VALIDATION OF THE SPRAYTRANS MODEL FOR PREDICTION OF LONG-RANGE PESTICIDE SPRAY DRIFT: PROGRESS REPORT

by

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EXECUTIVE SUMMARY

Objective

The objective of this study was to evaluate the performance of the new SprayTrans modelling system in predicting deposition of pesticide material up to 2 km downwind from the point of release. This report summarises the experimental design and preliminary results available to date.

Key Results

- The Utah trial was successfully implemented and a large dataset is being assembled that eventually will be tested against SprayTrans model predictions.
- The most effective spray deposit collectors in this study were artificial foliage and horizontal vinyl sheets.
- Deposition on Rotorod samplers was ineffectual, probably because of poor retention on the rod surfaces.
- As expected, deposition was proportional to source strength and downwind distance and follows an exponential decline with downwind distance.
- Deposition at levels > 50 IU/collector typically occurs only at distances < 500 m downwind.
- Low level deposition to 2000 m downwind is possible but levels are typically less that the level of quantification and probably are below any meaningful biological effect threshold levels.

Application of Results

- The application of this work will eventually be through the implementation of improved models for predicting spray deposition and drift. The first step, however, is to complete the analysis of the dataset and compare model predictions with the data (see below).

Further Work

- A significant amount of work is required to complete the analysis of the Utah dataset and then to compare field data with model predictions. This process will continue onto 2007/08.

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INTRODUCTION

Aerial application of pesticides is an important tool used in both pest management and pest eradication programmes. Because of public concerns over potential environmental and health impacts from pesticide use, there is ongoing pressure to improve application systems and to develop tools that will increase accountability. The need to explicitly address public concerns is probably highest in eradication campaigns in urban environments. Aerial application simulation modelling is one tool that has proved very useful for developing best aerial application practices in both forest and urban environments.

Since the 1970s the USDA-Forest Service, has led the international effort to develop models to calculate the deposition of material from aerial pesticide application operations. The result of this work is a modelling system called AGDISP, (Teske *et al*., 2003) that simulates the landing position of droplets released in aerial and ground pesticide application.Today, AGDISP and its derivatives are the most widely used modelling systems internationally. Its GIS-based version, SpraySafe Manager (Ray *et al*. 2001; Schou *et al*. 2001), developed by Ensis in collaboration with the USDA FS, has contributed to decision making in successful insect pest eradication campaigns in New Zealand (Richardson and Thistle 2002). A new and upgraded GIS-based model incorporating ADISP, called Spray Adviser, is almost complete.

AGDISP

The power of AGDISP-based models is their ability to simulate the aircraft wing tip vortices that largely control near field movement of spray material (i.e. movement of spray material close to the aircraft). The strength of these vortices dissipates with time and distance from the aircraft. At distances beyond a few hundred meters downwind of the spray line, the vortices are weak enough that the prevailing meteorological conditions control further movement of the remaining airborne fraction. Unfortunately, the current formulation of AGDISP does not effectively handle this long-range atmospheric dispersion of fine droplets and recent validation data of this model extends out to a maximum of 800 m.

The deficiency of AGDISP in the far-field is explained by the fact that the model is driven by a single point of meteorology and that the original formulation is effectively a two dimensional model using an infinite line source with a lineal source strength and winds perpendicular to the line source. The single point, steady-state meteorology used in the model becomes less appropriate with distance from the release, especially in spray areas with non-uniform (complex) terrain. Further, the simplified line source geometry becomes more limiting with distance. These deficiencies are made more apparent when model predictions are overlain onto a GIS system using either SpraySafe Manager or Spray Adviser.

SprayTrans

To address the limitations of AGDISP in the far field, an established air pollution model known as CalPuff/CalMet has been interfaced with AGDISP to create a new model referred to as SprayTrans. CalPuff/CalMet is a combination of a Gaussian puff transport model (CalPuff) with a meso-scale meteorological interpolator (CalMet). This modelling system incorporates land use and complex terrain as well as time and space varying meteorology into its deposition calculations. In effect, the terrain features contribute to the calculation of a meteorological field over the spray zone which in turns influences dispersion of the spray material.

In SprayTrans, AGDISP is run to correctly calculate the influence of the wake vortices and evaporation on the sprayed material in the near field. The material remaining aloft and available for drift after the wake and evaporative processes have played out is then handed to CalPuff /CalMet as the source material for that model. The CalPuff/CalMet module in SprayTrans then calculates deposition out to 10 km from the source utilising a 15 minute time step for long range transport. This relatively short time step capability was a modification of the hourly time step originally in CalPuff to yield higher resolution in the domain of interest.

Though both AGDISP and CalPuff/CalMet have had extensive validation data sets collected to evaluate and understand their performance in many situations, the assumptions made to couple the two models are not trivial. AGDISP is utilised as a source model for the CalPuff/CalMet modelling system.

Validation of this coupled system of models in SprayTrans is the purpose of the spray drift trials described here. The focus is on the transition region between AGDISP and CalPuff (250 to 750m downwind from the point of spray release) where the handoff is occurring combined with the region immediately downwind from there (750 to 2000m).

Objective

The objective of this study was to evaluate the performance of the SprayTrans modelling system in predicting deposition of pesticide material from the immediate vicinity of the flight line of the spray aircraft to 2 km downwind. The purpose of this report is to summarise the experimental design and the results available to date.

The study provides an excellent example of multi-agency and international collaboration with participation from: USDA Forest Service, Canadian Forest Service, Ensis (New Zealand / Australia), Environmental Protection Agency (USA), Forest Protection Ltd (Canada).

MATERIALS AND METHODS

Trial location and sampling scheme

The trial site was located on the eastern area of the US Army Dugway Proving Ground in Central Utah USA (UTM Zone 12, easting 337000, Northing 4454000 approximate). The area was relatively flat but gullied, gently ascending towards the Cedar Mountains in the east, with sage and generally steppe, sparse, xeric vegetation. A 2 km by 2 km area was surveyed along with grid of lines at 500 m interval lines (Figure 1). The basic concept was to release spray material along the upwind edge of the square and allow the spray cloud to drift over the grid.

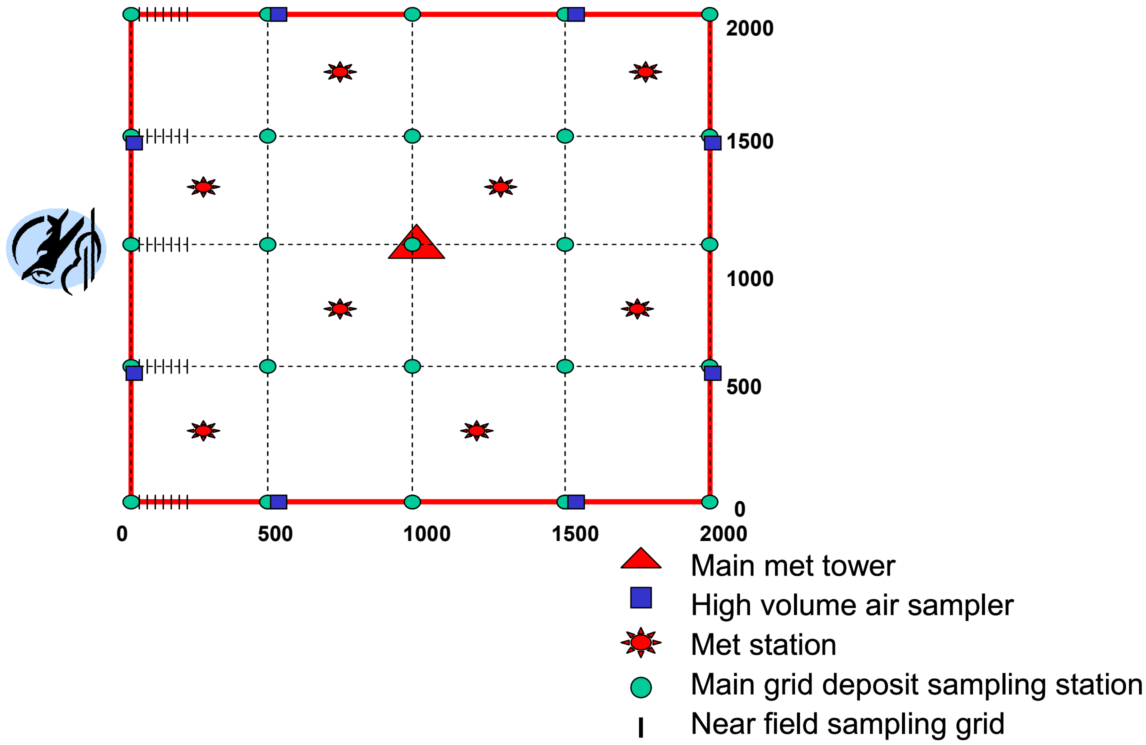

Figure 1: Spray block layout and deposit sampling scheme

An array of samplers was installed in the grid to collect spray deposition. Four types of samplers were used:

- Vinyl sheets (5.08 x 7.62 cm = 38.7 cm^2) stapled onto cards (VC) and mounted horizontally on top of wooden stakes approximately 1 m above the ground.
- Artificial conifer foliage (AF) collectors (Shenandoah Pine artificial Christmas tree foliage, Holiday Haus, Woodstock, NY) with approximately cylindrical dimensions of (15 cm length and 3.3 cm diameter). The projected surface area of the cylinder was approximately 50 cm^2.

Two types of Rotorod samplers were used. One mounted with U-rods for estimating spray deposition (Sampling Technologies, Minnetonka, MN). The diameter of the individual U-rods was 1.5 mm (square section), the sampling section diameter (distance between each rod) was 80 mm and the rotation speed was 2470 to 2500 rpm. A second type of Rotorod was used for measuring droplet size. The droplet sizing Rotorods were were plastic with a square section (3.2 mm by 3.2 mm and 75 mm length), rotating at approximately 600 rpm, and with a sampling section diameter (distance between each rod) of 200 mm.

In addition to the Rotords, eight high volume air samplers were distributed around the perimeter of the grid (Figure 1) and were set to a relatively low suction rate of approximately 7 l min^{-1}

Measurements of spray deposition and airborne spray concentrations were made on each of the five parallel lines in the grid that were perpendicular to the flight line (Figure 1). Sampling stations were located at the following downwind distances of (0, 10, 20, 30, 50, 100, 175, 250, 500, 1000, 1500 and 2000 m). VC, AF and RR samplers were located at all main grid points, that is at each 500 m node (i.e. five per line) (Figure 1). To measure deposition in the near field only VC collectors were deployed at 10, 20, 30 m, whereas both VC and AF collectors were used at distances between 50 and 500 m. Droplet sizing Rotorods were installed only at 500, 1000 and

1500 m main grid nodes along the three centre-most transects. A total of eight high volume samplers were distributed around the edge of the grid as shown in Figure 1.

Application parameters and deposit assessment

All applications were made using a Cessna AT-188 operated by Forest Protection Limited of Fredericton, New Brunswick. The aircraft was fitted with four Mircronair AU4000 rotary atomizers and applied Foray 76B (Btk at 20 BIU/L) at a rate of 4.94 L/ha using a flow rate of 14.6 L/min and a nominal release height of 10 m above ground level. The selected atomisers were chosen to ensure the production of a fine cloud of droplets with a large percentage of the mass in the driftable fraction. Small droplets would increase the likelihood that the material will remain aloft long enough to deposit on the farther downwind samplers. Actual time of application, release height, flow rate, and aircraft position were recorded using an Ag-Nav II electronic guidance system (Ag-Nav Inc, Newmarket, Ontario, Canada) and a radar altimeter(Bendix/King, Model = KRA 405B; Eastern Avionics).

An application consisted of either one, two or three passes along the upwind edge of the sampling grid. After each application approximately 1 hour was allowed for the spray cloud to traverse the grid (actual time derived from a simple calculation based on wind speed) and then the samplers were collected. Collection methods were employed to ensure that the risk of sample contamination was minimised e.g. collection from the downwind end of the sampling lines where doses would be lowest, use of sterile gloves, forceps to minimise handling, and sample storage in individually pre-labelled plastic bags. After sprayed samples were collected, new, clean samplers were deployed for the next spray application.

In total there were 20 spray applications applied over a period of 5 days. Three applications (trials 10, 14 and 20) were actually blanks used to test whether there was any contamination of samples due to handling methods or environmental loading via dust.

The droplet spectra for spray produced by the setup used in the trial are due to be measured using a Malvern 2600 laser diffraction analyzer set up in a wind tunnel in the droplet sizing facility at the Centre for Pesticide Application and Safety, University of Queensland, Australia.

Deposits of Btk on all samples were determined using a microplate redox assay technique similar to that previously described by Seligy et al. (1997a,b; 1999). The technique depends upon bio-reduction of XTT dye and is highly sensitive, with a limit of detection equivalent to 1 IU/collector.

Meteorological measurements

A number of meteorological stations were located within the grid to record the prevailing weather conditions throughout the area (Figure 1). A 32 m high meteorological tower was erected in the centre of the sampling grid. Three-dimensional sonic anemometers were located at five levels and temperature probes (accurate to 0.05°C) at 8 levels. In addition to the main tower, there was a SODAR station and eight distributed standard meteorological stations recording wind speed, wind direction, temperature and relative humidity at 2 m above the ground. These stations had a 1 sample/s sampling frequency and a 10-second averaging interval.

In addition to the measurements made in the sampling grid, the Dugway site has a standing array of meso-scale meteorological instruments. This meso-scale data will be made available to the project.

RESULTS AND DISCUSSION

Meteorology

All twenty replications were applied between September 8-13, 2006. Meteorological data acquisition was successful (Table 1) but there is still much data reduction and interpretation to be done. The weather conditions were fairly extreme for spraying during most trials (i.e. very hot and dry with some high wind speeds). Ten trials were undertaken with winds from west, seven from the south and three from the east.

Table 1: General meteorological conditions during spray trials.

	Local time during spraying	Wind speed (km/hr)	Temperature (°C)	Relative humidity (%)
Minimum	07:17	3.6	13.5	14
Maximum	17:45	23.4	31.0	45
Average		8.8	24.3	24

Deposition data

Quantification of Btk deposition on the various collectors has been completed. However there has been no work to interpret these data in a meaningful way e.g. adjust data for different collector sampling characteristics, source strength, or wind direction, or to compare model predictions with data.

Table 2 shows some of the notable observations from the dataset. It is clear that Btk is an effective tracer and the analytical method is quantitative and highly sensitive. Reassuringly the blank trials confirm lack of environmental contamination.

Table 2: Summary statistics for spray deposition on artificial foliage.

Case: (Spray no.)	SS[1] (L)	Wind speed (km/h)	Temp (°C)	RH (%)	Max Dep[2] (IU/coll)[3] > 500 m	Max. dist.[4] (m)	Average deposit at 2 km (IU/coll)
Typical (1)	11	8.9	27.3	16.0	3.6	500	0.1
Worst case wind speed (4)	9	24.5	19.4	45.6	46.8	2000	2.1
Worst case temp. & RH (12)	19	7.9	30.5	13.0	7.1	500	0
Highest deposit	29	3.8	18.3	30.5	209.8	1500	0

[1]Source strength (total amount of spray applied in litres along 2 km flight line).
[2]Maximum deposition value beyond 500 m downing of the flight line.
[3]IU/coll is the international units (of Btk) per collector.
[4]Maximum distance at which quantifiable spray deposits were observed.

Some of the key observations from preliminary data are:

- Deposition is proportional to source strength and downwind distance.

- Artificial foliage is the most efficient collector.
- Deposition (> 50 IU/collector) typically occurs only at < 500 m downwind.
- Deposition follows an exponential decline with downwind distance (Figure 2).
- Low level deposition to 2000 m downwind is possible but levels are typically less that the level of quantification and probably are below any meaningful biological effect threshold levels (Figure 3).

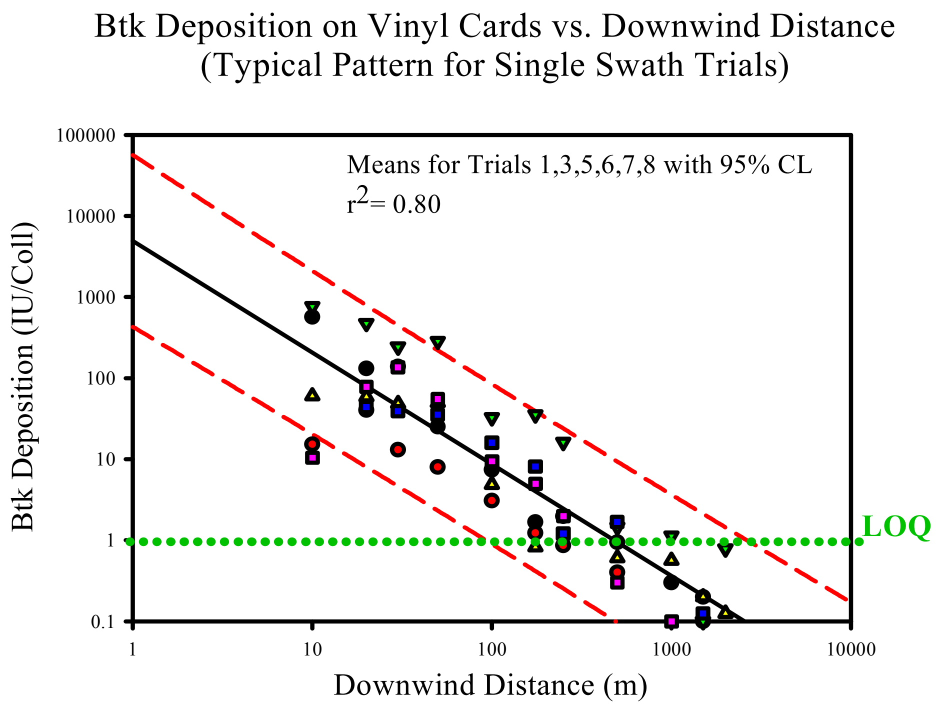

Figure 2: Unadjusted Btk deposition on artificial foliage versus distance downwind

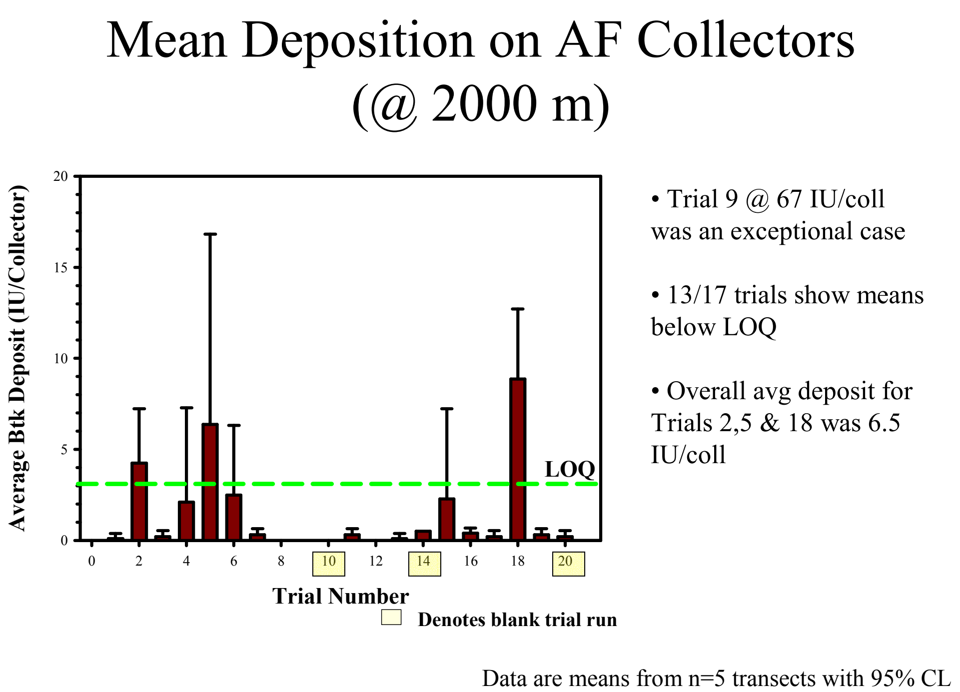

Figure 3: Mean deposition on artificial foliage at 2000 m downwind.

Rotorods

Two types of Rotorods were used in the trial for (i) quantifying deposition and (ii) for measuring droplet size.

The deposition Rotorods revealed very little Btk. This is an unexpected result because Rotorods are a standard and effective sampling device used in many previous studies. In some instances Rotorod collection surfaces are greased to ensure that impacting droplet stick and are not thrown off. In this trial they were not greased because of concerns that grease would interfere with the analytical method.

The droplet sizing Rotorods, however, did capture sufficient droplet to allow analysis of droplet sizes as described in (Richardson *et al.*, 2007).

CONCLUSIONS

- The Utah trial was successfully implemented and a large dataset is being assembled that eventually will be tested against SprayTrans model predictions.
- The most effective spray deposit collectors in this study were artificial foliage and horizontal vinyl sheets.
- Deposition on Rotorod samplers was ineffectual, probably because of poor retention on the rod surfaces.
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ACKNOWLEDGEMENTS

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- Other contributors to the field study included: FPL for in-kind support (aircraft & expert crew); Valent BioSciences for Btk (and trial support); US Army for access to the experimental site and extensive meteorological equipment and infrastructure; an excellent international field crew from the USDA-FS, CFS, ENSIS NZ and the USEPA who worked many long hours under extreme conditions.

REFERENCES

Ray, J.W.; Richardson, B.; Schou W.C; Teske, M.E.; Vanner, A.L.; Coker, G.C. 1999: Validation of SpraySafe Manager, an aerial herbicide application decision support system. *Can. J. For. Res. 29*: 875-882.

Schou, W.C.; Richardson, B.; Teske, M.E.; Thistle, H.W. 2001: SpraySafe Manager 2 – Integration of GIS with an aerial herbicide application decision support system. Paper No. 011050, ASAE, St Joseph, MI, USA.

Richardson, B. and Thistle, H. 2002. The role of Aerial Application simulation models for pest eradication operations in urban environments. Pp 125-135 in S.L. Goldson and D. M. Suckling (Eds) Defending the Green Oasis: New Zealand Biosecurity and Science, NZ Plant Protection Society, Symposium on Biosecurity, August, 2002.

Richardson, B, Gous, S. and Kimberley, M 2007. Droplet sizing and sampling eficiency from Rotorods deployed during the Long Range Pesticide Drift trial: Utah, USA. Ensis Report Number 12325.

Seligy, V.L. *et al*. 1997a. Quantitative bioreduction assays for calibrating spore content and biability of commercial *Bacillus thuringiensis* insecticides. J. Industr. Microbiology and Biotechnology 18: 370-378.

Seligy, V.L. *et al*. 1997b. Comaprative performance of conventional and molecular dosimetry methods in environmental biomonitoring. Rapid Methods for the Analysis of Biological Materials in the Environment. NATO ASI Series. Kluwer academic publishers, Netherlands. 1997, pp 18.

Seligy, V.L. and Rancourt, J.M. 1999. Antibiotic MIC/MBC analysis of Bacillus-based commercial insecticides: use fo bioreduction and DNA based assays. J. Industr. Microbiology and Biotechnology 22: 565-574.

Teske, M. E.; Thistle, H.W.; Ice, G.G. 2003. Technical advances in modeling aerially applied sprays. Transactions of the American Society of Agricultural Engineers 46(4): 985-996.