Data Report

The Effectiveness of Riparian Vegetation at Intercepting Drift from Aerial Pesticide Application

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A Study by the Washington State Department of Agriculture

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The Effectiveness of Riparian Vegetation at Intercepting Drift from Aerial Pesticide Application

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Summary

A pilot study was conducted to assess the effectiveness of riparian vegetation at reducing pesticide loading to streams during aerial applications of the organophosphate insecticide malathion. Control sites for this targeted monitoring study had no established native riparian vegetation, and no vegetation (native or invasive) greater than 2m in height. Vegetated sites included one site with a large naturally occurring riparian buffer (greater than 6m wide) and two sites with small planted riparian hedgerows (between 3m and 5m wide). Site characteristics documented include distances between field, vegetation, and stream, and characteristics of riparian vegetation. Eight total malathion application events were monitored at two control sites (four events) and three vegetated sites (four events). Observations before, during, and after application events included weather, grab or composite water samples, depositional sampling at multiple field locations, stream discharge, and conventional water quality parameters. Water and depositional samples were extracted and analyzed by Pacific Agricultural Laboratory in Portland, OR. A preliminary statistical analysis was conducted by Washington State University (WSU) on depositional results, focusing on what vegetation characteristics most affected instream malathion deposition. This analysis confirmed that instream malathion deposition was significantly lower at vegetated sites than at control sites. In addition, five parameters had a statistically significant effect on the $\log_{10}$ of instream malathion deposition: canopy cover, canopy angle, distance between field and edge of vegetation, distance between field and center of waterbody, and bank slope. Increases in canopy cover, canopy angle, distance between field and edge of vegetation, and distance between field and center of waterbody all resulted in decrease in instream malathion deposition, while an increase in bank slope resulted in increase in instream malathion deposition. Additional analysis on a reduced set of parameters indicated that increasing distance from field (both to vegetation and to water) and increasing canopy angle and canopy cover all resulted in statistically significant reductions in malathion deposition. The statistical model developed by WSU indicates that an additional 26% reduction of instream malathion deposition could be achieved by either increasing the distance between the field and the beginning of the riparian vegetation by an additional 0.6 m or increasing canopy cover by an additional 9%. The benefits of riparian vegetation for habitat and water quality are already well known. This evidence that riparian vegetation is also effective at reducing drift into streams from aerial pesticide applications makes installation of more riparian buffer vegetation even more important.

1. Introduction

The organophosphate insecticide Malathion 8 (Gowan Company, LLC), containing the active ingredient malathion (butanedioic acid, [(dimethoxyphosphinothioyl)thio]-, diethyl ester), is aerially applied by helicopter in northwest Washington State on blueberry and red raspberry fields to control Spotted Wing Drosophila (SWD) (*Drosophila suzukii)* larvae. *D. suzukii* is a vinegar fly originally from southeast Asia that was first identified in Washington berry crops in 2009. Unlike other *Drosophila* species that only infest rotting fruit, this fly infests soft fruit early during the ripening stage, making it a significant pest in berries. Malathion is one of many older pesticides that is under review for potential negative impacts on federally listed endangered species. The Environmental Protection Agency (EPA) and the National Marine Fisheries Service (NMFS) are under court order to complete an updated national Biological Opinion on malathion by the end of 2017. This study was identified as an opportunity to demonstrate the usefulness of targeted monitoring in identifying potential mitigation measures that can be used to protect listed salmonid species.

Malathion is a broad-spectrum organophosphate insecticide that ranges from moderately to highly toxic to bees, beneficial insects, fish and other invertebrates. First registered for use in 1956, malathion is still heavily used in tree fruit, small berries, and for mosquito control. When *Drosophila suzukii* first appeared in Washington State berry fields in 2009, entomologists at WSU began investigating control methods and efficacy. Malathion was one of only four insecticides that showed good control in field trials, and because it is off patent and generics are available, it is considerably cheaper for large-scale control operations. Because *D. suzukii* is present when fruit is ripening, the use of ground equipment could result in significant crop losses during application. As a result helicopter applications are becoming an increasingly popular choice for pesticide applications in berries.

A study was designed by the Washington State Department of Agriculture (WSDA) in collaboration with scientists at EPA, NMFS, pesticide registrant's FIFRA Endangered Species Task Force (FESTF), and leading spray drift researchers at Washington State University and the United States Forest Service (USFS). The study goal was to investigate the effectiveness of riparian vegetation at reducing pesticide loading to streams. The area selected for the study was Whatcom County, in northwest Washington State, which is bordered to the north by Canada, the west by the Puget Sound, and the east by the Cascade Mountain Range. Whatcom County currently produces 60% of the nation's red raspberry crop, and has over 5,000 acres of high bush blueberries in production. The 15,000 acres of berries in the county have shown a high infestation of SWD and have been receiving aerial applications of malathion throughout each summer harvest period. This study monitored deposition of malathion and its degradate malaoxon during and immediately after aerial applications. Deposition at sites with dense, woody riparian vegetation was compared to deposition at sites with little to no riparian vegetation. In-field deposition monitoring locations were field edge, edge of vegetation (or, in the absence of vegetation, edge of stream bank), and the center of the water body. Although the focus of this study was aerial malathion applications in blueberries, it has implications for identifying replicable best management practices that could be used by EPA, NMFS, and U.S. Fish and Wildlife Service to reduce and customize no spray buffers for numerous pesticides and many crops based on these and other site specific characteristics.

2. Site Selection and Events

Five monitoring sites were selected for this study, two control and three vegetated. All five sites are within Whatcom County and are located in areas that drain into the Nooksack River basin (WRIA 1). The two control sites (Control1, Control2) are located on unnamed agricultural ditches and the three vegetated sites (Veg1, Veg2, Veg3) are on naturally occurring water bodies in the Fishtrap Creek and Fourmile Creek basins.

The riparian vegetation communities at the two control sites were very similar to each other and dominated by a single plant species, reed canary grass (*Phalaris arundinacea)*. Himalayan blackberry *(Rubus armeniacus)*, which is considered a noxious weed in Washington State, was also present throughout the riparian habitat of both sites. At site Control1, cattail (*Typha* sp.) was present at several locations within the stream channel, and duckweed (*Spirodela polyrrhiza* and *Lemna* spp.) covered the majority of the water surface. Due to the unusually low snow pack in the Cascade Mountain Range along with a dry and very warm summer, site Control2 was dry and Control1 contained only standing water throughout the duration of the study. The wetted width of Control1 averaged 1.78 m, with an average thalweg depth of 16.5 cm. The streambed of Control1 was composed of fine sediment.

The vegetated sites contained much more diverse riparian vegetation communities that were dominated by dense woody vegetation, such as willows (*Salix* spp.), spiraea (*Spiraea* sp.), red-osier dogwood (*Swida sericea*), and alder (*Alnus* sp.). Pacific ninebark (*Physocarpus capitatus*), and salmonberry (*Rubus parviflorus*) were also present at vegetated sites but were not among the dominant species. *P. arundinacea* was present at all vegetated sites, however it was never a dominant species. Noxious weeds *R. armeniacus* and evergreen blackberry (*Rubus lacinatus*) were also present at vegetated sites. The average height of the riparian vegetation of 8.04 m at Veg3 was the tallest among study sites, with several locations measuring near 24 m. The riparian vegetation community at this site was well-established and mature, intermixed with large cotton woods (*Populus* sp.) and western redcedars (*Thuja plicata*) . Veg3 also had the highest average width of riparian vegetation with an average width of 8.36 m. Sites Veg1 and Veg2 had mature plantings of riparian vegetation, with heights averaging 3.88 meters at Veg1 and 6.44

meters at Veg2. Width of riparian vegetation was similar at Veg1 and Veg2, averaging 4.84 and 4.9 meters respectively.

Sites Veg1 and Veg2 had an average wetted width of 2.8 and 3.87 m with thalweg depths averaging 74.0 and 58.3 cm respectively. The stream at Veg3 was the widest, with an average wetted width of 6.36 m and an average thalweg depth of 43.2 cm. The streambed of both Veg1 and Veg2 consisted of fine sediment, while the streambed of Veg3 was primarily composed of coarse gravel.

A total of eight application events were monitored, four at control sites and four at vegetated sites. Four application events occurred in the early morning, between 05:00–09:00, with clear skies. Four application events occurred in the evening hours, falling between 20:00-21:30, with clear skies for one event and overcast conditions for three. Duration of application events ranged from 14 to 42 minutes and averaged 28 minutes.

The pesticide used was Gowan Malathion 8 Flowable (Gowan Company LLC), which was applied to all fields used for this study. The tank mix application rate was 10 gallons/acre for every site. The malathion application rate was either 16 oz/acre or 20 oz/acre. Several different additives were used, either Sb-56 (Genesis Agri-Products, Inc.), Epoleon (Epoleon Corporation), Grip (J.R. Simplot Company), or Interlock (WinField Solutions, LLC). Additive concentration in the tank mix was either 4 or 8 oz/100 gal. Based on nozzles, nozzle settings, and flow rate the droplet size distribution met the ASAE Standard S572 droplet size classification of Coarse/Very Coarse (Table 1).

Table 1. Application rates, additives, and additive concentrations used

Site	Event	Tank mix application rate (gallons/acre)	Malathion application rate (oz/acre)	Additive	Additive concentration in tank mix (oz/100 gal)
Veg1	1	10	16	SB-56	8
Veg2	1	10	16	SB-56	8
Veg2	2	10	20	Epoleon	8
Veg3	1	10	20	Grip	4
Control1	1	10	16	none used	n/a
Control1	2	10	20	SB-56	4
Control2	1	10	16	Interlock	8
Control2	2	10	16	SB-56	4

Maps of each site with layout and specifics are included in Appendix A.

3. Field Methods

More detailed discussion of field methods can be found in the following documentation: this project's Quality Assurance Project Plan (Bischof et al., 2016B) and the three Standard Operating Procedures that were developed for equipment used in this study (Bischof and Hancock., 2015A and 2015B, Bischof et al., 2016A).

3.1. *Site Layout*

At each site, the Total Field Length (TL) (straight-line distance measured by setting an arbitrary datum parallel to a representative stream channel azimuth) was measured and divided by seven to determine the increment between each of six transects (Figure 1). The furthest downstream and upstream transects were transects one and six, respectively. Transects were set perpendicular to the datum using a hypsometer. At each transect the left bank, right bank, edge of vegetation (V), and edge of field (F) were marked with flagging.

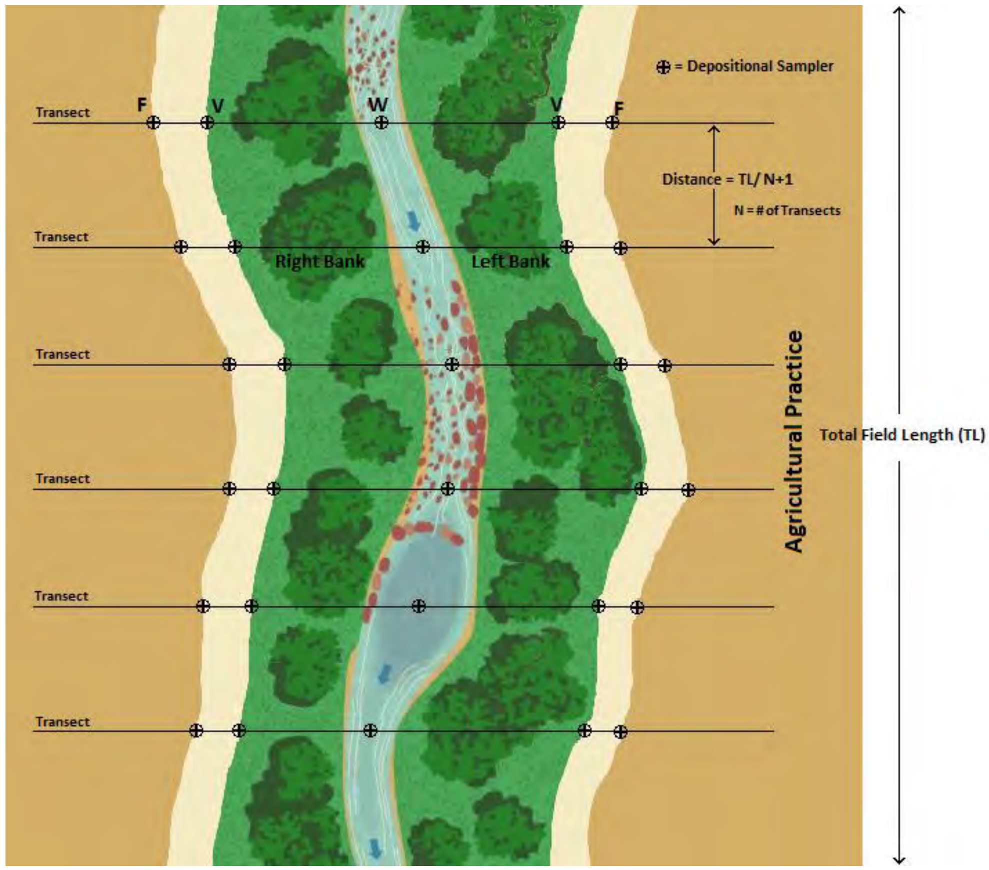

Figure 1. Layout of transects at a two-sided vegetated site

3.2. *Instream Habitat Assessment*

Wetted width, bankfull width, thalweg depth, bankfull height, and bankfull depth were measured at each transect using a measuring tape, measuring rod, and clinometer. Instream canopy angle was measured from the center of the channel using a clinometer. Convex densiometers were used to assess instream canopy cover following the methods of Mulvey et al.,1992. Percent fish cover was visually estimated for various matrices including but not limited to macrophytes, woody debris, overhanging vegetation, and undercut banks.

3.3. *Vegetation Assessment*

At each transect, vegetation plots were established extending 5 m upstream, 5 m downstream, and encompassing the width of the streamside vegetation. Vegetation width was measured as the distance between the bankfull edge of the stream and the outer edge of the vegetation, facing the field. Average vegetation height was calculated from three height measurements taken at each transect using a hypsometer. Within each plot, ground cover (< 0.3 m height) and understory (0.3 to 1.5 m height) were assessed by estimating the percent cover of woody and non woody vegetation. Slope of the vegetation plot was measured with a clinometer and a wooden staff. Trees were categorized and counted according to diameter at breast height (DBH). Densiometer readings within the vegetation were taken in the four cardinal directions. Vegetation assessments were completed within one month of monitored application events to ensure habitat characteristics were consistent.

3.4. *Depositional Sampler Set up*

Depositional sampler stands were constructed in two parts: a removable platform and a T-post or section of rebar installed in position for the duration of the study. The removable platform consisted of PVC pipe large enough in diameter to slide over a T-post or piece of rebar, with a wood platform and foam block fastened on top. Holes were drilled through the PVC at regular intervals, and a bolt inserted through holes allowed adjustment of platform heights when used with T-posts (Figure 2).

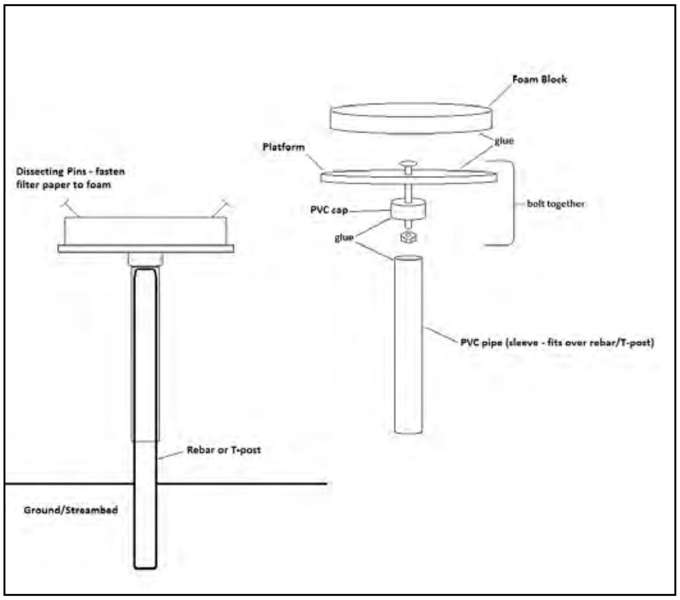

Figure 2. Depositional sampler stand and assembly

T-posts or rebar sections were installed in the streambed in the center of the water body (W), at the edge of the vegetation (V), and at the edge of the field (F) at pre-flagged locations. When agricultural practices occurred on both sides of the stream depositional samplers were placed at V and F locations on both sides. GPS locations were recorded for all samplers and distances between W and V locations and V and F locations along each transect were measured. For control sites, V samplers were placed at the mowed edge of the field closest to the channel. Depositional sampler stands at F were placed at the average crop height at each site. If a site received a second aerial pesticide application depositional sampler stands were installed at the same height used for the first event. Depositional samplers at V and W locations were placed at a height of 0.5 m above the ground or water surface.

Sampler stands were cleaned and wrapped in aluminum foil and placed on T-posts or rebar prior to pesticide applications. No more than one hour prior to application, while wearing nitrile gloves, one piece of filter paper (Grade 4 Qualitative cellulose Filter Paper, circle, 270mm diameter, Whatman) was placed on each stand and secured to the covered foam block using t-pins.

Replicate QA stands for V and F locations were installed parallel to the corresponding V or F samplers at a distance of 1 m from sampler edge to sampler edge. For W samplers, the replicate QA stand was placed in line with the stream center at a distance of 1 m up or downstream from the corresponding W sampler.

3.5. *Depositional Sampler Retrieval*

One hour after the pesticide application was complete, field staff entered the site to collect filter papers. Staff wore a new pair of nitrile gloves for each paper and worked in pairs to prevent contamination of filter paper and sample containers. Filter paper was folded following a standardized procedure and placed into a pre-cleaned 4 oz amber glass jar. Sample jars were immediately capped with PTFE-lined lids, labeled and placed in a cooler at 4 °C. Clean filter paper was placed into jars on site for blank QA samples following the same procedure as experimental samples.

3.6. *Weather Station Deployment*

Onset HOBO U30 weather stations were deployed at least one hour prior to all application events. Weather stations were placed in a location nearby that would not be impacted by local helicopter turbulence, tall structures, powerlines, paved areas, or other factors (at a maximum distance of 5 km from the center of the stream channel). Weather stations were leveled, oriented north, and programmed to collect temperature, relative humidity, wind direction, wind speed, solar radiation, and dew point every 30 seconds for the entire application period. Weather station data was downloaded a minimum of one hour after the application event.

3.7. *Water Sampling Methods*

At sites where flowing water was present in the stream channel, stream water was sampled throughout the course of the pesticide application period using two Teledyne ISCO 6712 automated samplers. One automated sampler was installed upstream of the targeted field to capture background water chemistry data to account for any malathion use occurring upstream of the study site. A second automated sampler was installed immediately downstream of the targeted field to capture any pesticide contamination of stream water occurring during the aerial application event.

The automated samplers were placed on the stream bank and installed perfectly level to ensure delivery of consistent sample volumes. A PTFE-lined suction line for each automated sampler was installed at a continuous slope and placed mid-level in the main current of the stream.

Four pre-cleaned 950 mL glass bottles were placed in each automated sampler. A fifth bottle was included for events and locations requiring blank samples. Automated samplers were programmed to collect 100 mL of stream water subsamples every six minutes, with three suction line rinses between each subsample. Four subsamples were composited into each bottle, resulting in a composited sample of 400 mL collected every 24 minutes; the entire sampling program had a duration of 96 minutes. Both upstream and downstream automated samplers were synchronized to begin the sampling program at the start of each application event.

Additional water parameters monitored included water temperature, dissolved oxygen, pH, and conductivity, which were measured immediately before and 1 – 1.5 hours after each pesticide application event with a Hydrolab MS5 Water Quality Mutliprobe (OTT Hydromet, Kempten, Germany) (Ecology SOP EAP033 *Standard Operating Procedure for Hydrolab DataSonde® and MiniSonde® Multiprobes* (Swanson, 2010). Stream discharge was also measured 1 – 2 hours after each pesticide application event with an OTT MF pro flow meter and top-setting wading rod, as described in Ecology SOP EAP056 (Shedd, 2014).

Samples were collected from the upstream and downstream automated samplers one hour after the pesticide application was complete. Upon opening the automated samplers, sample bottles were immediately capped with PTFE-lined lids, labeled, wrapped with aluminum foil, placed in a cooler and kept on wet ice at or below 4 °C. Field blanks were filled with 400 mL of de-ionized water immediately after the automated sampler was opened and before capping the four composited samples, in order to account for any possible contamination from handling and the ambient air.

At sites with only standing water, grab samples of the standing water were collected immediately before the application event, and again one hour after the application event was complete at each of the six transects.

3.8. *Field Documentation, Sample Packaging, and Shipping*

Sample collection was documented at the time of collection using waterproof paper Chain of Custody (COC) forms.

Samples were shipped to Pacific Agricultural Laboratory (PAL) in Portland, Oregon on the day of collection. If samples could not be sent on the day of collection, they were kept on wet ice to maintain sample temperatures at or below 4 °C. Prior to shipping, samples were packaged in coolers with blue ice and wrapped with bubble wrap. Samples were shipped via FedEx overnight priority. Upon receipt of the coolers laboratory staff transferred samples to a walk in cooler until sample extraction.

4. Analytical Methods

Sample extraction and analysis was completed by PAL in Portland, Oregon, which is accredited by the Washington State Department of Ecology. A full analysis of QA/QC samples is presented in Appendix B.

4.1. *Sample Extraction*

Malathion and malaoxon residues were extracted from whole cellulose filter paper circles by EPA method 3572 using 40 ml of HPLC grade methanol (EPA, 2014). Clean filter paper was used for field blank QA samples and for laboratory QC samples. Samples and sample extracts were stored at 4° C.

Pesticide residue was extracted from grab and composite water samples by EPA method 3535A using a C-18 SPE cartridge (EPA, 2007A). Reverse osmosis or equivalent water was used for field blank and laboratory QC samples. Samples and sample extracts were stored at 4 °C.

All samples were to be extracted within a 15-day hold time (depositional samples and QA depositional samples) or a 7-day hold time (water samples and QA water samples). Sample extracts were to be analyzed within 40 days per EPA method guidelines.

4.2. *Sample Analysis*

Sample extracts from depositional samples and water samples were analyzed for malathion and its degradate malaoxon according to EPA Method 8321B using high-performance liquid chromatography/thermospray/triple quadrupole mass spectrometry (HPLC/TS/MS) (EPA, 2007B).

The method reporting limit limit (MRL) for malathion and malaoxon on whole cellulose filter paper circles by this method was reported by the laboratory as 0.70 µg/m^2 (0.040 µg/filter paper). All depositional sample extracts and depositional QA sample extracts were diluted by 10x post extraction to account for background noise. The 10x dilution is accounted for in the reporting limit.

The MRL for malathion and malaoxon was reported by the laboratory as 0.05 µg/L for 20 ml of surface water by this method.

5. Data Analysis Methods

Analytical results were reported as µg/filter paper and were converted to µg/m^2 by the following method:

$$Filter\ area(m^2) = \pi\left(0.5\ \times 270\ mm \times \left(\frac{1m}{1000mm}\right)\right)^2$$

$$Result\left(\frac{\mu g}{1\ filter}\right) \times \left(\frac{1\ filter}{filter\ area(m^2)}\right) = Result\left(\frac{\mu g}{m^2}\right).$$

Data analysis was conducted in Microsoft Excel 2010 and 2013. Wind roses in Appendix A were generated using RStudio version 0.99.489 with R 3.1.2. Figures were generated using R Commander 2.1-5 with R 3.1.2 and Microsoft Excel 2010 and 2013.

Wind speed components perpendicular to the stream were calculated based on site layout and wind direction.

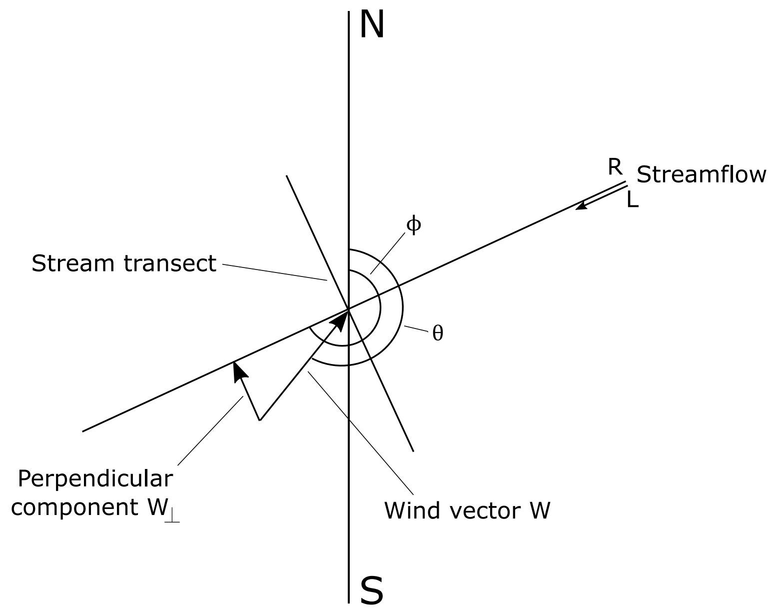

Figure 3. Site geometry and angles used to calculate wind components perpendicular to stream

Where

$$\theta = angle\ of\ wind\ (degrees)$$

and

$$\phi = angle\ from\ N\ to\ left\ (L) side\ of\ waterbody\ (degrees).$$

These angles were used to calculate the perpendicular wind component

$$magnitude\ of\ W_{\perp} = Wcos(90 - (\phi - \theta)).$$

Statistical analysis was completed using SAS v9.4 and was performed by Todd Coffey, PhD, Clinical Assistant Professor, Department of Mathematics and Statistics, Washington State University, Pullman WA. Linear mixed models were used to compare control and vegetated sites and assess relationships between site characteristics and malathion deposition. These models properly account for the site layout of the study design and are described further in Section 6.5. For analyses relating site characteristics to instream malathion deposition, double-sided sites (containing parameters for both left and right sides) were treated by averaging left and right values before conducting the analysis.

6. Preliminary Results, Analysis, and Discussion

6.1. *Study Site Physical Characteristics*

As discussed in Section 2, the two control sites were man-made ditches, while the vegetated sites were naturally occurring water bodies with dense woody riparian vegetation. One site (Veg3) was populated with naturally occurring rather than intentionally planted vegetation while the other two vegetated sites were intentionally planted streamside hedgerows developed through the Whatcom County Conservation District's Hedgerow program. Average site geometry characteristics were calculated using measurements from all six transects at each site (Table 2). Veg3 was the largest site in all distance parameters: bankfull width, distance from water to the edge of the riparian vegetation, distance from the edge of the riparian vegetation to field edge, and distance from water to field edge. The other two vegetated sites, Veg1 and Veg2, were next in size, followed by the two control sites, although bankfull width was similar for Veg1 and Veg2 and the two control sites. In contrast, bank slope was the steepest at Control1, then Control2, followed by Veg3 and then Veg1 and Veg2. Veg1 and Veg2 were both located on the same stream, in very close proximity, which accounts for much of the similarity between these two sites.

Table 2. Site geometry averages for vegetated and control sites

Site	Side	Bankfull Width (m)	Bank Slope (%)	W – V Distance (m)	V – F Distance (m)	W – F Distance (m)
Veg1	L	4.79	14.67	6.34	5.79	12.74
Veg2	R	6.04	15.00	7.61	6.87	14.48
Veg3	L	7.91	33.67	11.49	7.21	18.70
	R		27.83	12.60	7.44	20.04
Control1	L	4.21	86.33	2.55	3.63	6.18
	R		72.17	2.84	2.87	6.18
Control2	R	6.15	42.17	4.30	3.10	7.41

Vegetation characteristics including canopy cover, canopy angle, vegetation width and height, and tree count are summarized by site in Table 3. Sites Veg1 and Veg2 had complete instream canopy cover; so canopy angles (measured from the center of the water) were 90° and stream canopy cover and bank canopy cover were close to 90%. The stream at site Veg3 was wider with a lower canopy angle and lower instream canopy cover, although bank canopy cover was still very high. No dense woody vegetation was present at control sites, so canopy angles were zero. *P. arundinacea* was the dominant species present at control site instream locations, reaching heights of roughly 1 to 1.5 m. This provided some amount of canopy cover, although the amount of deposition that *P. arundinacea* would intercept may be very different from the amount that the dense woody vegetation present at vegetated sites would intercept. As a result, instream canopy cover at control sites were not only nonzero but in one case (Control2 Event 1) even similar to instream canopy cover at vegetated sites. Between the first and second application events site Control2 was mowed, and instream canopy cover was reduced to zero before the second application event. Bank canopy cover was zero for control sites; the dominance of *P. arundinacea* dropped quickly when moving outside the ditch channel and was replaced with a more diverse community of forbs and grasses which were, in general, much shorter. The parameter Stream+Bank Canopy Cover represents the average of instream and stream bank canopy cover and was used for statistical analysis (Section 6.5).

Vegetation width, height, and tree count were also measured. These metrics were either not applicable or zero at control sites, because of the absence of tall, dense woody vegetation of any sort. As described previously, site Veg3 had the widest, tallest, and most mature vegetation. Veg1 and Veg2 were similar to each other in vegetation width but vegetation at Veg2 was several meters taller than vegetation at Veg1. Tree counts were similar at Veg2 and Veg3 and slightly lower at Veg1. These findings are consistent with site history. Site Veg3 has the oldest vegetation, which was naturally occurring, while Veg1 and Veg2 were intentional riparian hedgerow plantings, established in 2002.

Table 3. Site vegetation characteristic averages for vegetated and control sites

Site	Side	Canopy Angle (°)	Stream Canopy Cover (%)	Bank Canopy Cover (%)	Stream+Bank Canopy Cover (%)	Vegetation Width (m)	Vegetation Height (m)	Tree Count (DBH = 3 - 90 cm)
Veg1	L	90.00	93.63	97.06	95.34	4.84	3.88	14.00
Veg2	R	90.00	99.75	98.53	99.14	4.90	6.44	26.00
Veg3	L	53.33	75.98	90.93	83.46	7.93	6.67	21.00
	R	53.58		96.57	86.27	8.80	9.41	20.17
Control1	L	0.00	43.87	0.00	21.94	n/a	n/a	0.00
	R	0.00		0.00	21.94	n/a	n/a	0.00
Control2	R	0.00	95.10 (0.00)*	0.00	47.55 (0.00)*	n/a	n/a	0.00

*Control2 site average for instream canopy cover was 95.1 % for the first application event due to presence of *P. arundinacea*. Before the second application event occurred, the *P. arundinacaea* was cut down and instream canopy cover measurements were 0 for the second application event.

Summary results were also calculated for all transects at control sites and all transects at vegetated sites, in order to compare them more generally (Table 4). Site distances were much lower at control sites than vegetated sites. The mean distance between the vegetation edge depositional sampler position (V) and the center water depositional sampler position (W) at vegetated sites was nearly triple that for control sites. The mean distance between the field edge location (F) and V at vegetated sites was more than double that for control sites. Instream canopy cover at vegetated sites was nearly double instream canopy cover at control sites. Bank canopy cover was zero at both control sites, as well as tree count. Bank slope was much higher at control sites than at vegetated sites. Other parameters (vegetation width and height) were not applicable to control sites. It was expected that the greater distance between the field edge and the stream at vegetated sites would result in decreased instream deposition, even without any effect from the presence of riparian vegetation.

Table 4. Comparison of mean vegetation characteristics between vegetated and control sites (means are shown ± one standard deviation)

Parameter	Vegetated Sites			Control Sites		
	N	Mean	Standard Deviation	N	Mean	Standard Deviation
Bankfull Width (m)	18	6.25	1.62	12	5.18	1.05
Bank Slope (%)	24	22.79	11.34	18	66.89	22.23
W – V Distance (m)	24	9.51	2.87	18	3.23	0.83
V – F Distance (m)	24	6.83	1.02	18	3.20	0.89
W – F Distance (m)	24	16.49	3.21	18	6.59	1.13
Canopy Angle (°)	24	71.79	21.61	18	0.00	0.00
Stream Canopy Cover (%)	18	89.79	16.24	18	46.32	47.79
Bank Canopy Cover (%)	24	95.77	11.78	24	0.00	0.00
Stream+Bank Canopy Cover (%)	24	91.05	12.74	24	22.86	23.40
Vegetation Width (m)	24	6.62	2.03	n/a	n/a	n/a
Vegetation Height (m)	24	6.60	4.26	n/a	n/a	n/a
Tree Count (DBH*=3-90cm)	24	20.29	10.20	18	0.00	0.00

6.2. *Weather Conditions during Applications*

Generally, application events took place either early in the morning or late in the evening when temperatures were lower than midday. Weather conditions were fairly consistent in general, with the exception of Control1 Event1 on June 26, which was hotter and drier than the rest of the application events. In general, temperatures were between 15 and 20°C and humidity was 67 and 86% (Table 5). Solar radiation was generally low with low values observed for evening application times and very early morning application times. The two highest values occurred at the two application events taking place latest in the morning, Veg2 Event 2 and Control2 Event 1, which both took place around 8:00 AM.

Table 5. Average weather data recorded during application events

Site	Event	Event date and time	Temperature (^{0}C)	Relative Humidity (%)	Solar Radiation (W/m²)
Veg1	1	7/7/15 20:47-21:16	18.8	69	10
Veg2	1	6/27/15 07:59 – 08:38	20.6	73	390
Veg2	2	7/7/15 21:19 – 21:34	18.0	72	0
Veg3	1	7/4/15 05:27 – 06:25	15.9	67	50
Control1	1	6/26/15 20:06 – 20:20	26.7	49	120
Control1	2	7/8/15 07:09 – 07:25	16.0	86	180
Control2	1	6/26/15 07:44 – 08:26	21.0	73	450
Control2	2	7/7/15 06:30 – 07:11	15.5	83	90

Wind speed and direction were used to calculate wind speed perpendicular to the stream during each application event (Table 6). Because of the early morning and late evening application times, winds during applications were generally low (often below the accuracy of 1.1 meters per second for the instrument). Wind speeds perpendicular to the waterbody were calculated following the method described in Section 5. Wind roses for each application event, together with site maps documenting depositional sampler results, site layout, and flight patterns, are presented in Appendix B.

Table 6. Wind speed range, direction range, and wind speed range perpendicular to stream during application events

Site	Event	Wind Speed Range (m/s)	Wind Direction Range (°)	Wind Speed Range (perpendicular to stream) (m/s)
Veg1	1	0 – 1.01	202.2 – 234.5	0 – 0.1, L to R 0 – 0.2, R to L
Veg2	1	0 – 1.76	136.2 – 289.2	0 – 1.2, L to R 0 – 0.8, R to L
Veg2	2	0 – 0.25	221.8	0
Veg3	1	0 – 0.76	105.3	0 – 0.8, L to R
Control1	1	0 – 0.76	186.7 – 227.4	0 – 0.6, R to L
Control1	2	0 – 1.26	108.1 – 144.6	0 – 1, L to R
Control2	1	0 – 1.01	113.7 – 199.4	0 – 0.7, L to R 0 – 0.5, R to L
Control2	2	0 – 2.52	109.5 – 181.1	0 – 1.8 L to R

6.3. *Water Sample Results*

During this summer's unusually hot and dry conditions, there was no flowing water at either control site. Flow was taken at all vegetated sites within two hours after the application (Table 7). Stream discharge was similar at all vegetated sites. At the only vegetated site with two application events, Veg2, flow dropped from 2.4 cfs to 2.0 cfs between Event 1 and Event 2. Malaoxon results are not presented here, but only account for a small proportion of the total concentration detected.

Table 7. Flow in cubic feet/second and cubic meters/second at each site during application events

Site	Event	Date	Time	Time between application and flow measurement (h:mm)	Flow (cfs)	Flow (cms)	Notes
Veg1	1	7/7/2015	23:15	1:59	2.0	0.056	
Veg2	1	6/27/2015	07:12	1:26	2.4	0.067	
Veg2	2	7/7/2015	23:15	1:41	2.0	0.056	
Veg3	1	7/4/2015	04:53	1:32	1.5	0.044	
Control1	1	6/26/2015	n/a	n/a	n/a	n/a	no flow, standing stagnant water
Control1	2	7/8/2015	n/a	n/a	n/a	n/a	no flow, standing stagnant water
Control2	1	6/26/15	n/a	n/a	n/a	n/a	no water present
Control2	2	7/7/15	n/a	n/a	n/a	n/a	no water present

Water samples were collected for all application events where water was present in the stream or ditch. Grab samples were collected before and after application events without flowing water (Control2 Event 1 and Event 2) plus one application event with flowing water (Veg3 Event 1) (Table 8). At Control2 there was no water present during the application events; water samples were not collected. For the first event at each site (Control1 Event 1 and Veg3 Event 1), there were no malathion detections in grab samples collected before the application, while grab samples collected after the application all had malathion detections. The average of all grab samples collected after application at Control1 Events 1 and 2 exceeded the endangered species level of concern (ESLOC) of 1.65 µg/L. At Control1 Event 2, half of grab samples collected before the application had malathion detections, although they were below the ESLOC. These detections are attributed to residual malathion still present due to Event 1, which took place 11 days before. With no flowing water present there would be no mechanism other than degradation to move malathion out of the system; with a half-life for malathion of six days (at pH 7) these detections are not surprising (Mastrota, et al. 2010).

Table 8. Grab sample water results

Site	Event	Sample Type	Date and Time	Average (µg/L)	Max (µg/L)	% of Samples with Detections
Veg3	1	Before	7/4/15 04:05 – 04:25	< 0.05	< 0.05	0
		After	7/4/15 07:18 – 07:44	0.14	0.28	100
Control1	1	Before	6/26/15 06:16 – 06:30	< 0.05	< 0.05	0
		After	6/26/15 21:55 – 22:24	4.14	7.1	100
Control1	2	Before	7/8/15 05:21 – 05:46	0.08	0.21	50
		After	7/8/15 08:37 – 09:01	3.45	7.8	100

Composite samples were taken at all vegetated sites for all events at the upstream and downstream ends of each field (Table 9). For all events except Veg2 Event 2, the percent of samples with detections was higher at the downstream of the application site than upstream. Average and maximum malathion concentrations also increase between the upstream and downstream water sampling location at each of these application events. The only event not fitting this pattern was Veg2 Event 2, with no detections at the upstream or downstream locations. All detections in composite samples were well below the ESLOC of 1.65 µg/L.

Table 9. Composite water sample results (taken with autosampler)

Site	Event	Sample Type	Date and Time	Average (µg/L)	Max (µg/L)	% of Samples with Detections
Veg1	1	Upstream	7/7/15 20:47 – 21:59	0.05	0.064	25
		Downstream	7/7/15 20:46 – 21:58	0.06	0.069	75
Veg2	1	Upstream	6/27/15 08:00 – 09:12	< 0.05	< 0.05	0
		Downstream	6/27/15 07:59 – 09:11	0.07	0.11	50
Veg2	2	Upstream	7/7/15 20:32 – 22:38	< 0.05	< 0.05	0
		Downstream	7/7/15 21:27 – 22:39	< 0.05	< 0.05	0
Veg3	1	Upstream	7/4/15 05:37 – 06:49	0.09	0.13	75
		Downstream	7/4/15 05:37 – 06:49	0.27	0.29	100

At one application event at a vegetated site (Veg3 Event 1) both grab and composite samples were collected. Malathion was detected in zero pre application grab samples and all post application grab samples. At this application event, malathion was detected in 75% of the upstream composite samples and all of the downstream composite samples. In addition, the average and maximum of the downstream samples were higher than for upstream samples. In both grab and composite samples malathion concentrations increased either with time (for grab samples) or with flow direction (for composite samples).

6.4. *Depositional Sampler Results*

Malathion deposition was extremely variable, even between samplers from the same field and same field position. In general, deposition decreased from F to V to W positions. In addition, instream deposition was much lower at vegetated sites than control sites (Table 10). Deposition at all field positions was strongly right-skewed, with a number of results much higher than the bulk of the data, which can be seen in the very large standard deviations. Malaoxon deposition results are not presented here, but only account for a small proportion of the total deposition. Depositional results are discussed in more detail in Section 6.5.

Table 10. Mean depositional sampler results (malathion) ± one standard deviation

Site	Event	Left Field (LF)		Left Vegetation (LV)		Water (W)		Right Vegetation (RV)		Right Field (RF)	
		Mean	n	Mean	n	Mean	n	Mean	n	Mean	n
Veg1	1	2,207±2,707	7	357±325	6	709±1,630	6				
Veg2	1					47±43	7	2,416±2,796	6	21,134±24,474	7
Veg2	2					21±8	7	83±98	7	79±64	6
Veg3	1	4,436±2,418	7	1,368±894	6	275±455	6	98±81	6	5,075±2,509	7
Control1	1	4,784±4,660	6	1,281±596	7	3,404±1,881	6	6,165±2,817	7	10,497±8,099	6
Control1	2	3,857±2,283	6	1,120±409	7	759±353	7	629±324	6	749±432	7
Control2	1					1,140±445	7	2,618±1,782	6	6,917±4,006	7
Control2	2					797±402	7	1,807±513	5	3,183±761	7

6.5. *Statistical Analysis*

Because of the short timeline between concluding field work and preparing this data report, statistical analysis was conducted only on malathion depositional results. Future analysis of these results will include grab and composite water samples as well.

A linear mixed model was used to model the $\log_{10}$ of malathion deposition as a function of site type (control vs vegetated) with random effects for site ID nested within site type and transect. Due to different variances at certain locations, the model was created separately for left field, left vegetation, center, right vegetation, and right field locations.

Mean estimates of malathion deposition from the mixed model (estimated best linear unbiased estimators, EBLUEs) at all field locations were higher at control sites than at vegetated sites (Figure 4). Results do not account for vegetation characteristics. Although EBLUEs for malathion deposition were higher for all locations at control sites than vegetated sites, the difference was statistically significant only for water deposition. The instream deposition was reduced 96.3% at vegetated sites compared to instream deposition at control sites ($p = 0.001$).

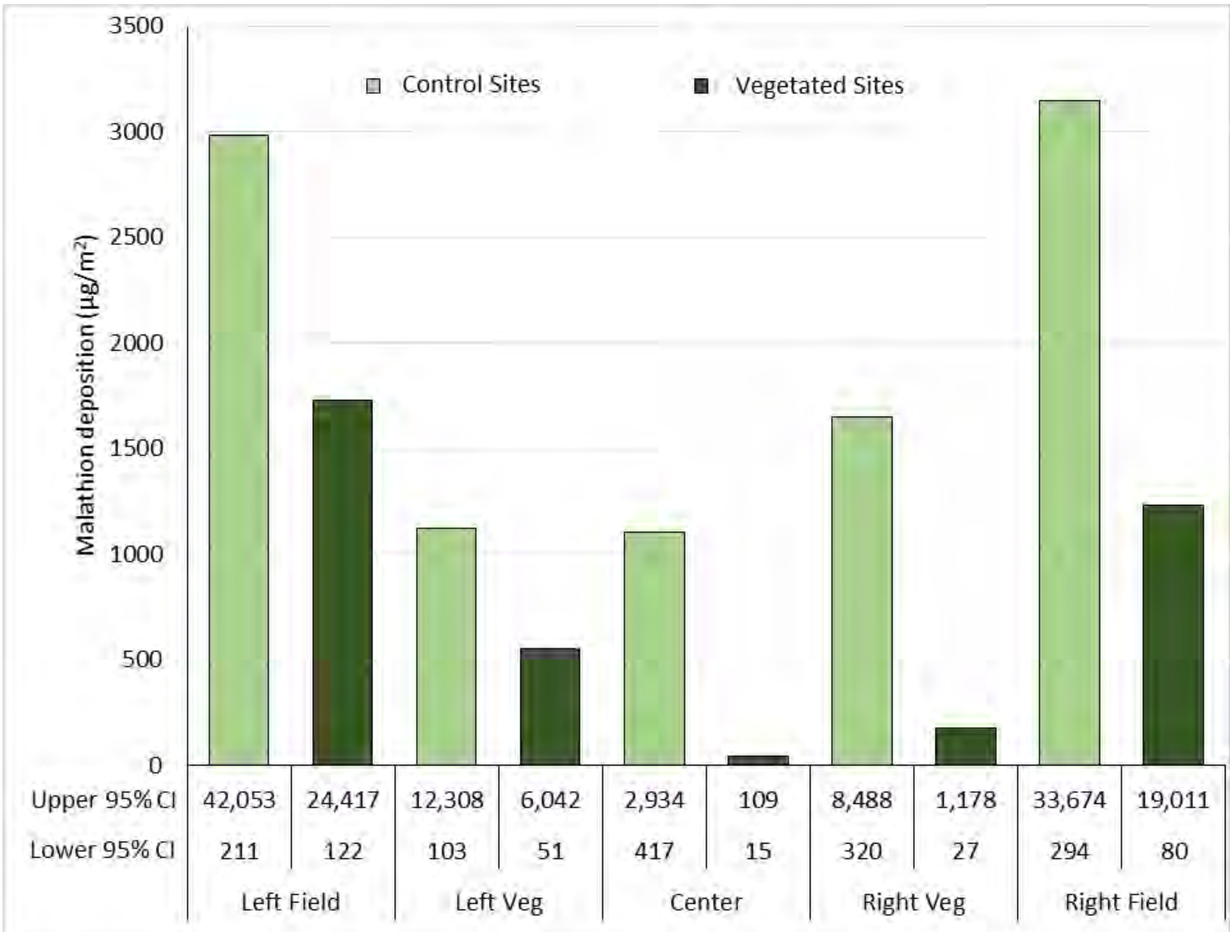

Figure 4. Mean estimates of malathion deposition at control and vegetated sites (EBLUEs)

Deposition reduction between field-edge (F) and water (W) depositional samplers was much higher at vegetated sites than control sites (Figure 5). This figure represents all application events at all 5 sites. Percent reductions were calculated from mean predictions of malathion concentrations at each site from the mixed model (estimated best linear unbiased predictors, EBLUPs) at all locations. Percent reductions were 69% and 61% at control sites and 97%, 96%, and 97% at vegetated sites (Figure 5).

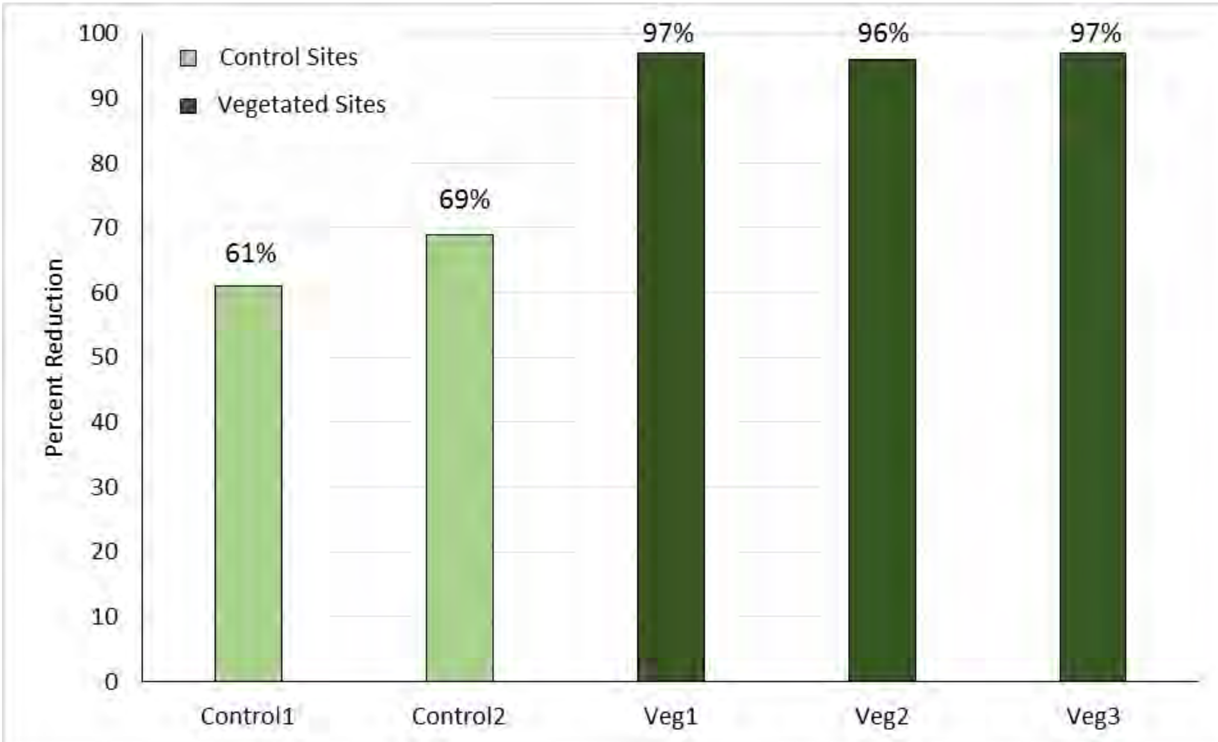

Figure 5. Percent reduction from field-edge (F) to water (W) for all sites, calculated from EBLUPs

In an effort to determine what site characteristics (including distances and vegetation characteristics) most influenced the amount of instream deposition, a univariable analysis of vegetation characteristics and instream malathion deposition was conducted. Characteristics included in the analysis were the site distances and vegetation characteristics presented in Table 2 and Table 3. Through this analysis, five variables were identified as having a significant relationship with instream malathion deposition: canopy cover, canopy angle, distance between field and edge of vegetation (F – V distance), distance between field and center of the waterbody (V – W distance), and bank slope. The relationships are as follows:

Increases in:	**Decrease in:**
Canopy cover (avg. of instream and bank canopy cover)	malathion deposition at W
Canopy angle	malathion deposition at W
Distance between field and edge of vegetation	malathion deposition at W
Distance between field and center of waterbody	malathion deposition at W

Increase in:	**Increase in:**
Bank slope	malathion deposition at W.

The first four relationships, between canopy characteristics and distances from the stream, are consistent with anticipated results of this study. Increasing canopy intercepts more malathion deposition, resulting in decreased instream deposition. Increasing distance between the application area and the waterbody allows more opportunity for malathion to deposit before it reaches the stream, resulting in decreased instream deposition. The last relationship, increasing bank slope correlated to an increase in instream malathion concentration, was unexpected, and is attributed to the striking difference in channel geometry between a natural water body (vegetated sites, with a shallower slope) and a man-made ditch (control sites, with steeper banks). It is not expected that intentionally altering bank slope would have an effect on malathion deposition in the way that increasing canopy cover or distance between the application area and the waterbody would be expected to reduce malathion deposition. Figure 6 through Figure 10 show the relationships between these five significant parameters and the $\log_{10}$ of instream malathion deposition.

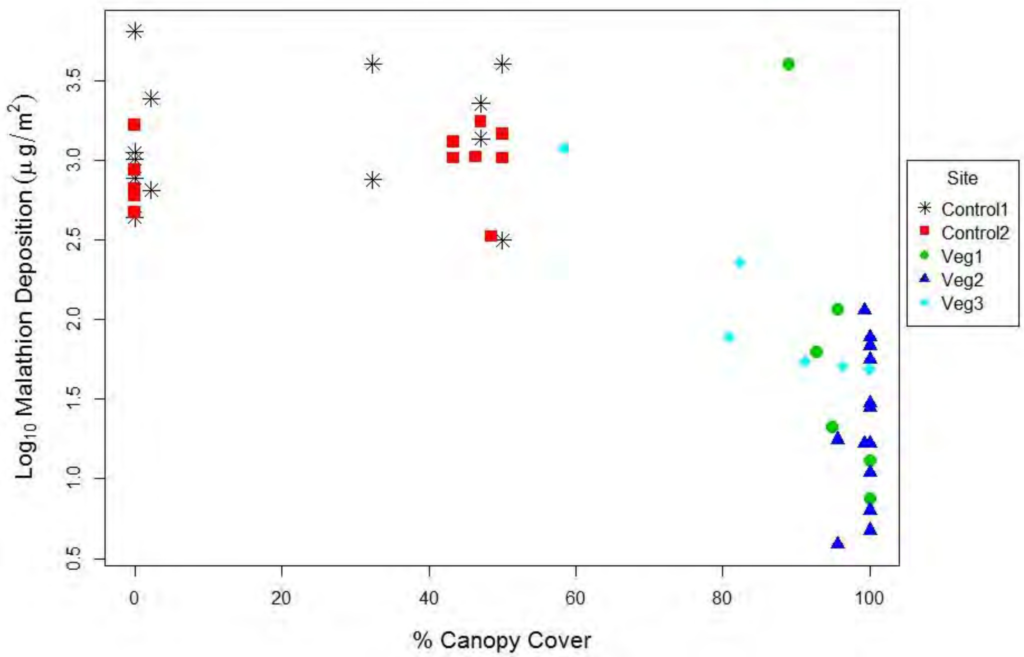

Figure 6. Inverse relationship between canopy cover and malathion deposition

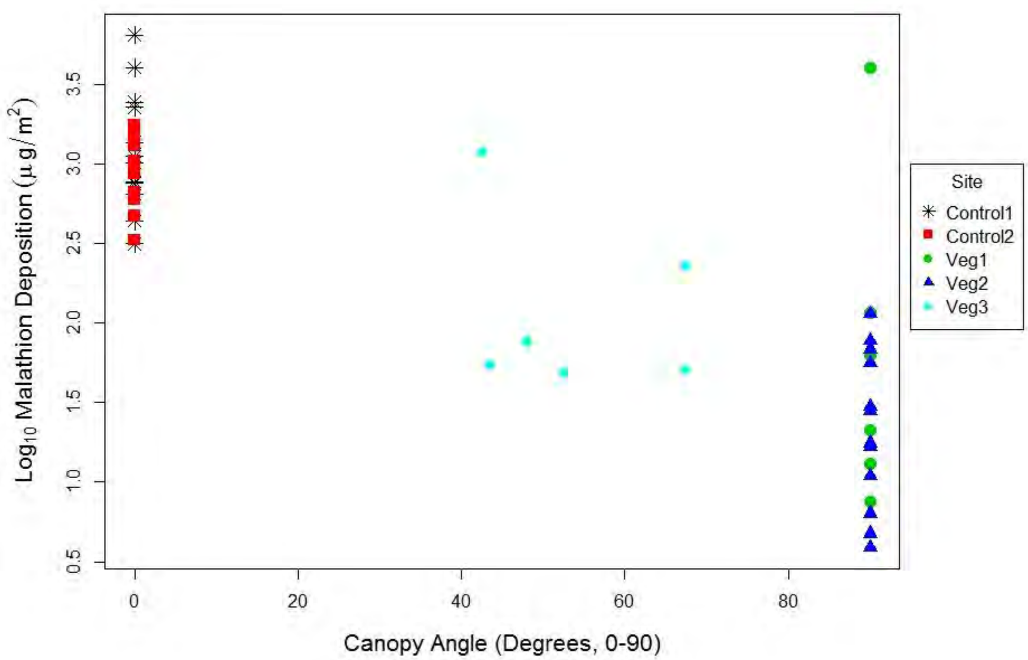

Figure 7. Inverse relationship between canopy angle and malathion deposition

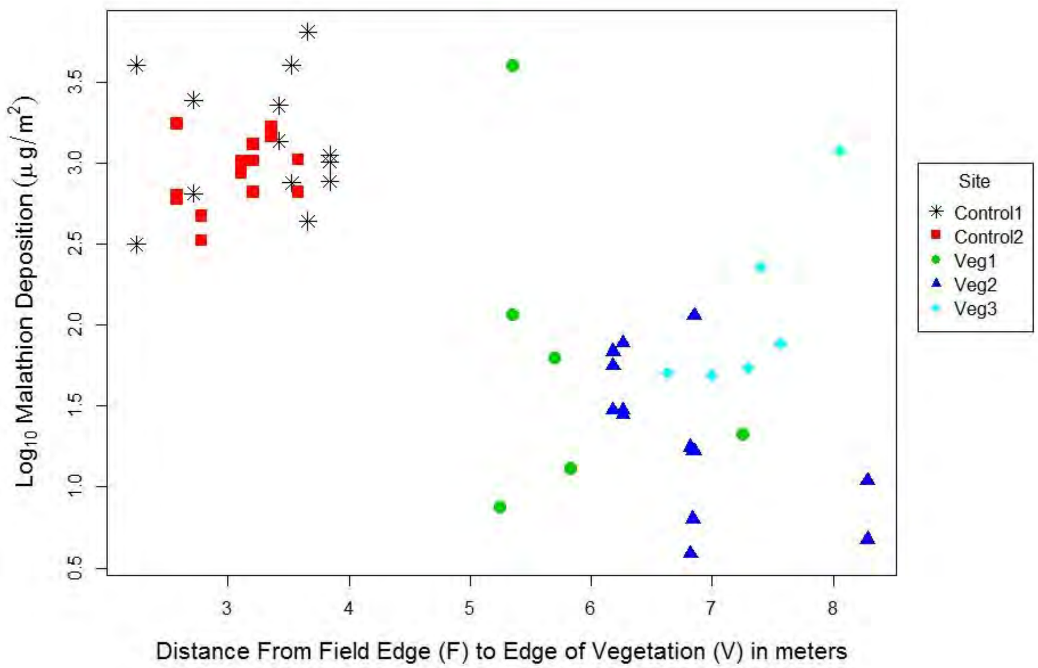

Figure 8. Inverse relationship between distance between field and vegetation and malathion deposition

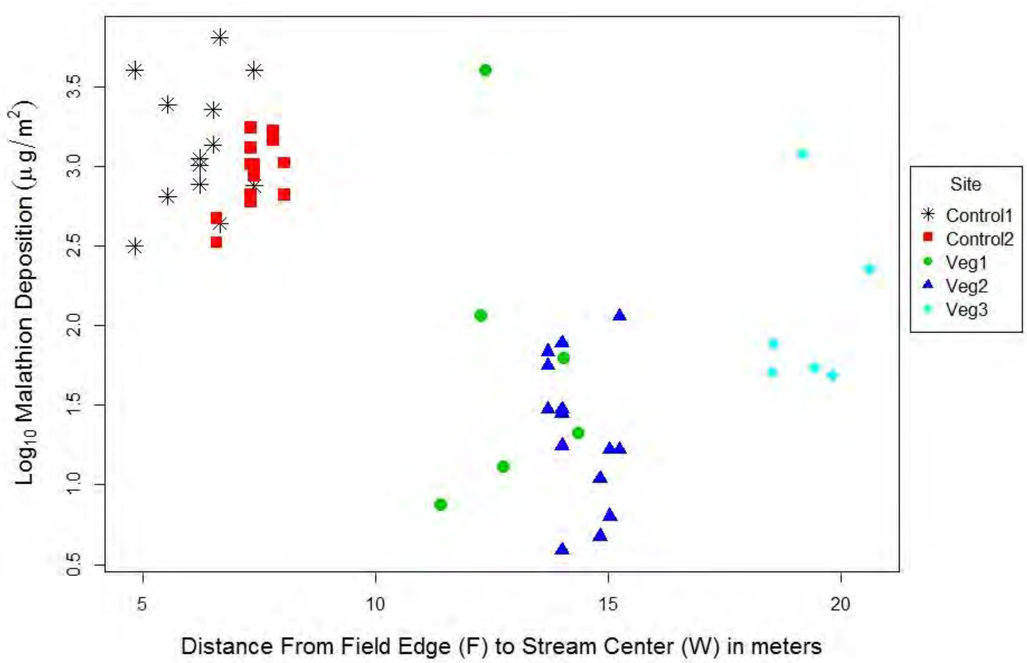

Figure 9. Inverse relationship between distance from field to center of waterbody and malathion deposition

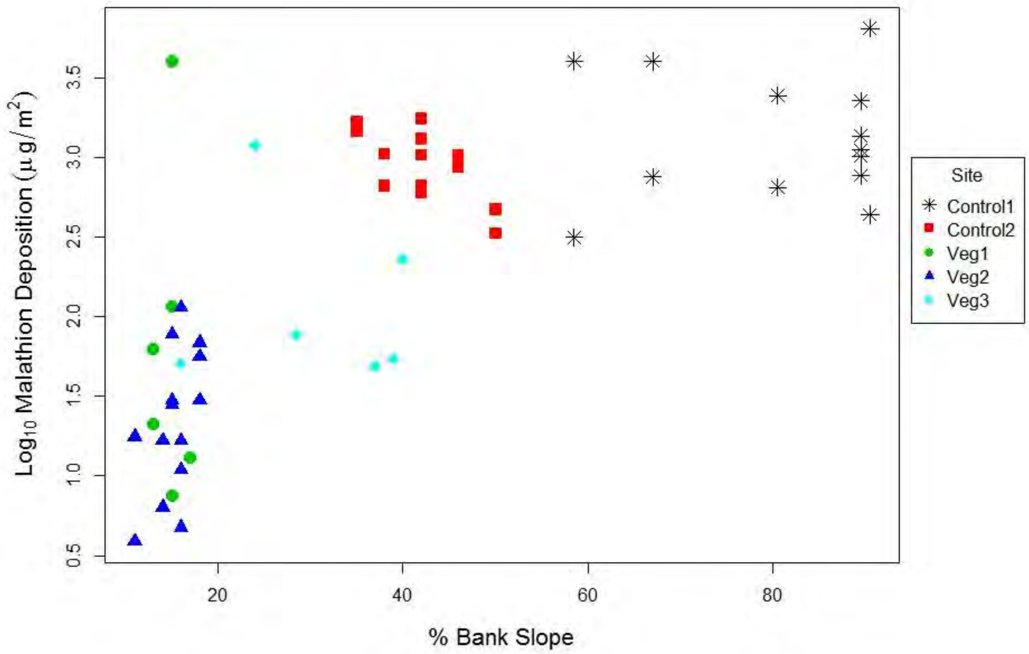

Figure 10. Direct relationship between bank slope and malathion deposition

Based on the initial analysis and an expectation of which parameters were likely to influence instream deposition, a smaller subset of vegetation and distance characteristics was identified for additional analysis. Additional parameters considered were the average of instream and bank canopy cover, the distance between the F and V depositional samplers, canopy angle, the distance between F and W depositional samplers, and bankfull width. For combinations of these parameters, linear mixed effects models were constructed, with random effects for transect and site ID nested within site type. Models with two, three, and four covariates were then developed. All three- and four-covariate models showed signs of multicollinearity and as a result only univariable and two-covariate models are discussed here.

As discussed above, results of the univariable analysis were that canopy cover, canopy angle, distance between F and V, and distance between F and W were all significantly inversely related to malathion deposition. For each, an estimate of the expected decrease in instream $\log_{10}$ malathion deposition due to an increase in the parameter was calculated (only statistically significant estimates are presented in Table 11).

Table 11. Results of univariable models: expected changes in malathion deposition due to increases in vegetation and distance parameters

Model	Parameter modeled	Expected change in $\log_{10}$ of instream malathion deposition*	p-value
1	Canopy cover (average of stream and bank canopy cover) (%)	-0.015	0.002
2	Distance between F and V (m)	-0.256	0.008
3	Canopy angle (°)	-0.018	0.0002
4	Distance between F and W (m)	-0.108	0.032

* This estimate represents the expected change in $\log_{10}$ of instream malathion deposition resulting from a 1-unit increase in the corresponding parameter

These parameters were then explored through two-covariate models comparing both distances and canopy-specific parameters. Four models with two covariates each were generated (Table 12). Of the four models generated, a distance variable was statistically significant in only one model. In Model 1 the distance between F and V was modeled with canopy cover and both were statistically significant (Table 12). However, in that two-covariate model the effect of F – V distance was reduced by more than half compared to the effect when F – V distance was modeled alone. In each of the two-covariate models the canopy-related parameter (either canopy cover or canopy angle) was statistically significant each time it appeared. In addition, when they were modeled in conjunction with a distance variable, the canopy-related parameter only had a slight reduction in effect. This suggests that variables related to canopy coverage are extremely important in reducing malathion deposition instream.

Table 12. Results of two-covariate models: expected changes in malathion deposition due to increases in distance and vegetation parameters

Model	Parameters modeled	Expected change in $\log_{10}$ of instream malathion deposition*	p-value
1	Canopy cover (average of stream and bank canopy cover) (%),	-0.011	0.005
	Distance between field-edge and vegetation-edge (m)	-0.167	0.028
2	Canopy angle (°),	-0.014	0.002
	Distance between field-edge and vegetation-edge (m)	-0.086	0.32
3	Canopy cover (average of stream and bank canopy cover) (%),	-0.011	0.021
	Distance between field-edge and center water (m)	-0.047	0.30
4	Canopy angle (°),	-0.017	0.005
	Distance between field-edge and center water (m)	-0.010	0.78

* This estimate represents the expected change in $\log_{10}$ of instream malathion deposition ($\mu g/m^2$) resulting from a 1-unit increase in the corresponding parameter

In order to compare the expected effects of changes in both distance and canopy related variables on an equal basis the change in each needed to reach a similar decrease in instream malathion deposition was calculated. Calculations were based on the results of two-covariate Model 1 in which both canopy cover and F – V distance were statistically significant. An average additional 0.1 decrease in $\log_{10}$ of instream malathion deposition (approximately 26% lower) could be reached by either increasing the F – V distance by an additional 0.6 m or increasing the canopy cover by an additional 9%.

7. Conclusions

This project involved extensive collaboration between EPA, NMFS, and WSDA during project design and planning. In order to execute this study WSDA developed collaborative relationships with landowners, crop consultants, and aerial applicators. The project was successfully planned and implemented in the field, lab testing produced high-quality data, and analysis revealed a number of important findings. Malathion deposition was reduced 61 to 69% between the edge of the field and the center of the waterbody at control sites, and 97 to 99% at vegetated sites. Instream malathion deposition was reduced on average 96.3% at vegetated sites compared to control sites. Increasing either distance from field or canopy cover can reduce malathion deposition. F – V distance was statistically significant in only one of the two-covariate models developed. In addition, the effect of F – V distance was reduced by more than half when it was modeled with a covariate in comparison to when it was modeled alone. Variables relating to canopy cover were statistically significant in all of the two-covariate models developed, and their effect was similar to their effect when modeled alone. Parameters relating to canopy cover were found to be extremely important in reducing malathion deposition instream. Total distances between the edge of the field and the stream of 13 – 20 m, combined with vegetative buffers of 5 to 9 meters in width, reduced instream malathion deposition 97 to 99 %. This study identified both distance and canopy cover as significant factors that reduce instream malathion deposition. Currently distance is the primary factor currently relied on as a mitigation strategy to reduce pesticide loading to streams in FIFRA-ESA pesticide consultations. The presence of vegetative buffers should be considered when determining pesticide application no-spray buffers for aerial applications on a site specific basis.

8. Recommendations

- A wide range of different buffer characteristics may play an important role in reducing instream malathion deposition and more research is needed to identify what the most important factors are and how they contribute.
- WSDA recommends that education and outreach efforts should focus on the potential benefits of riparian buffers, both to intercept pesticide drift and to improve habitat and other water quality parameters.
- When riparian vegetation of sufficient quality and quantity is present, reduced aerial no-spray buffers should be considered.
- Conservation districts should continue their work assisting and encouraging landowners to install riparian vegetation and hedgerows of effective size.
- Buffer demonstration projects on farms or research stations could be used to conduct research, education, and outreach.

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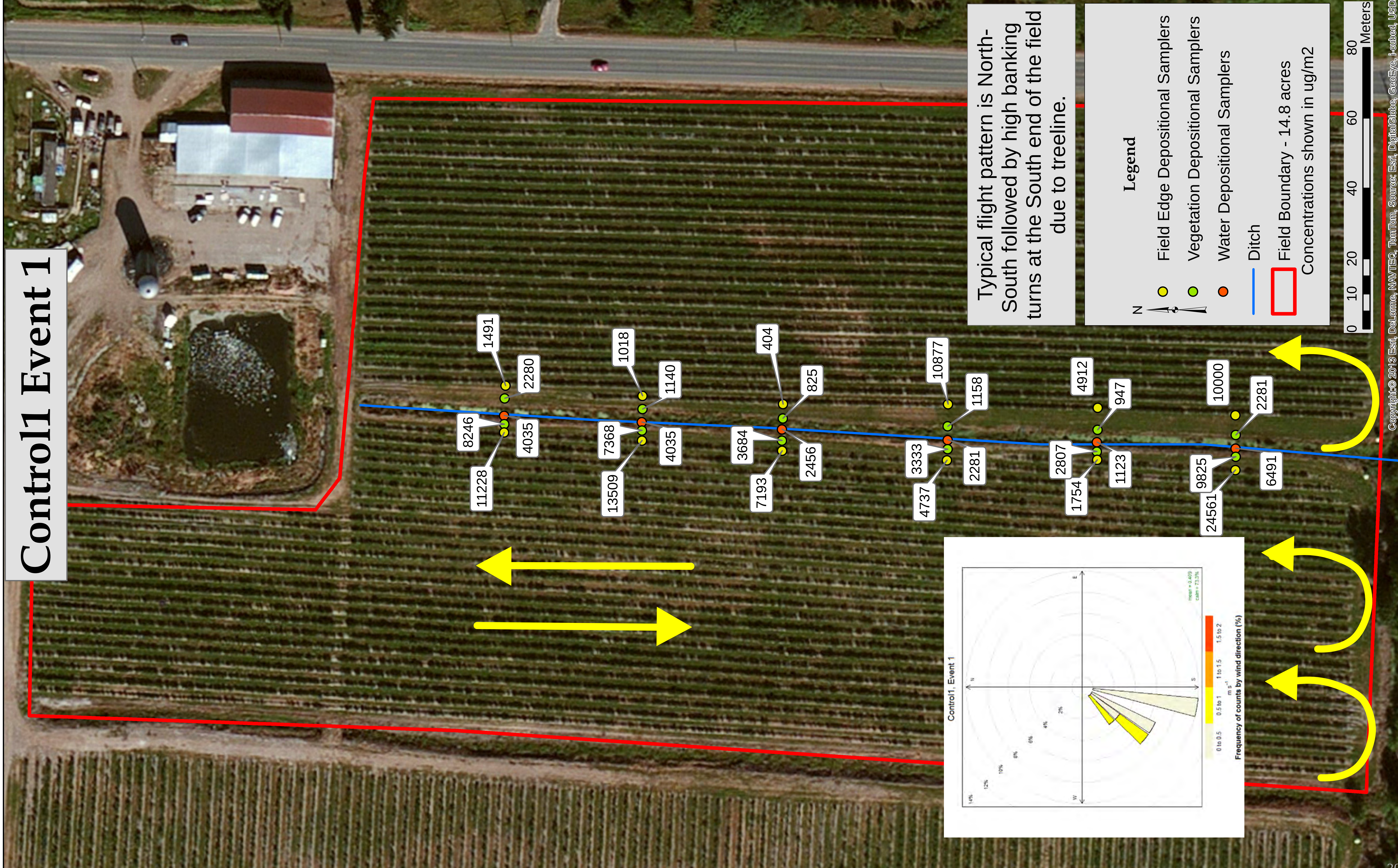
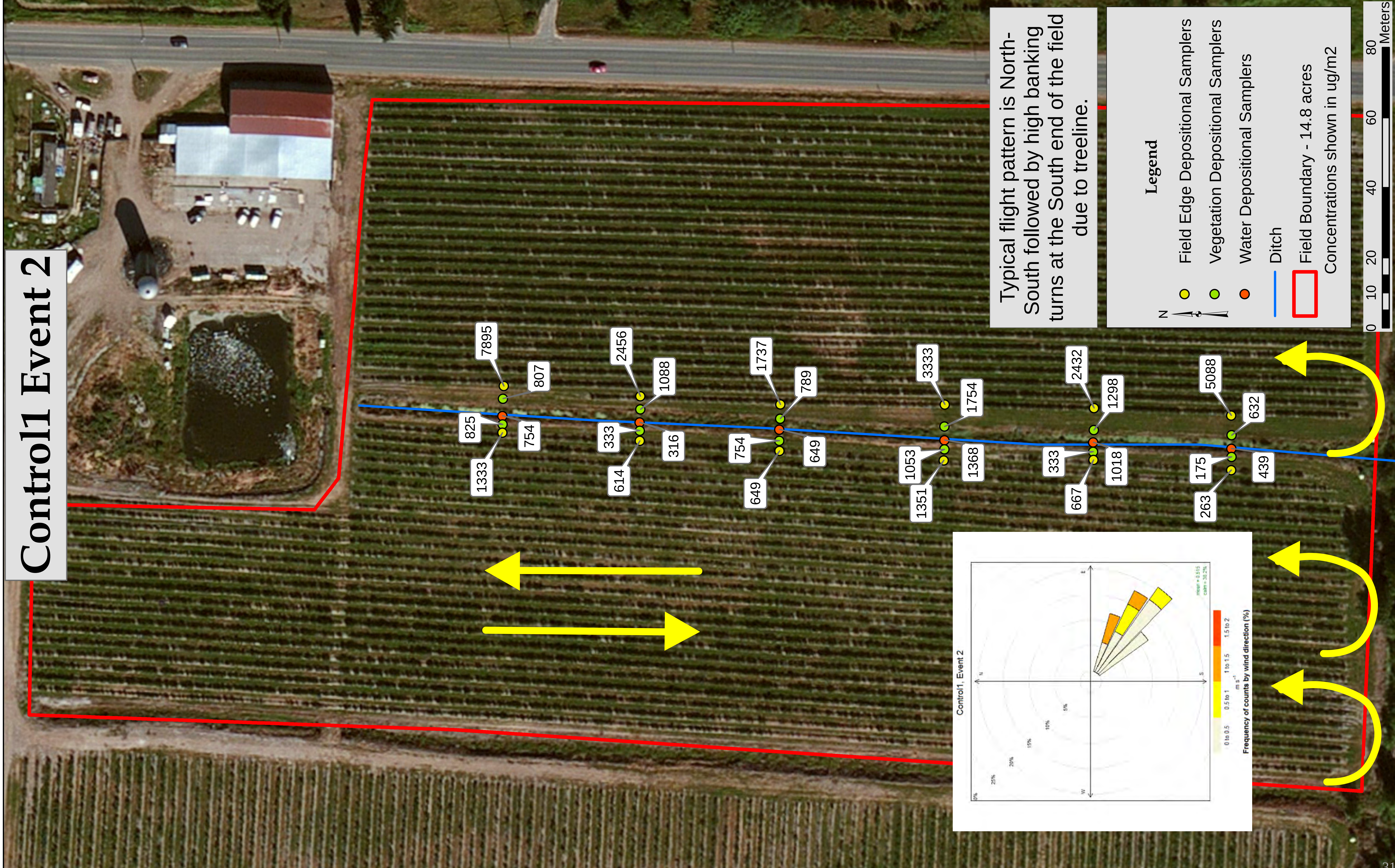
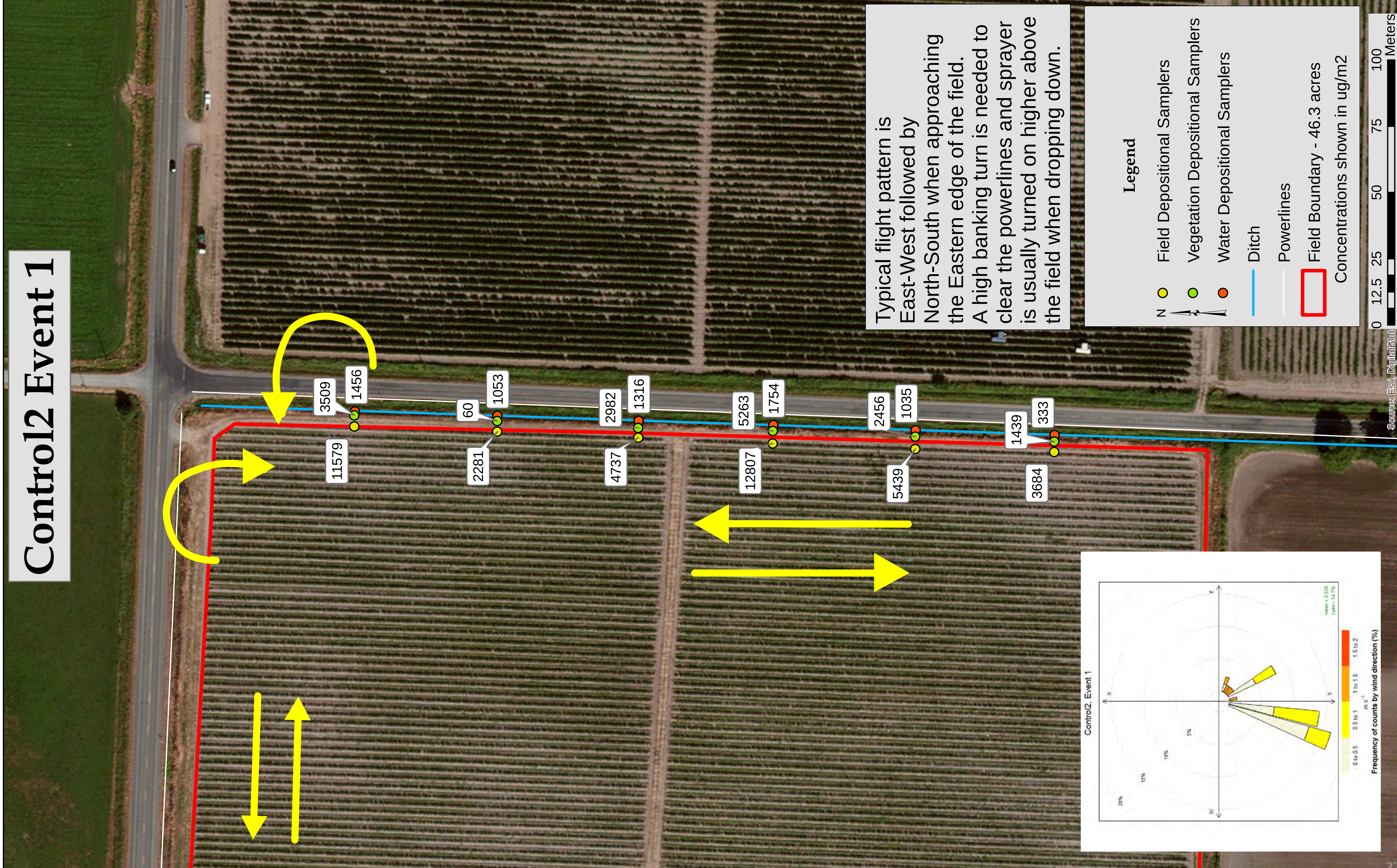
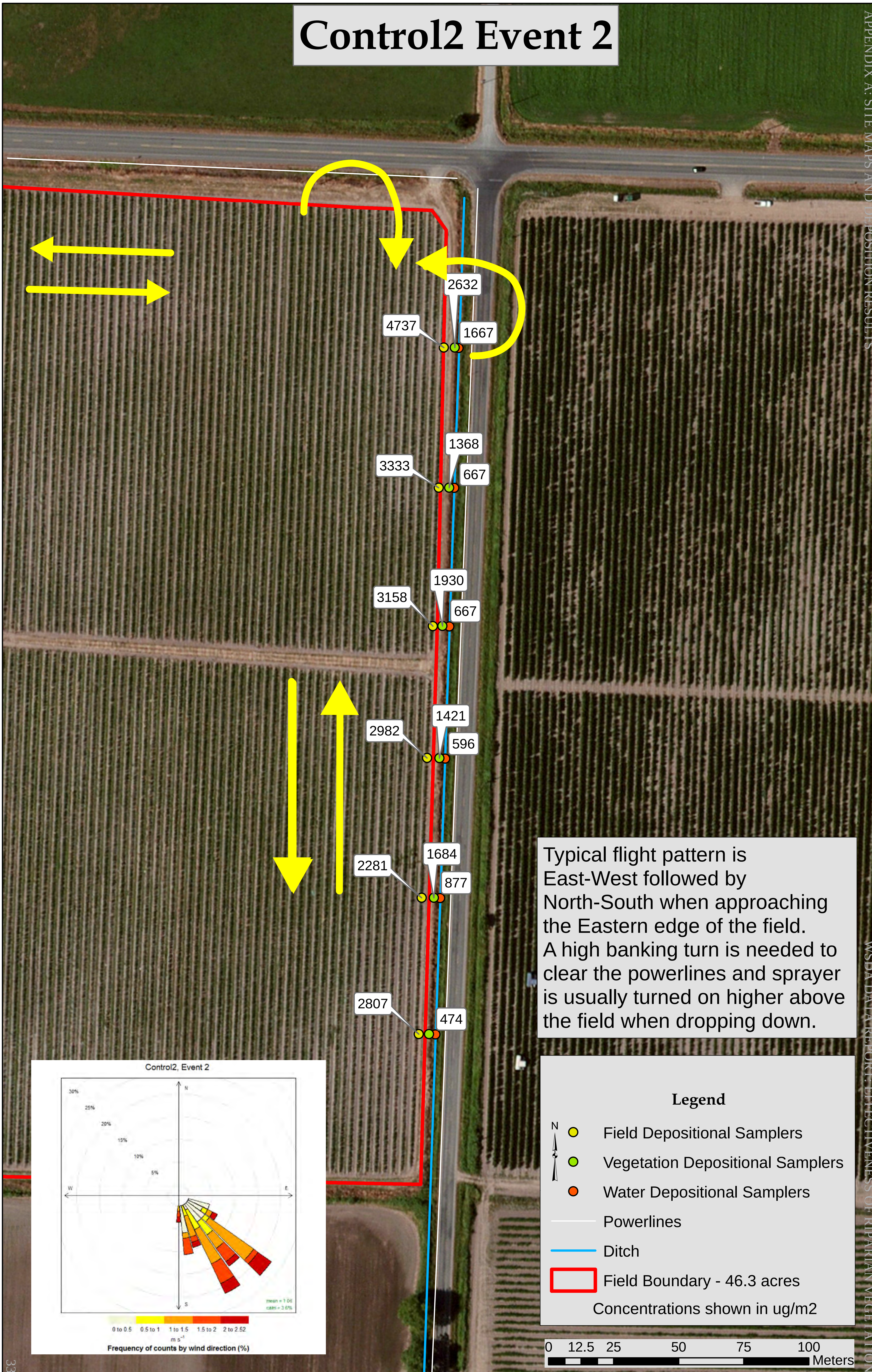
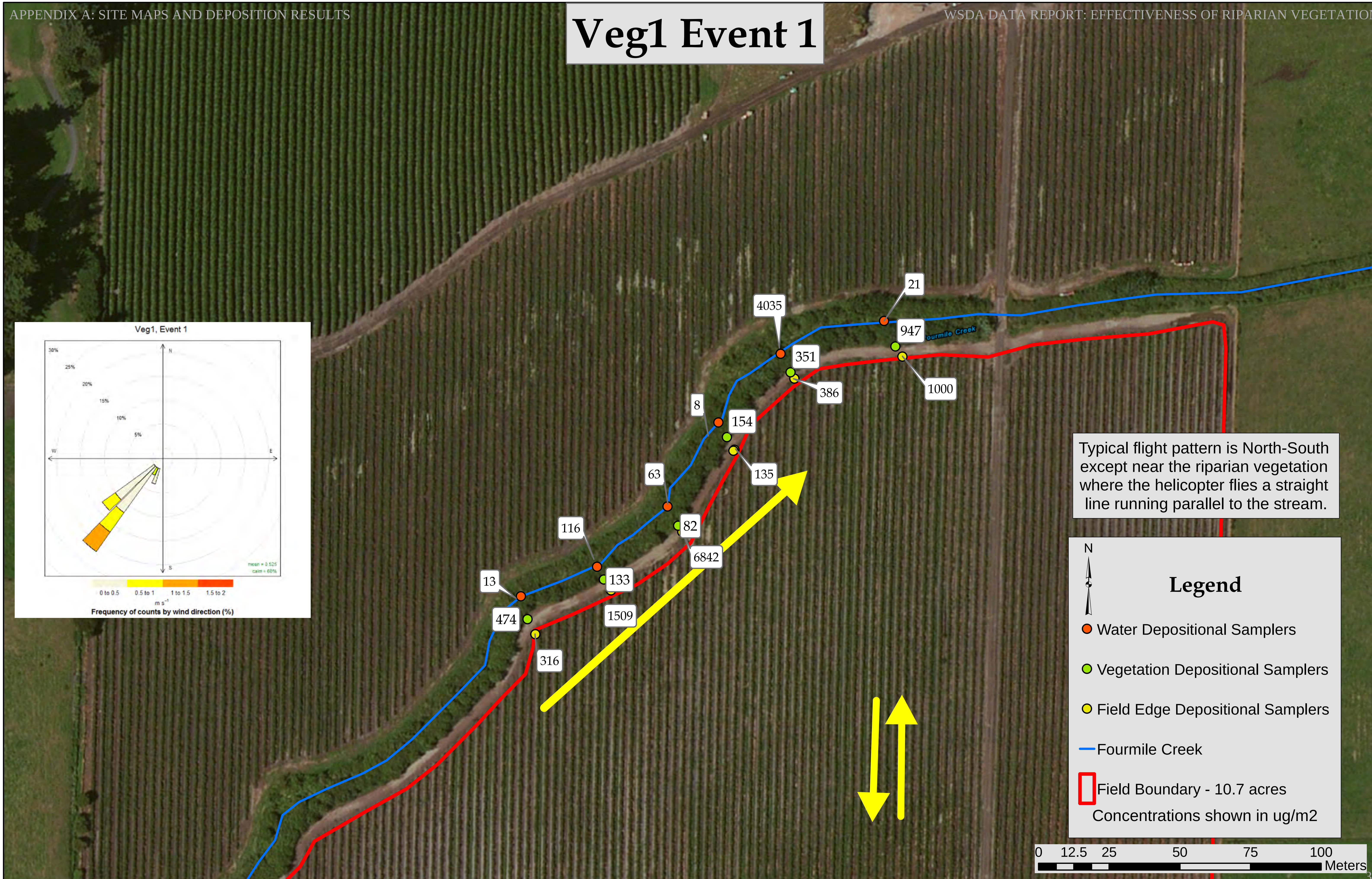
Appendix A: Maps and Depositional Results

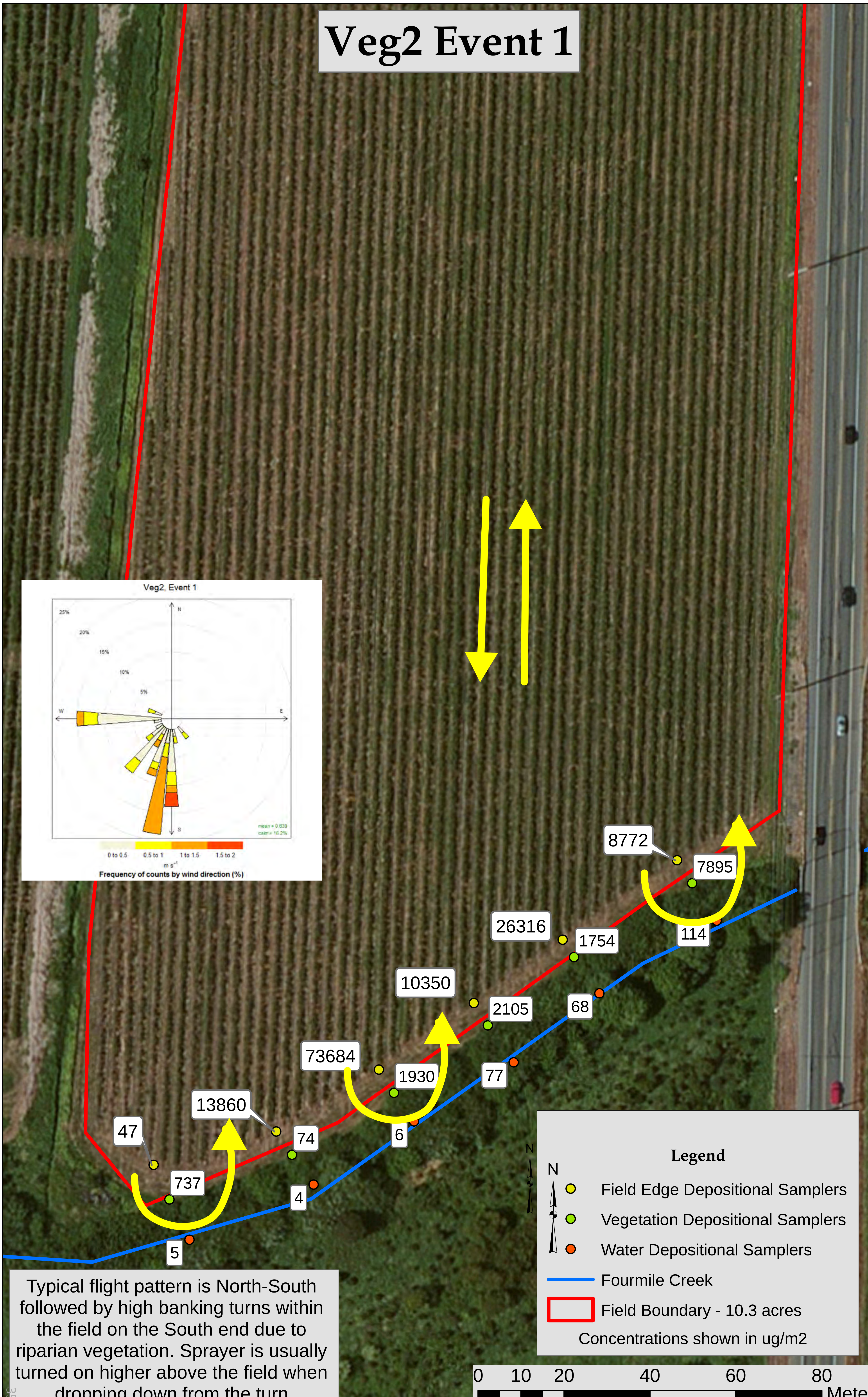

Control1 Event 1
Typical flight pattern is North-South followed by high banking turns at the South end of the field due to treeline.
Legend
Field Edge Depositional Samplers
Vegetation Depositional Samplers
Water Depositional Samplers
Ditch
Field Boundary - 14.8 acres
Concentrations shown in ug/m2
N
0 10 20 40 60 80 Meters
1491
2280
8246
4035
11228
1018
1140
7368
4035
13509
404
825
3684
2456
7193
10877
1158
3333
2281
4737
4912
947
2807
1123
1754
10000
2281
9825
6491
24561
Control1, Event 1
Frequency of counts by wind direction (%)
Copyright:© 2013 Esri, DeLorme, NAVTEQ, TomTom, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

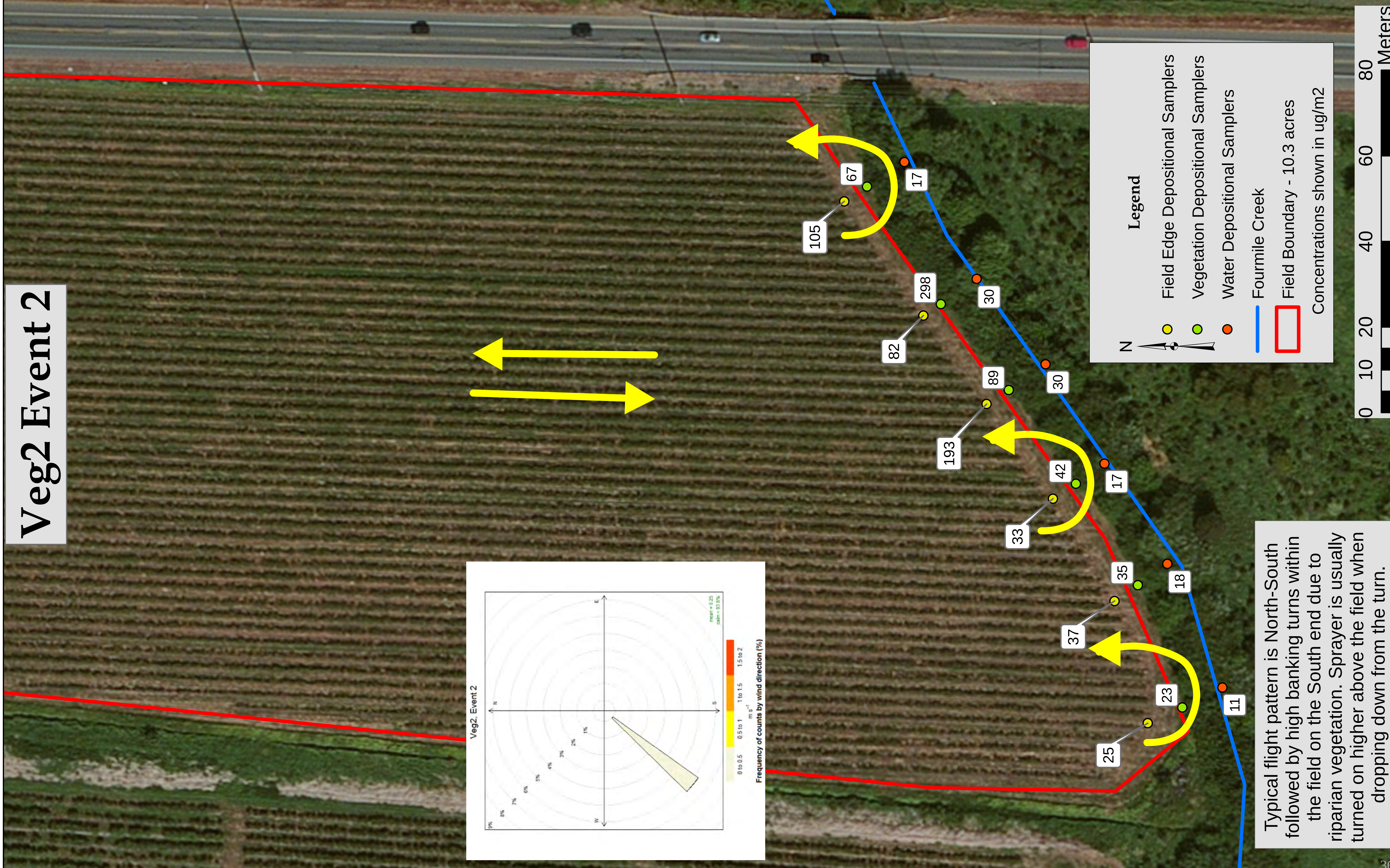

Control1 Event 2
Typical flight pattern is North-South followed by high banking turns at the South end of the field due to treeline.
Legend
Field Edge Depositional Samplers
Vegetation Depositional Samplers
Water Depositional Samplers
Ditch
Field Boundary - 14.8 acres
Concentrations shown in ug/m2
N
0 10 20 40 60 80 Meters
7895
807
825
754
1333
2456
1088
333
316
614
1737
789
754
649
649
3333
1754
1053
1368
1351
2432
1298
333
1018
667
5088
632
175
439
263
Control1, Event 2
Frequency of counts by wind direction (%)
0 to 0.5
0.5 to 1
1 to 1.5
1.5 to 2


Control2 Event 1
Typical flight pattern is East-West followed by North-South when approaching the Eastern edge of the field. A high banking turn is needed to clear the powerlines and sprayer is usually turned on higher above the field when dropping down.
Legend
Field Depositional Samplers
Vegetation Depositional Samplers
Water Depositional Samplers
Ditch
Powerlines
Field Boundary - 46.3 acres
Concentrations shown in ug/m2
0 12.5 25 50 75 100 Meters
N
3509
1456
11579
60
1053
2281
2982
1316
4737
5263
1754
12807
2456
1035
5439
1439
333
3684
Control2, Event 1
Frequency of counts by wind direction (%)
Source: Esri, DigitalGlobe, swisstopo, and the GIS User Community


Control2 Event 2
2632
1667
4737
1368
667
3333
1930
667
3158
1421
596
2982
1684
877
2281
2807
474
Typical flight pattern is East-West followed by North-South when approaching the Eastern edge of the field. A high banking turn is needed to clear the powerlines and sprayer is usually turned on higher above the field when dropping down.
Legend
N
Field Depositional Samplers
Vegetation Depositional Samplers
Water Depositional Samplers
Powerlines
Ditch
Field Boundary - 46.3 acres
Concentrations shown in ug/m2
0 12.5 25 50 75 100
Meters
Control2, Event 2
N
E
S
W
30%
25%
20%
15%
10%
5%
0 to 0.5
0.5 to 1
1 to 1.5
1.5 to 2
2 to 2.52
Frequency of counts by wind direction (%)


Veg1 Event 1
Veg1, Event 1
Frequency of counts by wind direction (%)
0 to 0.5
0.5 to 1
1 to 1.5
1.5 to 2
21
4035
947
Fourmile Creek
351
386
1000
8
154
135
63
116
82
6842
13
133
474
1509
316
Typical flight pattern is North-South except near the riparian vegetation where the helicopter flies a straight line running parallel to the stream.
N
Legend
Water Depositional Samplers
Vegetation Depositional Samplers
Field Edge Depositional Samplers
Fourmile Creek
Field Boundary - 10.7 acres
Concentrations shown in ug/m2
0
12.5
25
50
75
100
Meters


Veg2 Event 1
Veg2, Event 1
N
E
S
W
5%
10%
15%
20%
25%
0 to 0.5
0.5 to 1
1 to 1.5
1.5 to 2
m s^{-1}
Frequency of counts by wind direction (%)
8772
7895
114
26316
1754
68
10350
2105
77
73684
1930
6
13860
74
4
47
737
5
Legend
N
Field Edge Depositional Samplers
Vegetation Depositional Samplers
Water Depositional Samplers
Fourmile Creek
Field Boundary - 10.3 acres
Concentrations shown in ug/m2
0
10
20
40
60
80
Meters
Typical flight pattern is North-South followed by high banking turns within the field on the South end due to riparian vegetation. Sprayer is usually turned on higher above the field when dropping down from the turn.


Veg2 Event 2
Legend
Field Edge Depositional Samplers
Vegetation Depositional Samplers
Water Depositional Samplers
Fourmile Creek
Field Boundary - 10.3 acres
Concentrations shown in ug/m2
N
0 10 20 40 60 80 Meters
67
17
105
298
30
82
89
30
193
42
17
33
35
18
37
23
11
25
Veg2, Event 2
Frequency of counts by wind direction (%)
Typical flight pattern is North-South followed by high banking turns within the field on the South end due to riparian vegetation. Sprayer is usually turned on higher above the field when dropping down from the turn.

Veg3 Event 1

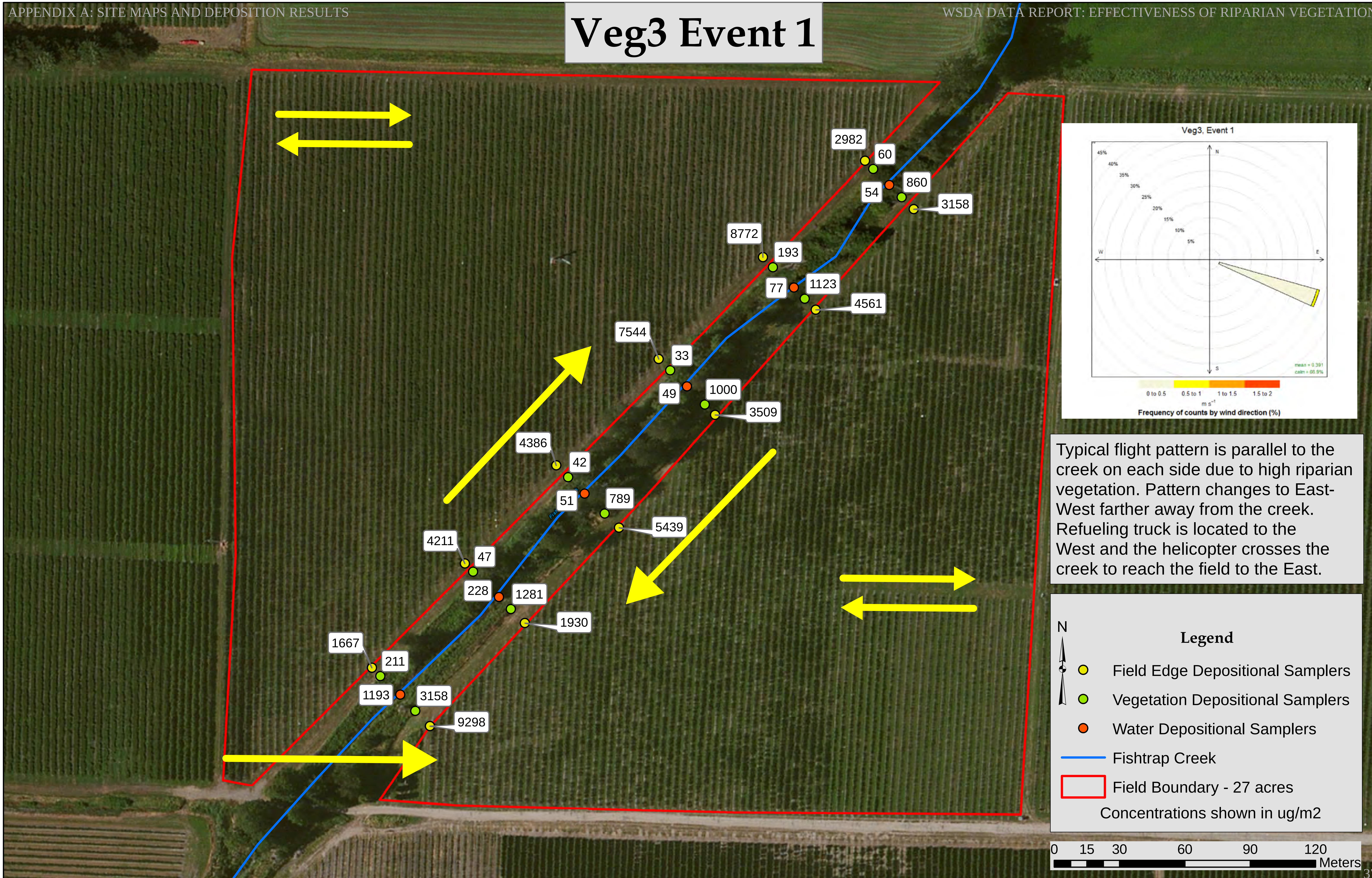

2982
60
860
54
3158
8772
193
77
1123
4561
7544
33
1000
49
3509
4386
42
51
789
5439
4211
47
228
1281
1930
1667
211
1193
3158
9298
Veg3, Event 1
N
S
W
E
Frequency of counts by wind direction (%)
Typical flight pattern is parallel to the creek on each side due to high riparian vegetation. Pattern changes to East-West farther away from the creek. Refueling truck is located to the West and the helicopter crosses the creek to reach the field to the East.
N
Legend
Field Edge Depositional Samplers
Vegetation Depositional Samplers
Water Depositional Samplers
Fishtrap Creek
Field Boundary - 27 acres
Concentrations shown in ug/m2
0 15 30 60 90 120
Meters

Table A-1. Depositional results and replicates (which are not shown on maps above)

Site	Event	Water (W) Veg (V) or Field (F)	Left(L) Right (R) or Center (C)	Transect	Sample Type	Result (µg/m^2)
Veg1	1	F	L	3	Sample	6,842.11
Veg1	1	F	L	3	Replicate	5,263.16
Veg2	1	F	R	6	Replicate	14,912.28
Veg2	1	F	R	6	Sample	8,771.93
Veg2	1	W	C	5	Sample	68.42
Veg2	1	W	C	5	Replicate	56.14
Veg2	2	V	R	1	Replicate	24.56
Veg2	2	V	R	1	Sample	22.81
Veg2	2	W	C	4	Sample	29.82
Veg2	2	W	C	4	Replicate	28.07
Veg3	1	F	L	4	Sample	3,508.77
Veg3	1	F	L	4	Replicate	3,157.89
Veg3	1	F	R	4	Sample	7,543.86
Veg3	1	F	R	4	Replicate	5,964.91
Control1	1	V	L	2	Sample	947.37
Control1	1	V	L	2	Replicate	684.21
Control1	1	V	R	6	Sample	8,245.61
Control1	1	V	R	6	Replicate	7,894.74
Control1	2	F	R	1	Replicate	368.42
Control1	2	F	R	1	Sample	263.16
Control1	2	V	L	2	Sample	1,298.25
Control1	2	V	L	2	Replicate	1,473.68
Control1	2	W	C	2	Sample	1,017.54
Control1	2	W	C	2	Replicate	771.93
Control2	1	F	R	3	Sample	12,807.02
Control2	1	F	R	3	Replicate	7,894.74
Control2	1	W	C	4	Sample	1,315.79
Control2	1	W	C	4	Replicate	1,035.09
Control2	2	F	R	2	Replicate	2,982.46
Control2	2	F	R	2	Sample	2,280.70
Control2	2	W	C	3	Replicate	631.58
Control2	2	W	C	3	Sample	596.49

Appendix B: Project Quality Assurance and Quality Control

Laboratory and Field Data Quality

Data from samples submitted to the laboratory for residue analysis may be qualified if one or more analytical factors affect confidence in the prescribed data value. Pesticide residue data was evaluated according to the National Functional Guidelines for Organic Data Review (EPA, 2008). Detections quantified below reporting limits are qualified as estimates according to Table B-1. Definitions of data qualifiers are presented in Table B-1.

Table B-1: Data qualification definitions

Qualifier	Definition
(No qualifier)	The analyte was detected at the reported concentration. Data are not qualified.
J	The analyte was positively identified and the associated numerical value is the approximate concentration of the analyte in the sample (due either to the quality of the data generated because certain quality control criteria were not met).
NJ	The analysis indicates the presence of an analyte that has been “tentatively identified,” and the associated numerical value represents its approximate concentration.
NAF	Not analyzed for.
R	The sample results are unusable due to the quality of the data generated because certain criteria were not met. The analyte may or may not be present in the sample.
U	The analyte was analyzed for, but was not detected at a level greater than or equal to the reporting limit for that sample and method.
UJ	The analyte was not detected at or above the reported sample reporting limit. However, the reporting limit is approximate and may or may not represent the actual level of quantitation necessary to accurately measure the analyte in the sample.

Method Reporting Limit

The method reporting limit (MRL) is the lowest concentration standard in the calibration range for each analyte. Reporting limits for individual samples were equal to the MRL multiplied by the final dilution factor. Only results greater than or equal to the reporting limit were reported by the laboratory. In addition to the MRL, the laboratory also reported the method detection limit (MDL). The MDL is defined by the Federal Code of Regulation 40 Appendix B to Part 136 as, “the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte.” The reporting limits and MDLs for water samples and depositional samples are presented in Table B-2.

Table B-2: Method reporting limit for malathion and malaoxon

Analyte	CAS Number	EPA Method†	Method Reporting Level*	MDL
Malathion	121-75-5	8321B	0.050 µg/L or 0.70 µg/m^2	0.020 µg/L or 0.11 µg/m2
Malaoxon	1634-78-2	8321B	0.050 µg/L or 0.70 µg/m^2	0.020 µg/L or 0.27 µg/m2

* µg/L for composite surface water or µg/m^2 for cellulose filter paper circles from depositional samplers
† Analysis by LC-MS/MS.

Quality Assurance and Quality Control Samples

Quality assurance (QA) samples are collected in the field at the same time as non-QA samples and analyzed by the laboratory in batches with non-QA samples. Quality control (QC) samples are generated by the laboratory for every batch of field samples submitted. Samples submitted to the laboratory were run in batches of 20 or fewer following standard EPA guidance. QA and QC samples assure consistency and accuracy throughout sample collection, sample analysis, and the data reporting process.

For this project, QA samples include: field replicates, field blanks, and matrix spike and matrix spike duplicates (MS/MSD). QC samples included laboratory control samples (LCS), LCS duplicates (LCSD), surrogate spikes, and method blanks. QC samples were run alongside non-QC samples and analyzed by the laboratory. QA samples accounted for 13.8% of the depositional samples collected and 9.2% of the total water samples collected. Table B-3 displays all of the QA samples collected for this project.

Table B-3: QA Sample schedule

Site	Single or Double-sided	Event	Depositional Sample QA	Water Sample QA
Veg1	Single-sided (Left)	1	Blank Rep 1 (Transect 3, left field) Rep 2 = None	Blank MS/MSD (Composite sample 4, downstream) Rep (Composite sample 3, downstream)
Veg2	Single-sided (Right)	1	Blank Rep 1 (Transect 5, water) Rep 2 (Transect 6, right field)	Blank MS/MSD (Composite sample 4, downstream) Rep = None
		2	Blank Rep 1 (Transect 4, water) Rep 2 (Transect 1, right veg)	Blank = None MS/MSD = None Rep (Composite sample 3, downstream)
Veg3	Double-sided	1	Blank Rep 1 (Transect 4, left field) Rep 2 (Transect 4, right field)	Blank MS/MSD (Composite sample 1, downstream) Rep (Composite sample 2, downstream)
Control1	Double-sided	1	Blank Rep 1 (Transect 6, right veg) Rep 2 (Transect 2, left veg)	Blank MS (Grab sample, Transect 1) MSD (Grab sample, Transect 2) Rep (Grab sample, Transect 5)
Control1	Double-sided	2	Blank = None Rep 1 (Transect 1, right field) Rep 2 (Transect 2, water) Rep 3 (Transect 2, left veg)	Blank MS/MSD (Grab sample, Transect 3) Rep (Grab sample, Transect 2)
Control2	Single-sided (Right)	1	Blank Rep 1 (Transect 4, water) Rep 2 (Transect 3, right field)	Blank = None MS/MSD = None Rep = None
		2	Blank Rep 1 (Transect 3, water) Rep 2 (Transect 2, right field)	Blank = None MS/MSD = None Rep = None

Performance Measures

Performance measures are used by the laboratory and field staff to determine when data should be qualified. Relative percent difference (RPD) is used as a performance measure to represent the precision of the analysis by comparing the difference between replicate pairs for matrix spikes, laboratory control samples and field replicates. The RPD is calculated by dividing the absolute value of the difference between the replicates by their mean, then multiplying by 100 for a percent value. Percent recovery is also used as a performance measure to represent the bias of the analysis by comparing the difference between replicate pairs for matrix spikes, laboratory control samples, and surrogate recovery. RPD and % recovery are also to qualify the results of the grab samples when quality assurance (QA) and quality control (QC) samples fall below the lower control limits or fall above the upper control limits. Control limits are default limits specified by the EPA method. Performance measures for QA and QC samples are presented in Table B-4.

Table B-4: Laboratory performance measurement objectives for malathion and malaoxon

Analyte	EPA Method†	% Recovery Limits for LCS/LCSDs, CRM, & CCV	RPD for Replicates & LCS/LCSDs	% Recovery Limits for MS/MSDs	RPD for MS/MSDs	% Recovery Limits for Surrogate Recoveries
Malathion	8321B	30-130%	≤ 25%	70-120%	≤ 40%	30-130%
Malaoxon	8321B	30-130%	≤ 25%	70-120%	≤ 40%	30-130%

† Analysis by LC-MS/MS.

Field Replicate Sample Results

Field replicates were placed adjacent to non-QC samples in the field determine data quality and sampling variability. Field replicate samples accounted for 10.7% of the depositional samples collected and 1.8% of the water samples collected. Precision between replicate pairs was calculated using the relative percent difference (RPD) statistic.

There were 16 replicate pairs for the depositional samples, and malathion and malaoxon were detected in all depositional sample replicate pairs. The average RPD for the depositional sample replicate pairs was 22.4% for malathion and 19.6% for malaoxon. Of the 16 replicate pairs, there were seven pairs (44%) that exceeded the 20% RPD criterion for malathion and four pairs (25%) that exceeded the 25% RPD criterion for malaoxon. However, only two of the 16 pairs (12.5%) had a RPD over 40% for malathion and only one pair (6.3%) had a RPD over 40% for malaoxon. This variability is attributed to field conditions and not to laboratory analysis or analytical matrix. Results for samples that exceeded the 20% RPD criterion were qualified as estimates (J) following this project's quality assurance project plan. Non-detect (ND) values refer to results where the analyte was analyzed for, but was not detected at a level greater than or equal to the reporting limit for that sample and method (U). Table B-5 presents the results for both the non-QA depositional sample and replicate samples, the averaged result, and the relative percent difference between them.

Table B-5: Field replicate results from depositional samples

Analyte	Site	Event	Water (W) Veg (V) or Field (F)	Left(L) Right (R) or Center (C)	Transect	Sample Type	Result (µg/m²)	Averaged Result (µg/m²)	RPD (%)	Qualifier
Malathion	Veg1	1	F	L	3	Sample	6842.11	6052.63	26	J
						Replicate	5263.16			J
	Veg2	1	F	R	6	Replicate	14912.28	11842.11	52	J
						Sample	8771.93			J
			W	C	5	Sample	68.42	62.28	20	
						Replicate	56.14			
		2	V	R	1	Replicate	24.56	23.68	7	
						Sample	22.81			

Analyte	Site	Event	Water (W) Veg (V) or Field (F)	Left(L) Right (R) or Center (C)	Transect	Sample Type	Result (µg/m²)	Averaged Result (µg/m²)	RPD (%)	Qualifier
Malathion			W	C	4	Sample	29.82	28.95	6	
						Replicate	28.07			
	Veg3	1	F	L	4	Sample	3508.77	3333.33	10	
						Replicate	3157.89			
			F	R	4	Sample	7543.86	6754.39	23	
						Replicate	5964.91			
	Control1	1	V	L	2	Sample	947.37	815.79	32	J
						Replicate	684.21			J
			V	R	6	Sample	8245.61	8070.18	4	
						Replicate	7894.74			
		2	F	R	1	Replicate	368.42	315.79	33	J
						Sample	263.16			J
			V	L	2	Sample	1298.25	1385.96	13	
						Replicate	1473.68			
			W	C	2	Sample	1017.54	894.74	27	J
						Replicate	771.93			J
	Control2	1	F	R	3	Sample	12807.02	10350.88	47	J
						Replicate	7894.74			J
			W	C	4	Sample	1315.79	1175.44	24	
						Replicate	1035.09			
		2	F	R	2	Replicate	2982.46	2631.58	27	J
						Sample	2280.70			J
			W	C	3	Replicate	631.58	614.04	6	
						Sample	596.49			
Malaoxon	Veg1	1	F	L	3	Sample	1.33	1.26	11	
						Replicate	1.19			
	Veg2	1	F	R	6	Replicate	28.07	23.68	37	J
						Sample	19.30			J
			W	C	5	Replicate	ND	n/a	n/a	U
						Sample	ND			U
		2	V	R	1	Sample	ND	n/a	n/a	U
	Veg2	2	V	R	1	Replicate	ND	n/a	n/a	U
			W	C	4	Sample	0.91	0.87	10	
						Replicate	0.82			
	Veg3	1	F	L	4	Sample	3.51	3.16	22	
						Replicate	2.81			
			F	R	4	Sample	6.67	6.23	14	
						Replicate	5.79			
	Control1	1	V	L	2	Sample	ND	n/a	n/a	U
						Replicate	ND			U
			V	R	6	Sample	2.11	2.11	0	

Analyte	Site	Event	Water (W) Veg (V) or Field (F)	Left(L) Right (R) or Center (C)	Transect	Sample Type	Result (µg/m²)	Averaged Result (µg/m²)	RPD (%)	Qualifier
Malaoxon						Replicate	2.11			
		2	F	R	1	Replicate	1.00	0.89	26	J
						Sample	0.77			J
			V	L	2	Replicate	3.16	2.89	18	
						Sample	2.63			
			W	C	2	Sample	1.93	1.80	15	
						Replicate	1.67			
	Control2	1	F	R	3	Sample	21.05	17.02	47	J
						Replicate	12.98			J
			W	C	4	Sample	1.75	1.52	31	J
						Replicate	1.28			J
		2	F	R	2	Sample	6.84	6.58	8	
						Replicate	6.32			
			W	C	3	Replicate	1.56	1.46	14	
						Sample	1.35			

There were four replicate pairs for water samples. Malathion and malaoxon were detected in all water sample replicate pairs. Table B-6 presents the results for both the non-QA water samples and replicate samples, the averaged results, and the relative percent differences between them.

Table B-6: Field replicate results from water samples

Analyte	Site	Event	Position	Sample Type	Result (µg/L)	Averaged Result (µg/L)	RPD (%)	Qualifier
Malathion	Veg1	1	Downstream	Composite Sample	0.065	0.059	20	J
				Replicate	0.053			J
	Veg2	2	Downstream	Composite Sample	ND	n/a	n/a	U
				Replicate	ND			U
	Control1	1	Transect 5	Grab Sample (after)	3.1	2.7	30	J
				Replicate	2.3			J
		2	Transect 3	Grab Sample (after)	1.3	1.25	8	
				Replicate	1.2			
Malaoxon	Veg1	1	Downstream	Composite Sample	ND	n/a	n/a	U
				Replicate	ND			U
	Veg2	2	Downstream	Composite Sample	ND	n/a	n/a	U
				Replicate	ND			U
	Control1	1	Transect 5	Grab Sample (after)	ND	n/a	n/a	U
				Replicate	ND			U
		2	Transect 3	Grab Sample (after)	ND	n/a	n/a	U

Analyte	Site	Event	Position	Sample Type	Result (µg/L)	Averaged Result (µg/L)	RPD (%)	Qualifier
				Replicate	ND			U

The average RPD for the water sample replicate pairs was 19.3% for malathion. All of the results for replicate pairs for malaoxon were non-detects. Of the four replicate pairs, two pairs exceeded the 20% RPD criterion for malathion. However, none of the four pairs had a RPD over 40% for malathion. Results for samples that exceeded the 20% RPD criterion were qualified as estimates (J) following this project's quality assurance project plan.

Field Blank Sample Results

Field blank detections indicate the potential for sample contamination in both the field and laboratory as well as the potential for false detections due to analytical error. If field blank detections occur detections may be qualified as estimates. There were no detections of malathion and or malaoxon in the water sample field blanks. Of the seven depositional sample field blanks there were zero detections of malaoxon and four detections of malation. Malathion detections in the field blanks ranged from 1.2 to 7.5 times the reporting limit for those samples. Table B-7 lists the depositional sample field blank results. Average deposition at those events is shown to illustrate relative difference in magnitude between the level of contamination in the blank and the average deposition at the field locations

Table B-7: Detections in depositional sample field blanks

Analyte	Site	Event	Result ($\mu g/m^2$)*	Reporting Level ($\mu g/m^2$)	Times Above the Reporting Level	Average Deposition at Event ($\mu g/m^2$)
Malathion	Control1	2	0.982	0.70	1.4	1373
	Control2	1	3.509	0.70	5.0	3606
	Veg1	1	0.807	0.70	1.2	1150
	Veg2	1	5.263	0.70	7.5	8138

* Only results for events with detections in the field blanks are shown in this table.

Blank contamination was limited to the depositional sample field blanks and none of the other blanks for the project were contaminated at levels above the reporting limit. The contamination of the field blanks is attributed to the very high levels of malathion in the study area at the time of sample collection combined with the sensitivity of the analytical method. In addition, field blanks were collected after all of the other depositional samples had already been collected, and at that point field staff had had been in significant contact with contaminated dust and vegetation, presenting many opportunities for contamination. The amount of malathion detected in the four field blanks was low compared to the average deposition results from the same events. Blank contamination averaged 3.8 $\mu g/m^2$ while deposition results ranged from 1373 $\mu g/m^2$ to 8138 $\mu g/m^2$ at those same events. For sampling events where there was a depositional sample field blank with a positive detection, depositional results from non-QA samples and replicate samples were qualified as estimates (J) as follows: if the non-QA or replicate sample had a detection that was less than or equal to ten times the amount detected in the contaminated blank. Sample results were qualified to indicate that there may be more uncertainty around the exact concentration of those specific samples for those events.

Matrix Spike/Matrix Spike Duplicate Sample Results

MS/MSD results reflect the process of sample duplication (field), analyte degradation, matrix interactions (sample/standard), extraction efficiency, and analyte recovery. No MS or MSD samples were collected for the depositional samples as there was expected to be no matrix interference in those samples. MS/MSD samples were each spiked with 0.25 µg/L of malathion and 0.25 µg/L of malaoxon. Table B-8 presents the percent recovery for the MS and MSD samples as well as the RPD between them for water samples.

Table B-8: MS/MSD recoveries and RPDs

Analyte	Sample Type	Recovery (%)	RPD (%)
Malathion	MS	99	2
	MSD	101	
	MS	n/a*	n/a*
	MSD	n/a*	
	MS	104	2
	MSD	99	
	MS	113	13
	MSD	96	
Malaoxon	MS	104	1
	MSD	105	
	MS	110	18
	MSD	89	
	MS	111	10
	MSD	100	
	MS	111	8
	MSD	103	

* Recovery and RPD were not reported by the laboratory due to a high concentration of the target analyte in the source sample.

All MS and MSD samples were well within the target range for recovery (70-120%) and RPD (≤ 40%) for malathion and malaoxon. The average recovery for malathion and malaoxon was 102% and 104% with standard deviations (SD) of ± 5% and ± 7% respectively. The average RPD between the MS and MSD samples was 6% for malathion and 9% for malaoxon.

Method Blank Sample Results

Method blanks are used to assess the precision of equipment and the potential for internal laboratory contamination. If method blank detections occur, the sample RL may be increased, and detections may be qualified as estimates. There were no detections of malathion or malaoxon in any of the depositional method blanks or water method blanks.

Surrogate Results

Surrogates are compounds used to spike field samples at the laboratory. Surrogates are used to assess recovery for a group of structurally related compounds. Triphenyl phosphate is typically used as a surrogate for organophosphorus insecticides. Triphenyl phosphate was used to spike all water samples collected in the field. The average surrogate recovery was 72% (SD ± 18%). Only 2 samples (2.7%) did not meet the surrogate recovery control limits (30-130%). Malathion and malaoxon concentrations were qualified as estimates (J) for samples not meeting the control criteria.

Laboratory Control Sample Results

Laboratory control samples (LCS) are analyte compounds used to spike deionized water (for water samples) or clean filter paper (for depositional samples) at known concentrations and extracted and analyzed with every batch of field samples. They are used to evaluate accuracy of pesticide residue recovery for a specific analyte. Detections may be qualified based on low recovery, high recovery, and/or high RPD between the paired LCS and LCSD. For depositional samples LCS/LCSDs were each spiked with 0.2 µg/m^2 of malathion and 0.2 µg/m^2 of malaoxon. Table B-9 presents the percent recoveries for the LCS and LCSD depositional samples, as well as the RPD between them.

Table B-9: LCS and LCSD recovery and RPD for depositional samples

Analyte	Sample Type	Recovery (%)	RPD (%)
Malathion	LCS	114	5
	LCSD	109	
	LCS	99	8
	LCSD	107	
	LCS	131	24
	LCSD	103	
	LCS	88	7
	LCSD	82	
	LCS	87	5
	LCSD	82	
	LCS	100	1
	LCSD	101	
	LCS	106	17
	LCSD	125	
	LCS	70	7
	LCSD	75	
	LCS	82	2
	LCSD	83	2
	LCS	95	8
	LCSD	88	
	LCS	90	5
	LCSD	95	
Malaoxon	LCS	89	0.8
	LCSD	90	
	LCS	90	0.3
	LCSD	90	
	LCS	97	7
	LCSD	90	
	LCS	93	10
	LCSD	84	
	LCS	78	4
	LCSD	81	
	LCS	91	3
	LCSD	88	
	LCS	78	16
	LCSD	91	
	LCS	85	5
	LCSD	89	
	LCS	81	1
	LCSD	82	
	LCS	79	0.3
	LCSD	79	
	LCS	84	0.7
	LCSD	84	

Of the 22 LCS and LCSD samples one was outside of the target range for recovery (30-130%) for malathion. None of the LCS/LCSD pairs were outside of the target range for RPD (≤ 25%) for malathion or malaoxon. The average recovery was 96% (SD ± 15%) for malathion and 86% (SD ± 5%) for malaoxon. The average RPD between the MS and MSD samples was 8% (SD ± 6%) for malathion and 4% (SD ± 5%) for malaoxon. Malathion and malaoxon concentrations were qualified as estimates (J) for depositional samples in the corresponding batch not meeting the control criteria.

For water samples LCS/LCSDs were each spiked with 0.25 µg/m^2 of malathion and 0.25 µg/m^2 of malaoxon. Table B-10 presents the percent recoveries for the LCS and LCSD for water samples, as well as the RPD between them.

Table B-10: LCS and LCSD recovery and RPD for water samples

Analyte	Sample Type	Recovery (%)	RPD (%)
Malathion	LCS	99	9
	LCSD	109	
	LCS	92	26
	LCSD	120	
	LCS	117	4 4
	LCSD	112	
	LCS	100	7
	LCSD	92	
	LCS	90	15
	LCSD	105	
Malaoxon	LCS	125	14
	LCSD	109	
	LCS	122	14
	LCSD	141	
	LCS	115	5
	LCSD	109	
	LCS	95	1
	LCSD	96	
	LCS	110	1
	LCSD	109	

Of the 10 LCS and LCSD samples for water none were outside the target recovery range (30-130%) for malathion. One of the LCS/LCSD pairs was outside of the target range for RPD (≤ 25%) for malathion and all pairs were within the range for malaoxon. The average recovery was 104% (SD ± 10%) for malathion and 113% (SD ± 13%) for malaoxon. The average RPD between the MS and MSD samples was 12% (SD ± 8%) for malathion and 7% (SD ± 6%) for malaoxon. Malathion and malaoxon concentrations were qualified as estimates (J) for depositional samples in the corresponding batch not meeting the control criteria.

Hold time and Storage Requirements

All samples and QA samples meet the following hold time and storage requirements with two exceptions. The first exception was that 30 of the 48 field samples collected at Control1 Event 1 were extracted 16 days after they were originally collected, exceeded the 14 day hold time by 2 days. The results associated with these samples were not qualified as all storage requirements were met and no appreciable degradation should have occurred under proper storage conditions for these analytes. The second exception was that several sample coolers exceeded the storage requirements in transit to the lab and were logged in exceedence of the storage requirements. Control2 Event2 and Veg3 Event1 samples were received by the laboratory at 10 °C, 6 ° above the storage requirements. Control1 Event2, Veg1 Event1, and Veg2 Event2 samples were received by the laboratory at 11 °C, 7 ° above the storage requirements. After consulting with PAL it was decided not to qualify these samples.

Quality Assurance Summary References

EPA, 2008. USEPA Contract Laboratory Program. National Functional Guidelines for Superfund Organic Methods Data Review. U.S. Environmental Protection Agency.
USEPA-540-R-08-01. www.epa.gov/superfund/programs/clp/download/somnfg.pdf

Appendix C: Field Forms

Automated Sampler Form: Complete 1 Form/Autosampler
Section 1: Automated Sampler Installation/Programming
Date ___________ Site ______________ Recorder ________________
Table 1

Sampling Location Information at Time of Installation				
Begin Time:		End Time:		
Latitude:		Longitude:		
Installing personnel:				
Stream Conditions				
Water Temperature (°C):	Air Temperature (°C):		pH:	
Conductivity (µS/cm) :	Dissolved Oxygen (mg/L):		Dissolved Oxygen (%):	
Flow (CFS/CMS):	Thalweg depth (cm):		Wetted Width (m):	
Stream Water Clarity				
Clear	Slight Haze	Streambed Visible but NOT Distinct	Streambed Not Visible	Color:
Odors from water/air:				
Notes:				

Table 2.

Automated Sampler Installation			
Automated Sampler Model & ID:			
Automated sampler relation to Ag. Practice(s):	Upstream	Adjacent	Downstream
Sampler Level:	Yes	No	Degrees off:
Length of Teflon Tubing (m) (strainer not included):			
Vertical distance from water surface to sampler pump (m):			
4 Photos taken of sampler placement?	Yes	No	
Notes:			

Date __________ Site _____________ Recorder _______________

Table 3.

Automated Sampler Programming						
Programming personnel:						Time:
Battery ID:			Power Use (amp-hr)			
Battery Rating (amp-hrs):			Previous:		Current:	
Humidity Indicator (%):			Pump Tube Count:			
Calibration						
Required Sample Volume (mL):			(1) Volume Delivered (mL):			
Recalibration required?	Yes	No	(2) Volume Delivered (mL):			
Programming						
Program Name:					Site Description Entered:	
Programmed Sample Type						
Time Sequential	Flow Sequential		Time-Composite		Flow-Composite	
Bottle Configuration:	1	2	4	8	12	24
Total Number of Bottles used:			Volume/Bottle (mL):			
Number of Rinse Cycles:			Number of Sample Retries:			
1 Part Program (only fill out for Part 'A')						
2 Part Program (Part 'A' & Part 'B')						
Part 'A'			Part 'B'			
Bottle Numbers:			Bottle Numbers:			
Sampling Interval:			Sampling Interval:			
Number of Samples/Bottle:			Number of Samples/Bottle:			
Volume/Sample (mL):			Volume/Sample (mL):			
Minutes Program Delayed:			Program Launch Time:			
Programmed starting time of first sampling event:						
Pre-Application						
Minute Zero Grab Sample (Volume(mL) / Time):						
Note: If sample is based on flow, include how sampler has been programmed to react to changing water level or flow.						

Section 2: Sample Collection and Data Retrieval

Date ___________ Site ______________ Recorder ________________

Table 4.

Sample/Data Retrieval				
Post-Application				
Collecting Personnel:				
Targeted Ag. Practice(s):				
Automated samplers relation to Ag. Practice(s):		Upstream	Adjacent	Downstream
QA/QC Samples				
QA/QC sample(s) collected:	Duplicate	Field Blank	Equipment Blank	MS/MSD
QA/QC Sample Volumes (mL):			MS Bottle #/Time:	
MSD Bottle #/Time:			Equipment Blank Bottle#/Time:	
Sample Retrieval				
Vertical distance from water surface to sampler:				
Condition of Sampler:				

Date __________ Site _____________ Recorder _______________

Sample/Data Retrieval Continued		
Program Data		
Battery ID:	Power Use (amp-hr)	
Battery Rating (amp-hrs):	Previous:	Current:
Total Time Operated:	Estimated Power Remaining (amp-hrs):	
Humidity Indicator (%):	Pump Tube Count:	
Program Launch Time:	Program Delay Time:	
Program Start Time (Enabled):	Program Stop Time:	

Part 'A'/'B'	Bottle #	Sample Vol. (mL)	Time (hh:mm,24h)	Sample ID (E#AA#A#AA)	Part 'A'/'B'	Bottle #	Sample Vol. (mL)	Time (hh:mm,24h)	Sample ID (E#AA#A#AA)
A	1								

Bottle Collection Begin Time (Time Autosampler Opened):			
All bottles filled:	Yes	No	Note:
Any spillage? (if yes, is sampler level?):			
Condition of intake (debris blockage?):			
Bottle Collection End Time (All Samples Placed on Ice):			
Note:			

Date __________ Site _____________ Recorder _______________

Table 5.

Stream Conditions at Time of Sample Retrieval:					
Flow (CFS/CMS):		Thalweg depth (cm):		Wetted Width (m):	
Water Temperature (°C):		Air Temperature (°C):		pH:	
Conductivity (µS/cm) :		Dissolved Oxygen (mg/L):		Dissolved Oxygen (%):	
Stream Water Clarity					
Clear	Slight Haze	Streambed Visible but NOT Distinct		Streambed Not Visible	Color:
Odors from water/air:					
Notes:			Time Leaving Site:		

Transect Form: Complete 1 Form/Transect
Date: _________Samplers: ________________________________Site: __________Transect:________
Latitude: ____Ex: 47.123456
Longitude: ____ Ex: -120.123456

SECTION 1: INSTREAM MEASUREMENTS

Table 1

Bank Geometry	Measurement
Wetted Width (m)	
Bankfull Width (m)	
Left Bankfull Height (cm)	
Right Bankfull Height (cm)	
Thalweg Depth (cm)	
Left Bankfull Depth (cm)	
Right Bankfull Depth (cm)	

Table 3

Instream Densiometer	
Direction	Measurement (0-17)
Upstream	
Left	
Right	
Downstream	

Notes:

Transect Form: Complete 1 Form/Transect

Date: _________Samplers: ________________________________Site: __________Transect:________

SECTION 2: VEGETATION MEASUREMENTS

Table 5

Right Bank	Width of Buffer (m):			Average
	1=	2=	3=	
	Vegetation Height (m):			Average
	1=	2=	3=	
Left Bank	Width of Buffer (m):			Average
	1=	2=	3=	
	Vegetation Height (m):			Average
	1=	2=	3=	

Table 6

Understory Ground Cover	0=Absent (0%) 1= Sparse (<10%) 2=Moderate (10-40%) 3=Heavy (40-75%) 4=Very Heavy (>75%)	D=Deciduous C=Coniferous E=Broadleaf Evergreen M=Mixed N=None
	Left Bank	Right Bank
	Understory	
Woody Vegetation Type	D C E M N	D C E M N
Woody Shrubs & Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses, & Forbs	0 1 2 3 4	0 1 2 3 4
	Ground Cover	
Woody Shrubs & Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses, & Forbs	0 1 2 3 4	0 1 2 3 4
Barren, Bare Dirt or Duff	0 1 2 3 4	0 1 2 3 4

Table 7

Right Bank			Tree Count by DBH (cm)				Number of Species
Segment	GPS	% Slope	(3-15)	(15-30)	(30-50)	(50-90)	
A							
B							
Left Bank			Tree Count by DBH (cm)				Number of Species
Segment	GPS	% Slope	(3-15)	(15-30)	(30-50)	(50-90)	
A							
B							

Table 8

Densiometer in Vegetation (0-17)					
Right Bank	Segment	North	East	South	West
	A				
	B				
Left Bank	Segment	North	East	South	West
	A				
	B				

Transect Form: Complete 1 Form/Transect

Date: _________Samplers: ________________________________Site: __________Transect:________

Table 9

<table>
<tr><td rowspan="1">Noxious Weeds</td><td colspan="3">3= No noxious weeds present
2= Up to 5% riparian area with noxious weeds (a few are present)
1= Up to 10% riparian area with noxious weeds (abundant)
0= Over 10% riparian area with noxious weeds (very apparent and extensive)</td></tr>
<tr><td rowspan="3">Right Bank</td><td>Segment</td><td>Rating</td><td>Notes</td></tr>
<tr><td>A</td><td></td><td></td></tr>
<tr><td>B</td><td></td><td></td></tr>
<tr><td rowspan="3">Left Bank</td><td>Segment</td><td>Rating</td><td>Notes</td></tr>
<tr><td>A</td><td></td><td></td></tr>
<tr><td>B</td><td></td><td></td></tr>
<tr><td colspan="2" rowspan="2">Stream Channel</td><td>Rating</td><td>Notes</td></tr>
<tr><td></td><td></td></tr>
</table>

Species Diversity List:

____
____
____
____
____
____

Site Notes:

____
____
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____

General Site Visit Form						
Site ID:				Date:		
Begin Time:			End Time:			
Samplers:						
Vegetation Buffer Description						
None	Hedgerow	Vegetated Filter strip		Riparian Habitat (Natural or Restored)		
Age of plantings (if not natural, list of species used in restoration on back)						
Length of Field/Vegetation Buffer (m) (TL) =						
Distance between Transects (m) (TL/5) =						
Right Bank	Width of Buffer (m) at Transect :				Average	
	1=	2=	3=	4=		
	Vegetation Height (m) at Transect:				Average	
	1=	2=	3=	4=		
Left Bank	Width of Buffer (m) at Transect:				Average	
	1=	2=	3=	4=		
	Vegetation Height (m) at Transect:				Average	
	1=	2=	3=	4=		
Seasonal foliage stage of riparian vegetation						
Canopy (>3m)			Leaf Bud	Emerging	50%	Max Foliage
Understory vegetation (0.5-3m)			Leaf Bud	Emerging	50%	Max Foliage
Ground cover vegetation (<0.5m)			Leaf Bud	Emerging	50%	Max Foliage
Agricultural practices occurring adjacent to stream						
Life stage of crops						
Crop:	Leaf Bud	Emerging	50%	Max Foliage	Flowering	Fruiting

Site Measurements	Average
Wetted Width (m)	
Bankfull Width (m)	
Left Bankfull Height (cm)	
Right Bankfull Height (cm)	
Thalweg Depth (cm)	
Left Bankfull Depth (cm)	
Right Bankfull Depth (cm)	

Transect	Predominant Substrate
1	
2	
3	
4	

Transect #	Comments (ex: presence of culvert or erosion rills)

Field – Quick Reference Sheet
Substrate

CODE	TYPE	SIZE RANGE	SIZE GUAGE
RS	Bedrock (smooth)	> 4 m	larger than a car
RR	Bedrock (rough)	> 4 m	larger than a car
RC	Concrete/Asphalt	> 4 m	larger than a car
XB	Large Boulder	1-4 m	meter stick to car
SB	Small boulder	>250 mm – 1 m	basketball to meter stick
CB	Cobble	>64 mm – 250 mm	tennis ball to basketball
GC	Gravel, coarse	>16 mm to 64 mm	marble to tennis ball
GF	Gravel, fine	>2 mm to 16 mm	ladybug to marble
SA	Sand (2-16 mm)	>0.06 mm to 2 mm	gritty to ladybug
FN	Fines (silt/clay/muck)	< 0.06 mm	non gritty
HP	Hardpan - hardened fines	any size	
WD	Wood	any size	
OT	Other (doesn't fit choices above)	any size	

Site Geometry Sketch:

APPENDIX: FIELD FORMS

Date: _______________ Site: ________________________ Recorder: ____________________ Page: __________ of: __________

Section 1: Depositional Sampler/Weather Station Installation

Table 1: Sampling Location Information at Time of Installation

Begin Time:			End Time:		
Latitude:			Longitude:		
Installing personnel:					
Weather Station Programming personnel:					
Ambient Conditions at Installation					
Weather conditions:	Sunny	Partly Cloudy	Overcast	Light Rain	Heavy Rain
Air Temperature:		Barometric Pressure:		Relative Humidity:	
Wind Speed:		Wind Direction:		Solar Radiation:	
Site Measurements					
Total Field/Vegetation Length (TL) meters =			Distance between Transects (TL/5) meters =		

Date: _______________ Site: _________________________ Recorder: _____________________ Page: __________ of: __________

Table 2: Rebar/T-Post Installation

Sample ID	Transect #	Location	Latitude	Longitude	Wetted Width(m)	Distance from Wetted Edge(m)
	1	W				
		V			n/a	
		F			n/a	
	2	W				
		V			n/a	
		F			n/a	
	3	W				
		V			n/a	
		F			n/a	
	4	W				
		V			n/a	
		F			n/a	
	5	W				
		V			n/a	
		F			n/a	

Date: _______________ Site: _________________________ Recorder: ____________________ Page: __________ of: __________

Table 3: Depositional Sampler Installation

		Begin Time:			End Time:	
		Stand Installation			Filter Paper Deployment	
Transect #	Location	Height (cm)	QA	Level (Y/N)	Level (Y/N)	Notes
1	W					
	V					
	F					
2	W					
	V					
	F					
3	W					
	V					
	F					
4	W					
	V					
	F					
5	W					
	V					
	F					

Date: _______________ Site: ________________________ Recorder: ____________________ Page: __________ of: __________

Section 2: Event Data/Sample Collection

Table 4: Agricultural practices occurring adjacent to stream

Pesticide Products(s) Applied:				Number of Total Acres:		
Crop Type(s) /Average Height (m):	Leaf Bud	Emerging	50%	Max Foliage	Flowering	Fruiting
Pesticide Application Technique:						
Spray Boom - Type/Manufacture/Length (m):						
Application Start Time:	Application End Time:			Duration of Application:		
Nozzle - Type/Manufacturer/Number:						
Application Pressure: Units:	Rate of Application =					
Tank Mix: Yes / No	Tank Mix Products (if Yes):					
Access to GPS data from sprayer: Yes / No	Average Flight Elevation:					
Irrigation Technique:						
Notes or other applicable information:						

Table 5: Sample/Data Retrieval

Begin Time:			End Time:		
Weather Data Collecting Personnel:					
Depositional Samplers Collecting Personnel:					
Ambient Conditions at Retrieval					
Weather conditions:	Sunny	Partly Cloudy	Overcast	Light Rain	Heavy Rain
Air Temperature:		Barometric Pressure:		Relative Humidity:	
Wind Speed:		Wind Direction:		Solar Radiation:	
Notes (ex. odor present):					

Date: ________________ Site: _________________________ Recorder: _____________________ Page: ___________ of: ___________

Table 6: Filter Paper Retrieval

Retrieval Begin Time:					Retrieval End Time:	
Samples ID(s)	Transect #	Location	Level (Y/N)	Intact (Y/N)	Comment:	Replicate Sample ID
	1	W				
		V				
		F				
	2	W				
		V				
		F				
	3	W				
		V				
		F				
	4	W				
		V				
		F				
	5	W				
		V				
		F				