# Managing Spray Drift to Minimize Problems

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Welcome! The purpose of this course is to present a review of many aspects of spray drift--from practical, hands-on ways to minimize drift, to the regulatory issues surrounding spray drift.

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**Background information was obtained from**:

- Reports and other materials issued by the Spray Drift Task Force are available online at www.agdrift.com
- *The Safe and Effective Use of Pesticides*, second edition (ANR Publication 3324), written by Patrick J. O'Connor-Marer and published by the University of California's Integrated Pest Management Project
- *The Proceedings of the North American Conference on Pesticide Spray Drift Management* (1998)
- Numerous online sources, including: www.epa.gov and others

**SECTION 1 -- Introduction**

Spray Drift Management (SDM) has been a critical element for Western agriculture for decades. **Keeping crop protection chemicals on the crop for which they are intended has been a cornerstone of Western farming** not only to protect neighboring crops, but **to avoid wasting money** by allowing products to drift off the intended target.

**Spray drift management has taken on greater significance** as cities encroach upon rural areas. Every year, increasingly more houses and other types of developments are springing up in prime growing areas, oftentimes alongside fields, orchards or vineyards. This leads to increased concerns about the use of agricultural chemicals and the ways they are applied. Some of these issues surround pesticide spray drift. **Pesticide** is a general term that includes herbicides, fungicides, and insecticides. While **pesticide drift can impact residential areas** bordering agricultural fields and pose potential risks to human health, it can affect far more than nearby homes and residents. **Unnecessary spray drift can:**

- Endanger field workers
- Endanger livestock
- Endanger wildlife
- Contaminate sensitive off-target areas such as rivers and lakes
- Contaminate grazing lands
- Contaminate fields planted with crops susceptible to damage

**Spray drift also hits producers in the pocketbook.** Any material that lands off target means less reaches the plant, pest or soil surface and declining levels of control of the intended target. The advance of science permits the measurement of increasingly tiny residues of chemicals in the environment. Therefore, the likelihood of a collision between risk management and real-world of application becomes even more inevitable. The continuing advance of science permits the measurement of increasingly infinitesimal residues of chemicals in the environment. Therefore, the **likelihood of a collision between risk management and the real-world of application become even more inevitable.**

**Types of Spray Drift**

Experts commonly divide pesticide drift into two general types: **spray drift** and **vapor drift**.

1. **Spray drift**, the main topic of this course, is often referred to as "primary" or "physical" drift. It is the movement of droplets (or particles) downwind of the target area and is "generic--that is, the spray material's active ingredient has no impact on its tendency to drift.
2. **Vapor drift**, frequently referred to as "secondary" drift, is the gaseous airborne movement off-site, usually through volatilization, after the droplets have been deposited. In the case of vapor drift, the active ingredient *does* play a major role. Vapor drift and the corresponding effects of volatile

organic compounds (VOCs) in pesticides--of particular concern now in the San Joaquin Valley of California--are covered briefly in another section of this course. It should be noted there are many other ways a material can move off-target: via runoff, leaching and wind-blown particles.

## Occurrence of Pesticide Drift

**Drift can result from the use of:**

- **Liquid formulations of pesticides**
- **Granular and dust formulations of pesticides**
- **Pesticides applied by air, ground, or chemigation**

Drift can be **difficult to manage because its full range--aerosols, dusts, fogs--is largely invisible to the naked eye**, yet capable of moving over great distances. Pesticide drift isn't only **associated with agricultural use or outdoor applications**. Many pesticides and other **materials used indoors easily move offsite** via ventilation systems and forced-air cooling and heating systems. Although our understanding of the phenomenon and available tools to manage drift have advanced tremendously over the years, there will always exist factors that influence drift, some of them controllable and others not. Many of them are interdependent with the factors that affect application itself.

**As long as sprays are applied, some level of pesticide drift will be an unintentional--and inevitable-- byproduct of crop protection.**

**Minimizing drift is a team effort and requires ongoing training and open channels of communication.**

The more that individual applicators and agriculture as a whole can continue to improve techniques and technology, skills and knowledge, the less we will have to rely on regulatory solutions to the problem.

**SECTION 2 -- Mechanism of Spray Drift**

The mechanism of spray drift is basic. When a pesticide is sprayed by ground or by air application equipment, tiny droplets are produced by the spray equipment's nozzles. Generally, almost all the spray reaches its target; however, some droplets remain suspended in the atmosphere. These very small droplets can be carried by the wind or by a combination of atmospheric conditions and wind and deposited off-target.

Exact **definitions of "pesticide drift" or "spray drift" vary** among agencies and experts:

- **The U.S. Environmental Protection Agency** defines it as "the physical movement of a pesticide through air at the time of application or shortly thereafter, to any sites other than the intended for application (often referred to as off-target)." The agency's definition does not include pesticide movement to an off-target location "caused by erosion, migration, volatility, or contaminated soil particles that are windblown after application, unless specifically addressed on a pesticide product label with respect to drift-control requirements."
- **California's Department of Pesticide Regulation** defines it as "the pesticide that moves through the air and is not deposited on the target area at the time of application." Excluded from DPR's definition is any post-application movement of pesticide through avenues such as "translocation [movement through groundwater or surface water], volatilization, evaporation, or the movement of pesticide dusts or pesticide residues on soil particles that are windblown after application."
- **Arizona Administrative Code** defines drift as "the physical movement of pesticide through the air at the time of a pesticide application from the application site to any area outside the boundaries of the application site**.** Drift does not include movement of a pesticide or associated degradation compounds to any area outside the boundaries of an application site if the movement is caused by erosion, run off, migration, volatility, or windblown soil particles that occur after application, unless specifically addressed on the pesticide label with respect to drift control requirements."

**Pesticide overspraying** (the unintentional direct application of pesticides to a non-target area) is sometimes included within the overall definition of drift. At the same time, **drift is usually termed "unintentional"** to distinguish it from deliberate pesticide misuse. **Spray drift is not product-specific.** Studies have shown that the active ingredient in a product does not influence its potential to drift (vapor drift or volatilization, as stated earlier, is an entirely different matter). **The type of formulation and use of a spray additive, however, may play a role in either favorable spray deposition or enhancing spray drift potential.** Because the droplets a sprayer produces are extremely tiny, laser beams are used to measure them in units known as microns. **One micron equals 1/25,000 of an inch.** By comparison, a No. 2 pencil lead is approximately 680 microns in diameter while a human hair is about 100 microns in diameter. **Volume Median Diameter**

**(VMD)** is a common way of expressing drift potential. It is based on the droplet sizes in a given spray.

***VMD is the size at which half of the number of droplets are larger and half are smaller.***

VMD, however, is only part of the picture and perhaps not the most useful measure for evaluating drift potential. For example, a VMD of 300 could signify any number of things: It could mean that half the droplets are a relatively coarse 250 microns in diameter and half are 350 microns--or that half are 50 microns and very susceptible to drift while half are 650 microns. **Drift potential is also influenced by the droplet size spectrum** (range of large to small droplets) produced by the nozzle. A narrow droplet spectrum is desirable. Also of interest is droplet size distribution, or the proportions of droplet sizes within a certain range, often expressed in terms of median droplet size. **Most agricultural spray equipment produces a wide range of droplet sizes,** usually averaging in diameter between 40 microns and 500 microns. An estimated 70% of the droplets produced by a typical sprayer will fall in the 100-250 micron diameter range, with an additional 20% larger than this and 10% smaller than 100 microns.

**SECTION 3 -- Spray Drift Task Force**

The **Spray Drift Task Force (SDTF)** is a consortium of agricultural chemical companies established in 1990 in response to U.S. Environmental Protection Agency spray drift data requirements.

Much of the recent literature on spray drift cites the findings of the SDTF, which conducted extensive field and lab studies that provide the basis for spray deposition and downwind drift predictions.

The SDTF has suggested that **drift potential be evaluated in terms of the percentage of spray volume that consists of droplets measuring less than 141 microns in diameter.** This number was selected because of the characteristics of the particle-measuring instrument that was used. It was also chosen because it is close to 150 microns, commonly considered the cutoff point below which droplets are more prone to drift. **However, 141 microns or 150 microns are only guides, and not absolute numbers.** Drift does not begin or end there. Rather, it occurs along a continuum, with drift potential decreasing as droplets grow larger and increasing as they grow smaller than these numbers.

**The larger or coarser the droplet, the heavier it is, and the lower its potential for drift--**but the more likely it is to cause other problems by bouncing or running off the target surface or providing less-than-adequate coverage. A 500-micron droplet is just 10 times larger in diameter than a 50-micron droplet, but it contains 1,000 times more active ingredient, so when the larger droplet bounces off, the result can be a considerable loss of pesticide as well as environmental concerns introduced by pesticide runoff.

A **"Catch-22" is created,** since droplets at the other end of the spectrum, below 100 microns, are generally the most efficient size for many types of pest control and for penetrating dense foliage, yet these **smaller droplets are most likely to drift off-target.**

**To protect sensitive areas from spray drift**, "buffer" or "no-spray" zones are specified in state regulations and are also contingent on pesticide product labels and prevailing weather conditions. Always check labels, state regulations and county permit conditions closely for any required buffer zones.

**A buffer zone** is defined by the U.S. Environmental Protection Agency as an area where "direct application of the pesticide is prohibited; this area is specified in distance between the closest point of direct pesticide application and the nearest boundary of a site to be protected, unless otherwise specified on a product label."

**Buffer zones are shields between direct pesticide application areas and sensitive areas where pesticides should not drift**.

For example, a buffer zone of 100 feet would require the applicator to leave a distance of 100 feet between the point of spray application and the nearest boundary of the specified protected site. Buffer zones may also be specified in terms of fractions of miles: 1/2 mile, 1/8 mile, etc. As a matter of good practice, whether stated or not, **experts recommend leaving untreated buffer strips of at least the width of one spray swath any time a treatment site adjoins sensitive areas.** The strip may need to be even wider depending on factors such as type of pesticide and application equipment, prevailing weather conditions and the sensitive nature of adjoining areas. Monitoring the sensitive area with spray cards should also be considered.

Some of the **sensitive areas that call for buffer zones include** those at or near:

- Surface water
- Residential areas, schools, playgrounds, hospitals and other institutions
- Wildlife refuges, parks or habitats of endangered species
- Apiaries
- Groundwater close to the surface or easily reached (wells, sinkholes, porous soil)
- Ornamental gardens
- Food or feed crops or other sensitive plantings
- Livestock

**SECTION 4 -- Balancing Coverage, Minimizing Drift**

The effective, legal **spray application of any pesticide**, regardless of mode, **involves a delicate balance between maximizing coverage and minimizing drift.** With care and careful consideration by both the Pest Control Advisor (PCA) and the applicator, these objectives can be achieved.

***The first step in ANY pesticide application, of course, is to ALWAYS read and follow label directions.***

The **"due care"** with which a pesticide must be sprayed is a matter of judgment, of understanding and applying the best practices to the variety of conditions encountered in the field and knowledge of any sensitive areas around the site. This generally includes an evaluation of everything within a half-mile radius as well as one mile downwind. Application decisions should always be made with sensitive locations in mind.

In addition to being well trained and skilled, it is important for the applicator to diligently **keep accurate and detailed written records** in case he or she is ever accused of pesticide drift (or any other misdeed or infraction).

These should include:

- **Exactly what material was applied and why**
- **What the field conditions were**
- **Weather (temperature, humidity, wind speed and direction)**
- **Equipment maintenance records**
- **Dates of calibration of equipment**
- **Nozzle and tip replacement dates**

Whether a material is sprayed from ground or air, several **key factors go into causing it to drift** and play a role when it comes to minimizing the phenomenon.

**Droplet size, the most important overall determinant,** is influenced by a number of things, including:

- **Nozzle size, style and condition**
- **Spray volume and pressure**
- **Weather conditions**
- **Physical properties of the formulation or tank mix**

**<u>Nozzles:</u>**

Most application equipment sprays a wide range of droplet sizes. **To enhance uniformity, use nozzles designed for the sprayer's working pressure and volume.**

- Use **low-pressure nozzles** whenever possible and **nozzle shields** to confine the spray and further reduce drift problems. Large-orifice nozzles and reduced output pressure increase droplet size by producing a coarser spray with less drift potential.
- Newer nozzle technology such as **air-inclusion nozzles** create coarser droplets that incorporate air bubbles to help prevent the droplets from rolling off of the target.
- **Rotary atomizers** used in conjunction with tower and cross-flow fan designs produce smaller droplets that are directed into the canopy and thus more targeted.
- **Controlled droplet applicators** (CDAs) produce more uniform droplets. This lowers the number of very small and very large droplets and reduces some of the drift potential.
- Opinions vary, but some believe that fewer droplets may drift with **electrostatic sprayers**, which emit electrically charged spray droplets that are attracted to the treatment surface.

**Nozzles are classified in six categories ranging from very fine (VF) to extra coarse (XC),** with their boundaries defined by the droplet size spectrum, flow rate and pressure (categories tend to be relatively conservative since the droplet size spectrum is defined by the finest portion of the spray).

Nozzle catalogs, Extension Service publications and other printed and on-line sources should be consulted for the most up-to-date information on nozzles.

**Worn or defective nozzles should be replaced** and equipment and nozzles should be **properly calibrated** on a regular basis (see following sections). The system should also be **checked for leaks**; small leaks under pressure can produce very fine droplets that may drift.

**The type of spray equipment used should suit the location and situation, as should application speed.**

A **large, uniform field**, surrounded by similarly planted crops for example, might be a good candidate for **aerial application**.

A **small, irregularly shaped field** would probably suggest **ground application**. Site characteristics and environmental hazards should also be taken into consideration--not only nearby sensitive areas but also power lines, poles and buildings on the site that require maneuvering over or around.

The last few downwind rows and other parts of the field closer to **sensitive areas may call for special techniques**, including using larger droplets here or other types of equipment (such as a hand-wand) to better direct spray, or waiting till the wind shifts to spray.

**Weather Affecting Spray Drift**

- **Weather--particularly wind--plays a significant role in drift.** Problems are exacerbated when applications are made during windy conditions while using high pressure and small nozzle sizes. Wind intensity is important, as is direction. Numerous studies have demonstrated that **drift only occurs downwind**.

- While too much wind (anything greater than 10 mph) is too strong for safe pesticide application, **a little air movement (three to five mph) helps provide good distribution in trees and leafy plants**. A hand-held anemometer can be used to accurately gauge wind speed, but as a rough gauge, a borderline wind in the 8-12 mph range will extend a light flag and put leaves in constant motion. A compass can help precisely determine wind direction. A prudent **guideline is to never spray at any wind speed if the wind is blowing toward a sensitive area**. Ideally, spraying should be done when a gentle, steady wind is blowing away from sensitive areas.

- **Wind speeds of less than two mph may indicate an inversion layer, which will also influence drift.** Inversion layers occur when the air 20 to 100 or more feet above the ground is warmer than that below it, forming a "cap" that blocks air movement upward. In an inversion layer, the air is likely to be still very early in the morning and at night, with very little mixing, which should preclude spraying. **Inversion layers can be detected by using a smoke bomb** or smoke generator, or burning a tire or diesel fuel (if permitted by air quality authorities). If the column of smoke begins to move sideways or concentrates in an area several hundred feet from the ground, an inversion layer probably exists.

- **Inversion layers are problematic because they trap fine spray droplets and concentrate them**; instead of dispersing, the pesticide can drift up to several miles away from the treatment site in a concentrated cloud. Eventually it falls earthward onto the ground or other non-target surfaces. **The time of day can provide some clues as to whether an inversion layer exists or there is adequate air movement.** As the air starts to heat up, it begins to move, resulting in more favorable conditions. Generally, clear skies favor the formation of an inversion layer, while inversion layers are discouraged by low, heavy cloud cover, winds greater than five to six mph, a temperature rise of 5°F and bright sunshine.

- **Temperature and humidity also play roles.** The treatment area itself may have its own microclimate. An irrigated field, for example, will have lower temperatures and higher humidity than the drier areas nearby. This can create a "mini inversion layer" that impacts pesticide concentration and movement. **Inversion areas are also more apt to be found around bodies of water**.

- **Evaporation**, which results in smaller droplets, occurs when temperatures are high and humidity low. Higher humidity and cooler temperatures slow down the evaporation process and keep droplets larger.

**Pesticide Formulation Affects Spray Drift:**

- **Oil-based sprays** volatilize more slowly than **water-based sprays** but have the potential to drift farther because they are lighter (especially at temperatures above 95°F). Lightweight dust particles are also carried by air currents more readily than heavier formulations that settle out more quickly.

- The physical properties of the pesticide such as its **viscosity, or the liquid's thickness**, influence the droplet size spectrum and drift potential. The thicker or more viscous a liquid is, the more difficult it is to break up into smaller droplets. Increased viscosity results in spray clouds of larger droplets and fewer fine droplets.

- **Certain tank-mix adjuvants--**deposition aids, thickeners and stickers**--may assist in increasing spray droplet size or reducing evaporation potential and help minimize drift.** Most drift-reduction adjuvants are polymers that raise the viscosity of the spray mixture. The mode of action of other adjuvants is not well understood but may be associated with reducing evaporation or altering the electrical charge of droplets.

  Opinions vary as to the **effectiveness of spray-drift adjuvants**. For this reason, **drift adjuvants should not be regarded as the first or only line of defense** against pesticide drift but as an added level of precaution. A potential downside is that adding a drift-control agent will reduce the uniformity of the spray distribution, which can result in localized over- and under-dosing.

- **Not all adjuvants assist with controlling drift**. Others used as wetting agents, spreaders or penetrants have the opposite effect, increasing drift by reducing the surface tension of the spray mixture, which results in droplets breaking up into greater volumes of smaller sizes. Special care should be paid to hardware and operating conditions when these types of adjuvants are used. The challenges are compounded when a product requires a crop oil concentrate to perform properly.

**Minimize Pesticide Use and Maximize Pesticide Efficacy:**

- **Integrated pest management** and other practices that minimize pesticide use and maximize product efficacy aid in the effort to keep material from moving off target by reducing the number of applications--less material applied means less potential drift.

**Drift potential is minimized by:**

- **Regular scouting for pests**
- **Proper target pest identification**
- **Pest population monitoring**
- **Treating only when conditions justify pesticide application**

- **Planning ahead** to avoid forcing a spray application under poor conditions helps, too. Enough time for weather delays should be built into any schedule.

- Some of the newer **computer and satellite technology such as GPS** can help with drift-related issues.

- **AgDRIFT, the computer drift model**, can be downloaded on-line. While it was not developed for making application decisions, it can be a useful tool for understanding the relative influence of different application and weather factors on off-target spray movement. **Precision agriculture, using satellite data** to determine plant development and soil conditions and thus fine-tune inputs, may have significant impacts on reducing the volume of pesticides drifting or otherwise going where unwanted in the environment.

- **Ultrasonic or laser sensors** can be fitted to air blast sprayers that detect the shape of a canopy and adjust the spray pattern accordingly. Increasingly, decisions can be based on precise equations and scientific instruments-rather than sticking a finger in the wind and hoping for the best.

## SECTION 5 -- Aerial Applicators

The Spray Drift Task Force (SDTF) confirmed that the **critical factors influencing drift during aerial application** include:

- **Nozzle type**
- **Orifice size**
- **Pressure**
- **Angle**
- **Air speed**

It also concluded that the **physical properties of the spray mix** and the **crop canopy** have a **minor effect on spray drift** from aircraft.

The growing complexity of aerial spray systems and the aerodynamics created by wings and fuselage further increase drift potential, which requires state-of-the-art technology to maximize the spray pattern and minimize physical drift.

- **Nozzle design** is extremely important. Place nozzles low and away from wing and fuselage disturbances and undercarriage obstructions such as steps, pumps and boom hangers. **The best designs avoid air shear across the nozzle tip by emitting the spray parallel to the dominant airflow.**

- **Air shear is a function of both nozzle angle and aircraft speed**; it significantly affects droplet size, always a key concern for spray drift. Applicators may further maintain good droplet size characteristics by using flat fan, sheet and straight stream type nozzles on their booms.

- **Air shear becomes even more critical as aircraft speed increases**, and studies have shown faster, newer aircraft are largely to blame for drift incidents as droplet size diminishes. Conversely, slower speeds, combined with lower pump pressures, produce larger droplets.

- **An aircraft's wings (or helicopter's rotors) produce air turbulences** known as vortices**.** When the boom length is too long, spray droplets get caught up in these vortices and follow the movement of air up and over the wing or rotor, increasing drift potential. Shorter boom lengths result in fewer droplets entering the vortices.

***The SDTF reaffirmed the standard practice of maintaining boom length at 70% or less of the wingspan as a means of minimizing drift***

- With faster, modern aircraft, pilots may also be inclined to fly higher, and the increased spray release height can result in more drift. **Pesticides should be applied at the lowest level possible** recommended by the manufacturer while providing for maximum safety during application.

- **Flying too low, however, can also compound drift problems**. The layer of air that compresses under the wing flows outward and upward and may carry spray droplets with it.

- As always, **weather should be monitored closely during applications** and windy conditions of 10 mph and over should be avoided. Pilots can fly closer to the edge of a field when the wind is low because most of the spray will be deposited right below the aircraft.

o As an example, a 150-micron droplet released from 10 feet in a five mph wind will travel 54 feet in 8.5 seconds, while in a 10 mph wind, the same droplet will travel 106 feet in eight seconds, becoming ever smaller.

- **When a crosswind is blowing**, the spray swath will be displaced downwind, meaning the pilot must compensate by adjusting the aircraft's position upwind. The degree of compensation will depend on wind speed and how close the application is to a sensitive area. The SDTF confirmed that with a crosswind blowing, **drift is substantially reduced by the standard practice of swath adjustment**, particularly in the first 100 feet.

- Ideally, when getting ready to pull up, the pilot should shut off the spray in advance while the aircraft is still level. Half-boom shutoffs may help reduce drift and allow the operator to make a sharp edge along the field perimeter for the first pass.

**<u>Ground Application:</u>**

Spray drift is not just an unwanted byproduct of aerial application. **Materials sprayed from the ground drift as well, although some of the major influencing factors are different.**

The Spray Drift Task Force (SDTF) confirmed that the **critical factors influencing drift during ground application** include:

- **Nozzle type**
- **Orifice size**
- **Spray pressure**

**The SDTF concluded that, unlike in aerial spraying, ground application speed did not have a significant effect on drift**. From the ground, wind speed affects nozzles that produce finer droplets but the task force found there was essentially no difference in drift when a coarser droplet spectrum was produced.

In spraying an **orchard or vineyard**, because the spray is released within and not above, the characteristics of the canopy are as important as droplet size. **The canopy's height, shape and density, and the amount of open space between trees all influence drift.**

As with application from an aircraft, nozzle height is another factor, with more drift occurring with a 50-inch boom height than a 20-inch, a difference that increases when nozzles produce finer droplet size spectrum. **To minimize drift, keep pressure and height as low as possible on all nozzles**--especially those that produce finer droplets--at the same time taking care that coverage is uniform. On the other hand, spraying should not be too close to the target surface or spray-back can result.

**SECTION 6 -- Orchards, Vineyards**

The highly visible spray plumes from **orchard and vineyard air blast sprayers** give the perception of a high level of drift. The SDTF concluded, however, that most of the time the actual amount of drift is relatively low, and that the drifting droplets typically do not contain much active ingredient due to the relatively low concentrations of the high spray volumes. Sprayed in an orchard or vineyard, many droplets are intercepted by the leaf canopy, which also tends to reduce the effects of wind. **Spraying in the outer downwind rows produces the most drift.**

**Lack of foliage or large gaps between trees (as in a dormant or young orchard) may result in more spray being deposited off-target downwind.** It seems counterintuitive, but taller trees can also result in more drift because spray droplets are forced up and over their tops. Propelled by the airflow to a greater height above the ground--in an orange or grapefruit grove, for instance--they are more inclined to drift. Similarly, dense continuous canopy appears to deflect more of the airflow from the sprayer over the treetops. Trees or vines planted on raised beds may also contribute to a higher level of spray drift and ground deposition.

**Drift can be minimized by properly adjusting sprayer nozzles so that they hit the target trees**. While the conventional air blast sprayer sends droplets in an air blast from a central fan upwards into the canopy, **tower-type sprayers** target the spray horizontally into the canopy, reducing drift and increasing deposition. The **over the top hydraulic sprayers** used in some vineyards have booms that are positioned horizontally over the tops of the rows and vertically along the sides and have no fan to increase airflow (unlike an air blast sprayer), which minimizes drift.

Other types of sprayers can exacerbate drift. The **"mist blower"** class of sprayers typically produces a finer droplet size spectrum resulting in a higher volume of very small droplets that are prone to drift.

**Changing Nozzles and Pumps:**

**Spray nozzles and pumps do not last forever.** Even with normal use, they wear out; orifices enlarge and pressures change, making regular and proper calibration an important part of minimizing spray drift as well as ensuring the correct amount of pesticide is applied to the treatment area.

Nozzle wear is also increased by abrasive formulations, such as wettable powders. **The time it takes to calibrate a sprayer can mean the difference between expensive inputs landing on their intended targets at the recommended rate ... or not.** Once calibrated, sprayers should be checked and tested periodically to make certain the calibration remains accurate. Equipment can quickly fall out of adjustment or become worn, sabotaging a spray program.

There are numerous **calibration shortcuts and quick calculations available** in equipment manuals and publications or on-line that apply primarily to specific situations or types of sprayers.

**Regardless of the method used, the basic principles are the same:**

**Determine the area covered by a tank of spray moving at a known speed and operating at a known pressure.**

It requires just a few simple tools:

- Stopwatch
- Pocket Calculator
- 100 foot measuring tape
- Calibrated Containers
- Rubber Gloves
- Protective Gear

The **first step is to check the application rate on the label**. To achieve this rate, the ground speed, equipment output and/or application patterns may need to be adjusted or modified. The process involves taking and applying the following measurements:

- **Exact tank capacity**, determined by filling the tank with measured volumes of clean water. The manufacturer's rating may not be exact enough for this purpose. Check capacity yourself.
- **Travel speed** under actual working conditions. Speedometers do not provide an accurate measurement; actual and indicated speed may vary by as much as 30%. To calculate speed,

1. Measure off a distance with the tape (for example, 255 feet).
2. Make several runs along this distance at normal operating speed and time them with a stopwatch.
3. Convert the times from minutes and seconds to minutes by dividing the seconds by 60 and adding this decimal to the minutes.

For example, if the running time is 1 minute 20 seconds, that time in minutes is 1.33. Take the average of several running times (e.g., the average works out to be 1.87 minutes) and divide it into the measured distance (255 divided by 1.87 = 136.36 ft/min). To convert this to miles per hour, divide this figure by 88 (the distance covered in 1 minute while traveling 1 mph) to arrive at 1.55 mph.

- Actual **output of the sprayer (flow rate)** when nozzles are new and then checking it periodically as the sprayer is used. Even new nozzles may vary slightly in actual output.

**Measuring their output** involves collecting a volume of water emitted from individual nozzles over a measured time (for low-pressure and small sprayers) or measuring the output of the sprayer over a known period (for air blast and high-pressure sprayers). The gallons-per-minute output of each nozzle is determined and compared to the manufacturer's rated output. If this is exceeded by more than

10% the nozzle should be replaced and the flow rate of all nozzles rechecked. The pressure in the entire system may be affected.

**The percentage of variation is figured** by dividing the actual measured output of the nozzle by the manufacturer's rated output, subtracting 1.00 from the figure and then multiplying it by 100. For example, if the actual output of a worn nozzle is 0.293 gpm but the nozzle is rated at 0.250 gpm, it varies by 17.2% and should be replaced (0.293 divided by 0.250 = 1.172 minus 1.00 = 0.172 X 100 = 17.2).

**To calculate the gallons per minute output** by a nozzle on a low-pressure sprayer, divide the fluid ounces (of clean water) you collect by the time, in seconds, spent collecting it. The resulting number is then multiplied by the constant 0.4688 (60 seconds per minute divided by 128 fluid ounces per gallon). For example, one of the nozzles sprays out 12 fluid ounces in 22.5 seconds. Ounces divided by seconds (12 divided by 22.5) equals 0.533 fluid ounces per second, multiplied by 0.4688 equals 0.250 gallons per minute. If there are six nozzles on the boom, the 0.250 gpm would be added to the figures arrived at for the other five for a number that represents the total output in gallons per minute.

With a **high-pressure sprayer**, the tank is filled with clean water to a known level and the sprayer is run under normal conditions for a timed period. The tank is then refilled to the original level, measuring the amount of water used to refill it.

Convert the measured running time to minutes (say, 1 minute 50 seconds becomes 1.83). The amount of water (in gallons) that was sprayed on the run is then divided by the minutes. If the sprayer's output is 38.5 gallons during the 1.83 minute period, the gpm is 21.0 gpm. To increase accuracy, repeat the exercise several times and then take the average.

Using a **portable spray check device** can give a visual representation of the spray pattern and show variations that point to nozzle problems or poor height adjustment. The device is placed under the boom and clean water is collected from several nozzles.

- The final measurement is the **width of the spray swath applied** by the sprayer, or the horizontal width covered by spray in a single pass (number of nozzles X nozzle spacing = swath width). The way it is measured will depend on the type of application and spray equipment used.

The above go into **calculating the total area covered** with each tank of material--and how much pesticide needs to be placed in the tank to cover it--as well as whether nozzles are wearing out and need to be replaced or adjusted. Once a sprayer is calibrated, its output rate for a specific speed has been determined, but circumstances change.

There may be **times when the output rate needs to be changed**, such as to accommodate variations in foliage or spacing. Adjustments can be made by changing the speed, changing the output pressure or changing the nozzle size.

When changes are made the sprayer should be recalibrated and its new total output refigured.

## SECTION 7 -- Laws and Regulations

A complex combination of **federal and state laws and regulations govern spray drift**, which is differentiated from intentional pesticide misuse and pesticide residue damage. **Violation of these laws--even though drift is unintentional--can result in substantial penalties for applicators**, who assume personal responsibility for accidents and injuries that arise as a result of each pesticide application. Courts may also hold their employer responsible in lawsuits for personal injury or damages or personal liability.

As a pesticide works its way through the federal registration and label development process, the **U.S. Environmental Protection Agency's Office of Pesticide Programs (OPP)** evaluates it to make sure its proper application does not cause harm to human health or pose risks to the environment. Spray drift is one of the factors analyzed, both as the agency considers proposed pesticides for new registration and existing pesticides for re-registration. As part of the process, OPP estimates the amount of off-target drift and its potential risks, and in the case of existing pesticides, looks at available information on actual drift incidents.

***The resulting product label is an important tool and the first line in minimizing spray drift.***

The label often dictates application guidelines to reduce drift. These can include:

- Prohibiting certain methods of application
- Requiring a buffer zone
- Requiring a foliage barrier
- A lower application rate and frequency
- Limiting allowable applicator pressures
- Limiting boom height

Historically, the U.S. EPA has required all agricultural and forestry pesticides to bear the simple label statement: **"Do not allow drift."** The agency, which recognizes that all applications will result in some level of drift, has been working on developing labeling for pesticides that more clearly addresses drift and incorporates information from the huge database developed by the Spray Drift Task Force as well as the AgDRIFT model (a mathematical model for predictive drift estimates) into its risk assessments.

Still, because drift is primarily related to use and the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) defines state law as primary in the regulation of use, **regulation of drift mainly falls under the purview of the individual states**. Too, federal label-based measures cannot possibly address all the unique local conditions that exist throughout the nation.

It is the **individual states that are primarily responsible for ensuring that applicators are licensed and certified to apply pesticides**, as required by federal and state laws, although U.S. EPA works with USDA and state agencies to carry out certification and training programs. Part of the program for certification may include training about how to protect humans and the environment from spray drift.

In general, **applicators and the others involved are responsible for knowing and understanding** a products use restrictions and for complying with all laws and regulations related to application to ensure a minimum of spray drift is produced. They are expected to take all available precautionary measures to avoid drift and to take into consideration label directions, equipment, weather conditions and proximity of people and sensitive areas.

**Individuals with complaints about spray drift should report them to the tribal or state agriculture or environmental protection agency** that is responsible for enforcing the proper use of pesticides for that location. The appropriate agency with primary responsibility for enforcing lawful pesticide use will investigate complaints. If appropriate, it will issue penalties for improper use and when called for, EPA will assist with the investigation.

**Pertaining to California:**

***With California's diversity of crops, a multitude of microclimates, and varied geography, spray drift is of particular concern and its minimization is addressed in both state laws and regulations.***

In addition, **California Department of Pesticide Regulation** creates "suggested" permit conditions for some chemicals for the counties to consider adopting on a site-specific or countywide basis. As with other laws and regulations pertaining to pesticides, those that apply to spray drift are administered and enforced by the director of DPR and the county agricultural commissioners. When one of the latter becomes aware of a pesticide-drift incident, he or she must investigate it and any complaints, even those that are anonymous or unwritten. The investigation must be completed even if the complaint is later withdrawn or the person making it is compensated for alleged damages.

**Spray drift management is implicit in California Food and Agricultural Code section 12003**, the section of law that requires Pest Control Advisors (PCAs) to put all recommendations in writing. When applicable, the written recommendation must include suggested conditions for application as well as "a warning of the possibility of damages by the pesticide application that reasonably should have been known by the agricultural pest control adviser to exist." To this end, the PCA needs an intimate knowledge of the surrounding area as well as the property to be treated (and the properties of the material to be used) in order to make recommendations for the site. What are the types and uses of surrounding non-target properties, and are there homes, schools and people, crops or animals nearby? Could contamination create a health hazard that would prevent the property's normal use?

Section 12972 of the code is specific to spray drift and the applicator's responsibility, stating that: "The use of any pesticide by any person shall be in such a manner as to prevent substantial drift to non-target areas." **Substantial drift is further defined as occurring when "the quantity of pesticide outside of the area treated is greater than that which would have resulted had the applicator used due care."**

**Due care**, according to DPR, is "the degree of care that a prudent and competent person engaged in the same line of business or endeavor would exercise under the same or similar circumstances. When a person does not exercise due care, the person is said to be negligent."

In **establishing whether due care was used**, factors such as weather and other conditions at the time of application are taken into consideration, as well as the applicator's actions or lack thereof. Lack of "due care"--poor judgment on the applicator's part--could include making the decision to spray under marginal weather conditions or to use inappropriate equipment: for example, to spray by air when a ground rig would be better advised.

The **"substantial drift" definition also applies to section 6614 of Title 3, California Code of Regulations**: Protection of Persons, Animals and Property. This is the key section relating to drift and requires the applicator to evaluate the equipment used, meteorological conditions and the property to be treated, as well as surrounding properties, to determine the likelihood of harm or damage, both prior to and during application.

It also contains a general **prohibition against non-target damage**.

**Pesticide application must not be made or continued when there is any reasonable possibility of:**

- Contaminating the bodies or clothing of people not involved in the application process
- Damaging non-target crops, animals, or other public or private property
- Contaminating non-target public or private property, including the creation of a health hazard, preventing normal use of the property. (The amount and toxicity of the pesticide, the type and uses of the property and related factors are considered in determining whether a health hazard has been created.)

**Thus, much more goes into spraying a pesticide reasonably and with due care than simply knowing how to operate the equipment properly**. There is a large element of good judgment and careful evaluation of the site and its proximity to roads or residential property or other sensitive areas and then considering distances, layout, wind direction and other weather factors, and possibly switching to a different application method than originally planned, based on this evaluation.

There are **specific drift control regulations that apply to certain restricted materials**. Other sections of the regulations apply to specific pesticides and/or geographic regions in California. Section 6460, for example, pertains to liquid dicamba, propanil and 2,4-D. Unless specifically authorized, use of these materials is limited in terms of the height at which they can be applied (no more than 10 feet above the crop or target) and wind velocity at the time of application (no more than 10 mph), among other precautionary measures. Other parts of the section spell out limitations to application by aircraft, including speed, nozzles and boom pressure. The section also limits application by ground equipment other than handguns by specifying nozzle orifice size and boom pressure.

Section 6464 applies to the same materials but is extremely specific to regions of the Central Valley, including the **Sacramento-San Joaquin Delta. It also limits application to various times of the year** to protect commercial plantings of crops such as grapes and cotton from potentially damaging drift.

The use of the **rice herbicide propanil in several Sacramento Valley counties** is covered further in section 6462.

- The concern in these counties is **preventing spray drift into prune orchards.** The section states that, except under special circumstances, aerial application is prohibited within four miles of cultivated commercial plantings of prunes.
- It also **limits the number of acres** that can be treated daily by aircraft within each county and the formulation that can be used.
- With some exceptions, the volume median diameter **(VMD) of droplets is further specified** to be no less than 600 microns, with no more than 10 percent of the droplets measuring smaller than 200 microns.

The implementation of DPR's regulations in the field are further refined in the permit conditions issued by the county agricultural commissioners who have the discretion to evaluate situations on a site-specific basis to determine general risk from spray drift and other concerns. In effect, the permit conditions are "real-life" application of the regulations.

Some of the permit conditions pertaining to spray drift are spelled out in the annual **Rice Pesticides Program** (along with worker safety, seepage control and other requirements); they cover all **restricted materials applied to rice in the Sacramento Valley**, including molinate, thiobencarb and methyl parathion. Some of these drift mitigation permit conditions are designed to minimize pesticides entering the Sacramento and Feather rivers by specifying the distance from the rivers for aerial applications and the maximum number of acres that can be treated by air each day.

**SECTION 8 -- Volatile Organic Compounds**

**<u>Volatile Organic Compounds:</u>**

The preceding sections were devoted to spray drift ("primary drift") as defined by the California Department of Pesticide Regulation. The "secondary" type of drift associated with pesticide vapor, however, is also of concern because of growing air pollution concerns under the Environmental Protection Agency's Clean Air Act.

Pesticide vapor drift is the movement of gas that forms when the material evaporates from plants, soil or other surfaces. Unlike "generic" or primary drift, vapor drift is product-specific.

**Volatile organic compounds (VOCs) --** carbon-containing substances that evaporate, or "off-gas," at room temperature are components of smog. VOCs face restrictions under the federal Clean Air Act because they have been tied to air pollution. VOCs are in countless household and commercial products ranging from cosmetics, paints and gasoline, to wood products, carpeting and draperies.

**Common VOCs include:**

- **Benzene**
- **Trichloroethane**
- **Styrene**
- **Perchloroethylene**
- **Heptane**
- **Hexane**
- **Toluene**
- **Methylene chloride**

**VOCs are found in both the active and inert ingredients of pesticides and are particularly prevalent in two broad categories:**

1. **Fumigants** (among them methyl bromide*, dichloropropene, metam sodium and chloropicrin) *In fumigants, virtually all the VOCs are active ingredients*
2. **Emulsifiable Concentrates** (e.g., chlorpyriphos, glyphosate, trifluralin, endosulfan, etc.). *Inert ingredients (solvents such as xylene and kerosene) account for most of the VOCs in emulsifiable concentrates*

Together, these two groups account for an estimated 80-90% of the agricultural VOCs emitted in the San Joaquin Valley.

(*While the United States Environmental Protection Agency has acknowledged that the VOCs in methyl bromide are not reactive in forming smog, it has not been removed from the list.)

**While only a small percentage of VOC emissions come from farming, agricultural emissions are nonetheless targeted.**

In the air, **VOCs react with oxides of nitrogen and sunlight to form ozone**. Ozone in the upper atmosphere provides a shield from the sun's harmful ultraviolet rays, but at ground level, concentrations above air quality standards may aggravate pulmonary disease symptoms and could even cause permanent lung damage. **Ground-level ozone is also harmful** to vegetation when present at high enough concentrations.

Under the federal **Clean Air Act**, each state must have an implementation plan for achieving and maintaining national **standards for airborne pollutants such as ozone.**

Several key regions designated as **non-attainment areas (NAAs), or regions that do not meet either federal or state ambient air quality standards, will require further VOC reductions** in the future.

<u>**Information for Arizona**</u>

**Spray drift is also of particular concern to lawmakers and regulators in Arizona, which boasts a diversity of crops amidst rapidly growing population centers.** Minimization of drift is addressed in both state law (Arizona Revised Statutes) and rules (Arizona Administrative Code).

The Arizona Administrative Code states that **"A person shall not allow drift that causes any unreasonable adverse effect."** "Unreasonable adverse effect" is defined as "any unreasonable risk to a human being or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide, or a human dietary risk from residues that result from a use of a pesticide in or on any food as documented by the Department through its investigation."

**Pesticide applicators are expected to be reasonable and prudent** in making pesticide applications, taking into account factors such as weather and other conditions at the time of application. Lack of care or poor judgment on the applicator's part could include making the decision to spray under marginal weather conditions or to use inappropriate equipment: for example, to spray by air when a ground rig would be better advised. The applicator is expected to evaluate the equipment used, meteorological conditions and the property to be treated, as well as surrounding properties, to determine the likelihood of harm or damage, both prior to and during application.

**Section 3-365 of the Arizona Revised Statutes requires buffer zones** around schools, day care centers, health care institutions and residences for odoriferous pesticides.

The section goes on to state that paraquat or **highly toxic pesticides are not to be sprayed:**

- Within 400 feet of a health care institution
- In liquid form, within 100 feet by aircraft or 50 feet by ground rig of at least 25 residents adjoining the field to be treated
- Within 300 feet of at least 25 residences adjoining the field to be sprayed, if applied as dust by aircraft
- Within 1/4 mile of schools, child care group homes, or day care centers, unless authorized activities are scheduled to occur at the facility after the reentry time period assigned by the product label elapses. (Distances are measured from the boundary of the school, residence, etc. closest to the field to be sprayed to the area that is to be sprayed.)

***The Director of the ADA also may designate pesticide management areas***

**Pesticide Management Areas are urban areas adjacent to farmlands that have a history of concerns over nearby aerial pesticide applications.**

If possible, an applicator is to give 24 hours' notice to the director--in any event, to make every reasonable attempt to notify ADA--before every application in a pesticide management area.

Section 3-367.01 states that a **person suffering damage or loss to crops** as a result of pesticide application by another are to file a written report with the ADA within a specified period of time (15–30 days).

Because **beekeepers can be impacted by spray drift**, Section 3-367.02 of the Arizona Revised Statutes requires them to give written notification to landowners on whose property the bees may forage, so that the beekeeper can be notified when a bee-sensitive pesticide is to be applied, otherwise, if the bees are damaged, it will not be considered a violation.