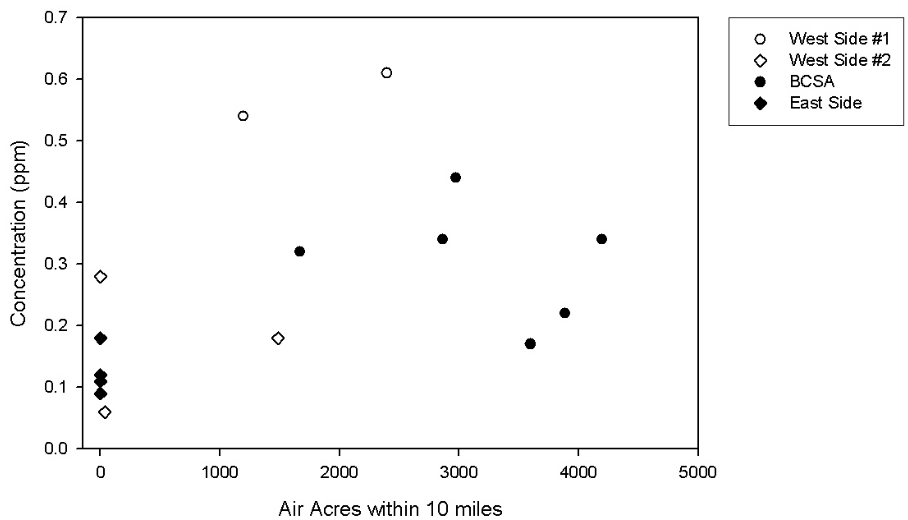

Figure 20. Peak Week propanil concentration (ppm) versus acres applied by ground within 1 miles. Note that the peak week varies according to site. See text for further discussion.

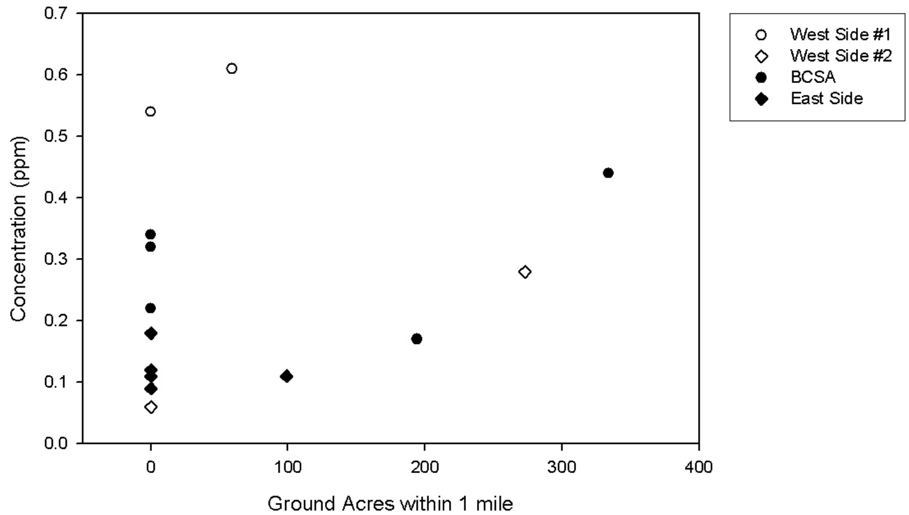

Figure 21. Peak Week propanil concentration (ppm) versus acres applied by ground within 2 miles. Note that the peak week varies according to site. See text for further discussion.

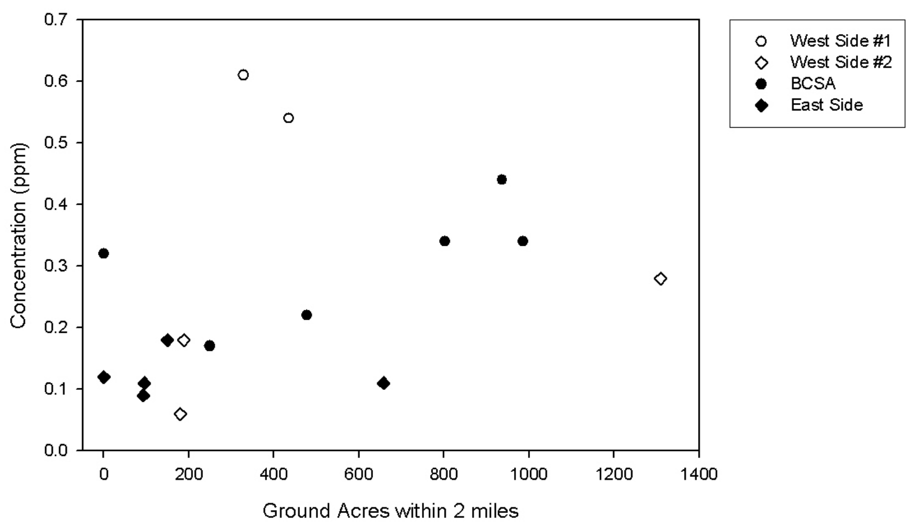

Figure 22. Peak Week propanil concentration (ppm) versus acres applied by ground within 4 miles. Note that the peak week varies according to site. See text for further discussion.

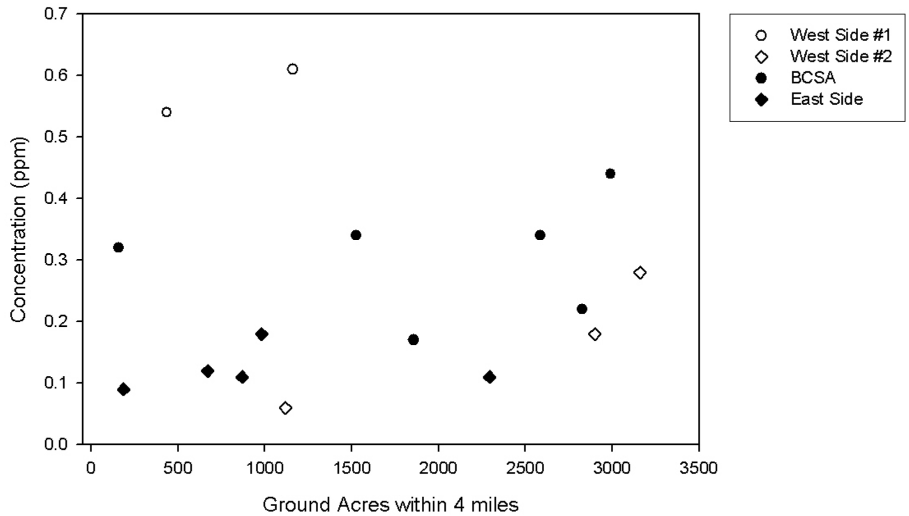

Figure 23. Peak Week concentration (ppm) versus acres applied by air within 6 miles and acres applied by ground within 1 mile. Note that the peak week varies according to site. See text for further discussion.

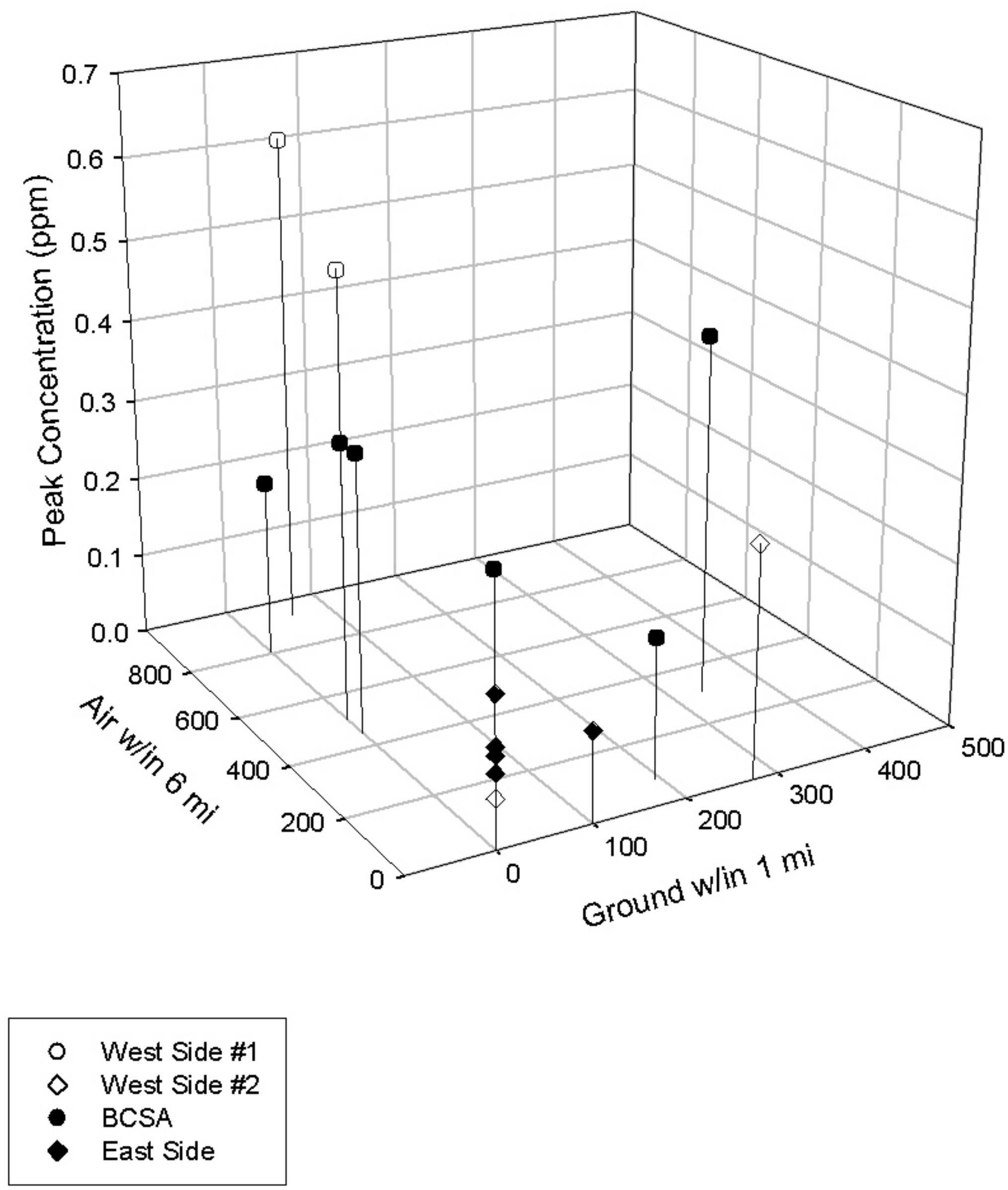

Figure 24. Colusa County compliance monitoring concentrations (ppm) and daily acreage (sum of ground and air) versus week.

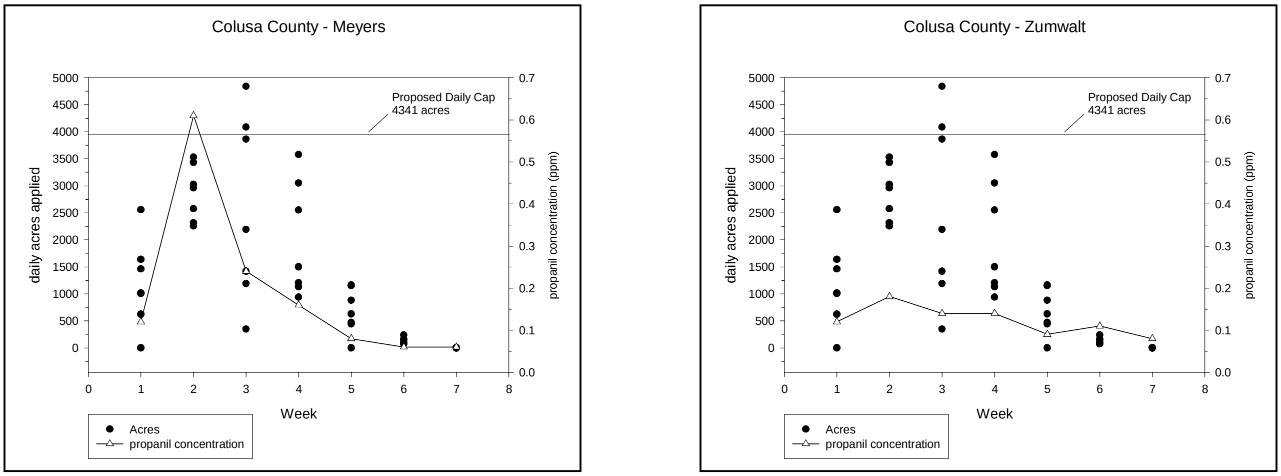

Figure 25. Glenn County compliance monitoring concentrations (ppm) and daily acreage (sum of ground and air) versus week.

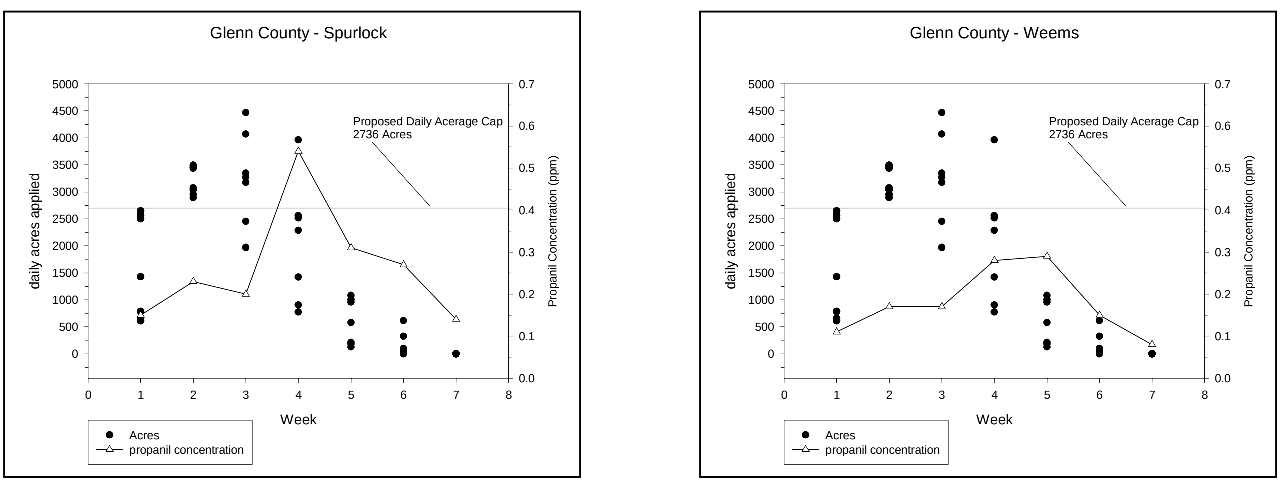

Figure 26. Colusa County compliance monitoring concentrations (ppm) and daily acreage (sum of ground and air) versus week.