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Preventing or Mitigating Potential Negative Impacts of Pesticides on Pollinators Using Integrated Pest Management and Other Conservation Practices

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The Xerces Society
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Cover photos: A bumble bee covered in squash pollen, photo courtesy of Nancy Adamson, Xerces Society; bottom left, a New Hampshire meadow adjacent to a crop, photo courtesy of Don Keirsted, USDA NRCS; and bottom right, a tower spayer, photo courtesy of USDA Agricultural Research Service.

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Introduction

This technical note is designed to help conservation planners use the NRCS conservation planning process to prevent or mitigate pest management risks to pollinators and pollinator habitat. Pollinators are a diverse component of on-farm wildlife and are critical for plant reproduction. More than 80 percent of plants either require or benefit from pollinators to produce seeds or fruit. Wildlife as diverse as songbirds and bears depend upon insect-pollinated plants. High-quality pollinator habitat supports abundant insects that provide food for most bird species, as well as important biological control agents of many crop pests.

In agricultural systems, 35 percent of global agricultural production, including more than 100 crop species, is either somewhat or completely dependent upon pollinators. The value of insect-pollinated crops in the United States alone ranges between $18 and $27 billion each year. Worldwide, pollinator-dependent crops are worth an estimated $215 billion annually. Managed honey bees and wild native bees both provide this important service.

Pollinators, including honey bees and bumble bees, also visit crops such as corn, cotton, and soybeans for pollen or nectar, even though these crops are not dependent on bees for production. Since pesticide use on all crops may drift onto adjacent habitat, all agricultural producers play an important role in pollinator protection and conservation, not just growers of fruits, berries, seeds, and nuts.

Unmanaged native bees are a wild, natural resource that nest and forage in cropped areas and adjacent habitat. Managed honey bees cannot always be moved out of agricultural areas to protect them from pesticide applications. Therefore, this technical note focuses on protecting all bees nesting and foraging on and around farm fields and rangeland. Assuming that pollinators cannot be removed from a site provides a conservative framework that can help protect other onsite pollinators (e.g., butterflies, flies, and moths), as well as other beneficial insects, such as predators and parasitoids of crop pests that can help reduce both crop injury and the need for some pesticide applications.

Through the conservation planning process, NRCS field staff, in collaboration with integrated pest management (IPM) specialists, university extension personnel, and pollinator conservation specialists, can help clients identify potential pesticide hazards to pollinators, incorporate pollinator protection into IPM plans, and coordinate other conservation practices to prevent or mitigate identified hazards to pollinators and beneficial insects.

IPM is a decision-making framework that utilizes least hazardous pest management options only when there is a demonstrated need, and takes special precautions to reduce the hazards of pest management activities to people, other living organisms, and the environment. It employs a four-phase strategy: (1) Reduce conditions that favor pest populations, (2) Establish an economic threshold of how much damage can be tolerated before pest control must occur, (3) Monitor pest populations, and (4) Control pests with the most specific pest control option when the preestablished damage threshold is reached.

This technical note will lead you through four main steps to determine whether pesticide use on a farm or ranch poses potential hazards to pollinators, and then help you develop conservation or IPM plans that prevent or mitigate these hazards. The steps are:

Step 1. Identify the pollinator resource concern: Work with the client to determine if crops grown onsite are visited by or require bees or other pollinators, assess pollinator habitat, and determine if honey bee apiaries are located nearby. Inform the client of the importance of minimizing hazards to all pollinators. Note that

by helping protect pollinators, this technical note also is useful for helping clients conserve other beneficial insects (predators and parasitoids of pest insects), wildlife, and biodiversity.

Step 2. Identify potential risks from planned pesticide uses: Determine if planned pesticide uses are toxic to bees. Look for bee toxicity warnings on the pesticide label, read extension publications, or use the Windows Pesticide Screening Tool (WIN-PST) bee toxicity database to determine if the pesticides being used are highly or moderately toxic to bees. If they are, then assess how long the pesticide may remain toxic in the field.

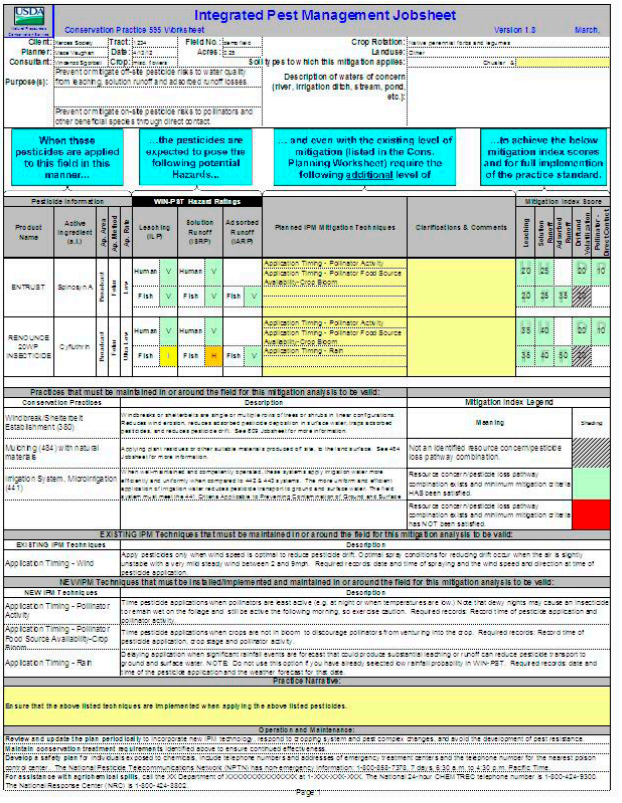
Step 3. Identify specific exposure pathways that should be prevented or mitigated: Work with the client, and an IPM specialist or pollinator conservation specialist to determine how pollinators may be exposed to pesticides, and which exposure pathways are likely. Bees can be exposed to pesticide sprays in the field or through offsite pesticide drift, as well as to pesticide residues that remain on flowers and foliage, in nectar and pollen, and in the soil where some bees nest or collect mud.

Step 4. Help develop a prevention or mitigation plan: Based on your assessment of toxicity and exposure, work with the client's IPM specialist to develop an IPM plan that prevents or mitigates specific onsite and offsite (i.e., drift related) risks to pollinators. To document that the conservation plan adequately addresses the pollinator risks that have been identified, use the information provided in this technical note to help select the appropriate IPM strategies and conservation practices in the State-supported 595 Integrated Pest Management Job Sheet (fig.1). The goal is to combine enough pollinator-protective IPM techniques to reach a minimum total score of 10 points for onsite pollinator protection (e.g., see table 2 for a summary). This is similar in approach to Technical Note (TN) 190-AGR-5, "Pest Management in the Conservation Planning Process," with regards to water quality hazard mitigation. See your State Field Office Technical Guide (FOTG) for an Excel® workbook or similar version of this job sheet. Appendix A includes guidance on how to use the 595 IPM worksheet. For offsite drift mitigation, use the approach outlined in TN 190-AGR-5, but see table 3 in this document for a summary of specific details regarding pollinator protection.

Identify the pollinator resource concern (Step 1)

If a client's hazardous pesticide application may come in contact with pollinator-visited plants or nearby pollinator habitat, the NRCS planner should identify pollinator protection as a natural resource concern. Plants visited by pollinators include specific insect-pollinated crops, adjacent wildflowers and flowering weeds, and many crops that don't require insect pollinators, such as corn, cotton, and soybean, but are still frequently visited

Figure 1 Screen shot of the 595 Integrated Pest Management Job Sheet portion of the Excel® workbook



by bees and other pollinators (fig. 2). In addition, the planner should identify pollinators as a natural resource concern if hazardous pesticide applications on neighboring properties may drift onto the client's farm.

The most important crop pollinators in the United States are bees, including managed bees, such as honey bees, bumble bees, and solitary bees (e.g., alfalfa leafcutting, mason/orchard, or alkali bees), as well as hundreds of species of wild native bees, such as bumble bees, mining bees, squash bees, and leaf cutting bees that live on and around farms.

Managed bee species are maintained in artificial nests (e.g., hives or special nest blocks) and can be moved into and out of farm fields corresponding to the bloom period of crops. Typically beekeepers can manipulate the population size of managed bees in anticipation of market demands by farmers who rent them for the service of pollination. Because the life cycle and nesting structures of these bees are controlled by the beekeeper, there are often basic strategies available for reducing the impact of pesticides on managed species. For example, the farmer and beekeeper can coordinate on the timing of when bees are released on a farm if pesticides are being applied before the crop blooms, or farmers can tell beekeepers when pesticide use is imminent. However, it is often difficult for beekeepers to move honey bee hives without significant preparation and planning, and it is impossible to move wild native bees. Despite such efforts, U.S. beekeepers are losing more honey bees each year than ever before and pesticide use is one of the causes.

Figure 2 Role of pollinators in various crops visited by bees

Essential to helpful: Alfalfa seed, almonds, apples, avocados, apricots, blueberries, canola, cherries, clover seed, cotton seed, cranberries, cucumber, macadamia nuts, melons, peaches, pears, plums, pumpkins, raspberries, squash, strawberries, hybrid sunflower seed, greenhouse tomatoes, vegetable seed, and watermelon.

Helpful, but not necessary: Eggplant, citrus (depends upon variety), fava beans, peppers, tomatoes, and soybean.

Not necessary, but bees likely present: Alfalfa hay, field beans, corn, cotton, and peas.

Worldwide, the acreage of insect-pollinated crops has tripled in the last 50 years, and demand for managed bees continues to increase. To help meet this demand, a growing number of scientists across the world are documenting the important role that wild native bees are playing in crop production. In many parts of the United States, hundreds of bee species have been identified on farms and, where sufficient habitat is available, these species are providing all of the pollination services needed for high crop yields and fruit quality (Garibaldi et al. 2013).

Depending on the species, native bees may nest in underground tunnels, in hollow plant stems and beetle tunnels in wood, or – in the case of bumble bees – in small cavities under lodged grass, abandoned rodent burrows, or even in trees or old bird nests. Unlike managed bees, wild or unmanaged pollinators are an onsite natural resource and cannot be moved from the farm when pesticides are used. Also, because most wild bee species are smaller than honey bees, they are thought to be more vulnerable to pesticide applications. Therefore, measures to protect unmanaged bees onsite are typically more conservative and afford significant protection for nearby beekeepers. Still, it is important for planners to stress the importance of knowing the location of nearby apiaries and communicating with those beekeepers.

Many other pollinators that are less important than bees for crop pollination also live on and around farms and require protection from pesticides. These pollinators include butterflies, moths, beetles, flies, and wasps. Many of these flower-visiting insects also play important roles in crop protection and pest management. Of greatest importance are many species of wasps, flies, and beetles that function as predators and parasitoids of many crop pests.

To learn more about native bees, visit http://www.xerces.org/native-bees/, or see "Attracting Native Pollinators" (Mader et al. 2011). For guidance on assessing pollinator habitat on farms, see the Xerces Society's Pollinator Habitat Assessment Guide (link: http://www.xerces.org/wp-content/uploads/2009/11/PollinatorHabitatAssessment.pdf). With this tool and the help of a pollinator specialist, pollinator habitat (bee nest sites and forage) can be mapped on the farm to determine what areas need special protection from pesticides.

Identify potential pesticide toxicity to bees and persistence in the field (Step 2)

The planner should work with the client and appropriate IPM advisors (i.e., IPM specialists, cooperative extension experts, or pollinator conservation specialists) to determine the acute toxicity of pesticides used onsite or nearby (step 2a) and the length of time these products stay toxic in the field (step 2b).

Step 2a: Assess pesticide toxicity to bees

WIN-PST is the NRCS-supported technical tool that is used to assess potential risk to water quality from pesticide leaching, solution runoff, and pesticides adsorbed to sediment that leaves the field. It provides an output indicating the potential risks pesticides pose to drinking water and fish in each of those loss pathways.

Since 2011, WIN-PST also has a honey bee toxicity viewer that allows users to see if pesticides applied on a farm may be acutely toxic to honey bees. As of 2013, acute toxicity values for honey bees are available for over 100 pesticide-active ingredients.

In many cases the acute toxicity values for native bee species will differ significantly from honey bees (Hopwood et al. 2012). However, when WIN-PST identifies a potential risk to honey bees, potential harm to native bees can be assumed. Follow the directions in figure 3 to view the honey bee toxicity data in WIN-PST.

Pesticide labels can also provide information on how toxic a pesticide is to honey bees and how the applicator can either prevent or mitigate honey bee exposure. Please note that pesticide label information about the toxicity of a particular product to native bees and label guidelines for reducing hazards to native bees is typically unavailable. Where pesticide labels list risk to honey bees, potential harm to native bees also can be assumed.

Low doses of pesticides also have chronic toxicities (the effect of exposure over long periods of time). However, this data is not readily available, even though chronic toxicity may be a critical factor for pollinator health, especially for developing bee larvae feeding on contaminated food stores.

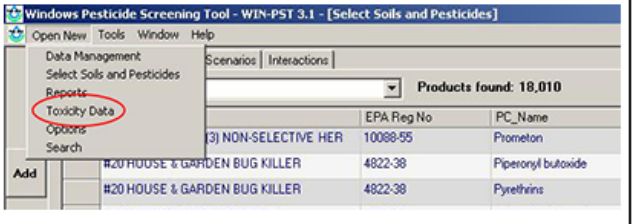
Step 2b: Determine pesticide persistence in the field

If WIN-PST, a pesticide label, or other source indicates potential hazard to pollinators from a pesticide application, then the next step is for the client to work with an IPM specialist, cooperative extension expert, a crop advisor, or any combination of these specialists, to identify the residual toxicity (i.e., how long it stays toxic to bees that encounter pesticide residue in the field) (see fig. 4). Different pesticide active ingredients can generally last in the field from just a few minutes to many days, and actual persistence can vary greatly based on specific field conditions. Active ingredients also can be formulated in commercial products that have proprietary ingredients or mixed with adjuvants in the spray tank to increase persistence.

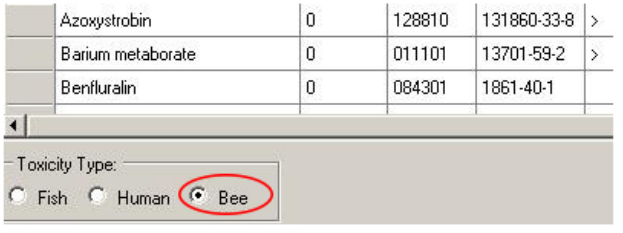
The Pacific Northwest Extension publication "How to Reduce Bee Poisonings from Pesticides" (Hooven et al. 2013) provides good information on residual toxicity periods for pollinators for many pesticides. However, to understand the impacts of various formulations or adjuvants, contact local extension agents or crop advisors for information on commonly used pesticides for a specific crop or area.

Figure 3 How to access the bee toxicity data from WIN-PST

1. Select "Toxicity Data" from the "Open New" menu.



2. Once the "Toxicity" screen is open, select to view "Bee" in the "Toxicity Type" section.



Note: The data displayed is acute toxicity data. It is not a hazard rating as can be obtained for humans and fish in WIN-PST. The user must determine if the pesticide has the potential to actually impact bee populations using the process outlined in this technical note.

Identify specific exposure pathways to be prevented or mitigated (Step 3)

If WIN-PST, a pesticide label, or other technical publication indicates that a particular active ingredient can be hazardous to bees, and if the active ingredient is determined to persist long enough in the field to allow for significant exposure, then the next step is for the client to work with their IPM specialist, pollinator conservation specialist, and NRCS conservation planner to determine if bees may be exposed to the pesticide. Table 1 outlines the exposure pathways that can bring bees and other pollinators into contact with pesticides. These pathways can be present both in the treated fields and in adjacent areas receiving drift or overspray. Identifying these exposure pathways will help guide mitigation efforts.

For example, chlorpyrifos[1] is very toxic to bees. However, spraying a 2-inch strip of soil along a seed row from 6 inches off the ground immediately after seeding to treat corn rootworm maggots likely poses a minimal threat to bees. In contrast, a less toxic chemical, such as the fungicide Captan[1], applied from an airplane during almond bloom, may pose a more significant risk to bees, because it is being applied over a wider area and at a time when bees are actively visiting a crop. In another example, if a producer knows that Russian wheat aphid is going to be a problem pest in the coming growing season, they may have the choice of spraying chlorpyrifos on wheat plants or using imidacloprid (also highly toxic to bees) as a systemic seed treatment at planting. Both pesticides are "highly toxic" to bees, but the application method is critical in determining the potential risk of bee exposure. Offsite drift onto adjacent blooming plants from the application of chlorpyrifos has a higher potential for bee exposure than the application of imidacloprid as a wheat seed treatment (assuming that offsite drift of imidacloprid dust is controlled at planting). Ideally, however, growers would plant wheat varieties or other small grains that are resistant to Russian wheat aphid.

Figure 4 Residual toxicity and the EPA

In 2012, the Environmental Protection Agency (EPA) started an effort to identify products with an extended residual toxicity (ERT) to honey bees. This effort aims to better reflect the true pesticide hazard to bees by gathering data on the RT25, which is the number of hours post-application after which 25 percent of exposed bees still die. An ERT of concern to honey bees will likely be defined as an RT25 greater than 8 hours.

To be of use for pollinator risk management, assessment and reporting of pesticide ERT will look beyond the active ingredient alone. For example, properties of the formulated product and its adjuvants can have a marked effect on the RT25 and will be reported to EPA.

ERT data is not widely available. However the Pacific Northwest Extension publication, "How to Reduce Bee Poisonings," does provide data on residual toxicity data for some pesticides (Hooven et al. 2013).

Help develop an IPM plan or mitigation measures that protect pollinators and integrate these into a conservation plan (Step 4)

Conservation planners should work with an IPM specialist and a pollinator conservation specialist to develop a plan that prevents or mitigates pesticide impacts on pollinators, and still protects the crop, when all of following conditions are met—

- A pesticide that may be used is toxic to bees (see step 2a).
- That pesticide is persistent in the field at a critical time for pollinators (see step 2b).
- Bees or other pollinators may be exposed to that pesticide (see step 3).

An IPM approach to pest control includes preventing and avoiding pests when possible, frequent monitoring of pest and beneficial populations, comparing pest levels to economic damage thresholds to determine if suppression is necessary, and if required, using the most targeted and least damaging pest suppression methods. NRCS conservation programs may be able to offset some of the costs incurred in implementing IPM plans or the costs of incorporating pollinator protection strategies into IPM plans. Similarly, many NRCS conservation practices can help mitigate specific pesticide risks to pollinators,

1. The inclusion of a specific active ingredient or product is for illustrative purposes only and is neither an endorsement nor a condemnation of a specific product.

such as reducing pesticide drift or creating refuge habitat.

Incorporating pollinator protection into a client's IPM or conservation plan usually requires guidance from an IPM specialist and a pollinator conservation specialist. Some components of such an IPM plan may include—

- Expanding the use of tools that prevent pest build up or avoid pest damage.
- Expanding the use of crop scouting and pest monitoring.
- Choosing alternative active ingredients, formulations, or application methods that offer less risk to pollinators.
- Adjusting the timing of pesticide applications to avoid periods when bees are more likely to be present.
- Scouting for bee habitat (nest sites, flowers, etc.) in and around fields, and protecting those areas from pesticides.

NRCS conservation planners can provide direct planning support to reduce the potential for bees to come in contact with pesticides (for example by helping a client design a windbreak that reduces pesticide drift onto adjacent pollinator habitat);

Table 1 Potential Pesticide Exposure Pathways Encountered by Pollinators

Exposure Pathway	Description
a. Direct contact	Direct contact may occur when bees are actively foraging on flowers or nesting in the ground within a field or orchard at the time of pesticide application. This can occur in insect-pollinated crops and weeds, and in crops, such as corn, soybean, or cotton, that do not require insect pollination but are still visited by pollen and nectar-gathering bees (see fig. 2 on page 3).
b. Residue contact	Pollinators may be exposed to pesticides within a field or orchard after a pesticide application when they visit flowers, walk on treated leaves, or gather contaminated pollen and nectar. This is especially problematic when a pesticide has a long persistence in the field. Residue contact occurs on contaminated insect-pollinated crops and weeds, adjacent habitat, and crops that do not require insect pollination, such as corn, soybean, or cotton, but which are still visited by pollen or nectar-gathering bees. (see fig. 2).
c. Pollen and nectar contaminated by systemic insecticides	Pollen and nectar may be contaminated internally by systemic insecticides applied as seed coatings, soil drenches, trunk injections, or foliar sprays (Rortais et al. 2005, Hopwood et al. 2012). Systemic insecticides, which include the neonicotinoid class of chemicals (e.g., imidacloprid, clothianidin, thiamethoxam, and others) and some organo-phosphates (e.g., acephate, methyl parathion, and coumaphos), are translocated within the tissue of the plant, and are present in the nectar and pollen. The incorporation of a systemic insecticide into nectar and pollen delivers it directly to individual bees and other pollinators, regardless of the original method or timing of application. Some systemic insecticides can be very persistent, staying in plant tissues and soil for many months or even years (see Hopwood et al. 2012). Because residues may persist in plant tissue, chronic exposure may be more likely than acute exposure. We do not know if concentrations build up after repeated use.
d. Contaminated water	Water sources may be contaminated by overspray, offsite drift, field runoff, or pesticides adhering to dust. Honey bees may be exposed to pesticides in water they gather to cool their hives or to dilute honey to feed to their offspring. Some native bees and beneficial wasps also collect water, using it for nest construction. Leaks in chemigation systems may provide another source for bees to encounter contaminated water. Similarly, butterflies and other less recognized pollinators sometimes use damp soil or puddles to consume minerals needed for nutrition and reproduction, and may be harmed by contaminated water sources.
e. Contaminated nesting material	Solitary bees used for crop pollination, such as alfalfa leafcutting bees (*Megachile rotundata*) or blue orchard bees (*Osmia lignaria*), may be exposed to pesticides when their nest materials are contaminated. For example, leaf-cutting bees cut pieces of leaf to wrap their brood cells, and mason bees separate their brood cells with walls of mud. Both the leaf pieces and mud may be contaminated with pesticide residues.

Exposure Pathway	Description
f. Dust released from pesticide seed coatings	Dust released from pesticide seed coatings (for example, clothianidin used on corn seed) during planting can carry pesticide residues onto adjacent flowers and weeds or into apiaries (locations where honey bee hives are maintained) and has resulted in bee kills (Alix et al. 2009, Krupke et al. 2012).
g. Pollen-like formulations	Wettable powders, dusts and microencapsulated formulations pose a unique exposure risk because they are pollen-like and adhere easily to the hairs on bees and other pollinators (especially dusts and microencapsulated formulations). They also typically remain toxic in the field longer than liquid formulations.
h. Contaminated nesting areas	When pesticides are applied to or drift onto areas of bare ground, even within fields, they may contaminate potential nest sites for ground-nesting bees. Similarly, pesticide drift into adjacent shrubby habitat may poison potential nest sites for wood-nesting bees, and pesticide drift into adjacent overgrown habitat or forest edges may contaminate potential bumble bee nesting sites.
i. Guttation fluid	Guttation is excess water exuded by plants along their leaf edges. For example, corn seedlings and strawberry leaves may exude droplets of water at the leaf tips in the morning under high humidity conditions. Pollinators may collect guttation fluid from plants treated with systemic insecticides, but the risk is considered to be low, because honey bees usually collect water when they need to cool their hives (much less likely in the morning), and they generally will only collect guttation fluid if no other water sources are nearby (Girolami et al. 2009).
j. Aphid honeydew	Bees may be attracted to a field by honeydew (a sugary excrement) secreted by aphids and related insects (such as scale) found within cropped areas or in adjacent habitat. The crop itself may not be in flower, yet bees may still be foraging within the crop to collect honeydew when pesticides are applied. Aphid honeydew may be even more attractive to other insects, including parasitic wasps that do not have the long tongues of bees and consequently have greater difficulty collecting flower nectar as a food source. Although parasitic wasps and other insects are typically minimal pollinators (or do no pollinating at all), they have an important role in controlling populations of crop pests.

however, these activities still should be coordinated with the client's IPM professional to ensure they are appropriately factored into other IPM decisions.

Techniques conservation planners can discuss with IPM professionals to mitigate the impact of pesticide use on pollinators and incorporate pollinator protection into a farm's IPM plan (shaded in grey in tables 2 and 3) are addressed in step 4a. Mitigation practices that NRCS conservation planners can directly assist in developing (shaded in blue in tables 2 and 3) are addressed in step 4b below.

To design specific strategies and determine mitigation scores, use tables 2 and 3 to work with your State's 595 Pest Management Considerations in Conservation Planning Worksheet (see appendix A) to track mitigation points associated with pesticide risk management techniques. These scores do not necessarily mean that all risks are entirely eliminated, but rather that a significantly positive impact can be expected in terms of pollinator protection.

Onsite (i.e., within the application area) pollinator risk reduction (table 2)

The planner's goal is to work with the client and pest management professional to agree to a set of mitigation techniques or NRCS conservation practices from table 2 that cumulatively add up to a minimum of 10 mitigation index points. IPM techniques or conservation practices with index values of 1 to 4 generally have a low potential to reduce negative impacts to pollinators. Techniques or practices with an index value of 5 to 7 generally have a significant potential to reduce impacts to pollinators. Techniques and practices with an index value of 8 to 10 are considered highly effective at reducing impacts to pollinators.

Offsite (i.e., drift outside application area) pollinator risk reduction (table 3)

The planner's goal is to work with the client and pest management professional to agree to a set of mitigation techniques from table 3 that

cumulatively add up to a minimum of 20 index points, indicating a significant reduction in drift hazards posed to pollinators. This is the same criteria established in TN 190-AGR-5 and Conservation Practice Standard (CPS) Code 595, Integrated Pest Management, for drift losses. Table 3 provides pollinator-specific considerations for designing practices or selecting techniques that prevent or reduce offsite drift, and follows the same scale and rating process used in TN 190-AGR-5, for drift losses. IPM techniques or NRCS conservation practices with a mitigation index value of 5 generally have the potential to reduce drift losses by 5 to 10 percent. IPM techniques or NRCS conservation practices with an index value of 10 generally have the potential to reduce losses by about 25 percent, and IPM techniques or NRCS conservation practices with an index value of 15 have the potential to reduce losses by 50 percent or more.

Step 4a: Collaborate with IPM specialists to prevent and mitigate pesticide hazards

NRCS planners can help reduce negative impacts of a client's pesticide practices on pollinators by facilitating communication between the client and IPM specialists and pollinator conservation specialists. Here are several risk prevention or mitigation techniques planners can ask their client and IPM specialist to evaluate. Remember, making decisions about these techniques is up to the client and their IPM specialist.

Choice of pesticide

Clients may choose to use a pesticide that has a lower impact on pollinators or other beneficial insects than a product currently being used. Switching to a lower-risk pesticide is an especially important consideration if a bee-toxic pesticide needs to be applied when a crop is in bloom. NRCS cannot make these determinations or pesticide recommendations. However, IPM specialists can provide pesticide recommendations for clients to consider.

If a client decides to switch to a less-bee-toxic pesticide, then it is important to assess all hazards posed by the newly selected pesticide and mitigate any new additional hazards (e.g., to humans, fish, or biocontrol agents). Lower risk to bees does not automatically mean the pesticide poses no risk and is IPM compatible.

Note also that organic-approved pesticides are not necessarily safer for pollinators than comparable conventional pesticides. The process for evaluating pesticides for potential risk described earlier (such as examining the toxicity data in WIN-PST) and the process for mitigating the risks of those pesticides should be considered on all farms (organic and conventional) whenever pollinators are identified as a resource concern. Information about the potential risk of organic-approved pesticides to pollinators is also available through the Xerces Society publication, Organic Approved Pesticides: Minimizing Risks to Pollinators (http://www.xerces.org/wp-content/uploads/2009/12/xerces-organic-approved-pesticides-factsheet.pdf).

Alternatives to pesticides

As part of an IPM plan, a client also may choose to use products that help reduce the need for pesticides. For example, kaolin clay barriers (e.g., Surround®) coat fruit or other plant parts in a thin layer of clay that makes it more difficult for insect pests to locate their host. Pheromone traps use artificial pheromones (the chemicals insects produce to find a mate) to lure insects to the trap where they become snared on a sticky coating and are monitored to estimate pest pressure or schedule targeted insecticide applications. Similar to pheromone traps is pheromone mating disruption (fig. 5). Pheromone lures or sprays are applied over a large area, which make it difficult for targeted pests to find mates. The result is a drastic decrease in the overall reproduction of pests with no impact on nontarget insects.

Insect repellents, such as garlic oil, are also available as a tool to discourage pest insects from visiting a crop. However, if used on blooming crops, they also may repel important pollinators.

Choice of formulation

Some pesticide formulations pose less of a risk than others to bees, and as with the choice of active ingredient, clients need to work with an IPM specialist, extension agent, or a qualified crop consultant to see what formulations are appropriate for addressing a specific crop pest. Whenever possible, lower risk formulations should be chosen and incorporated into an IPM plan.

For example, granular formulations generally pose less risk to bees and other pollinators, unless they are broadcast in an area where they may leach into ground-nesting bee nests or into water collected by honey bees, or they contain systemic insecticides that can be absorbed by adjacent plants and expressed in pollen and nectar. Water-based liquid formulations and dry flowable formulations are better than wettable powders because the

Figure 5 Case study: Mating disruption and pheromone traps in Pennsylvania apple orchards by Dr. David Biddinger, Pennsylvania State University

Scientists at Pennsylvania State University's Fruit Research and Extension Center worked with local apple growers over a 5-year period to implement IPM practices that use pheromone-monitoring traps and mating disruption to help manage moth pests, such as codling moth, oriental fruit moth, lesser peach tree borer, and peach borer.

Pheromone-baited traps designed for these species help farmers detect moth pests as soon as they are active and then measure their abundance. In this way, farmers can carefully target insecticide applications only when the pest is most active or at the most susceptible stage (often the egg or newly hatched worm). Monitoring also helps farmers spray only when moth populations are high enough to warrant treatment. This IPM strategy has often reduced pesticide sprays by at least 50 percent.

Similarly, orchardists are using pheromone-mating disruption to confuse the males of these pests so that they cannot find a mate. Subsequently, the females are mostly unsuccessful in mating and lay many fewer eggs, resulting in such low pest populations that there may be no need for some sprays. Mating disruption is completely safe to people, wildlife, and even other insects because each pest species has its own unique pheromone. Only the behavior of the pest is affected and nothing is actually killed, just frustrated.

Pheromone-mating disruption for susceptible pests, such as the lesser peach tree and peach tree borers, can completely replace insecticide applications after a single season of use. However, with other pests, pheromone-mating disruption often has to be supplemented with insecticide sprays until moth pressure is reduced to relatively low levels. High populations of codling moth, for example, need supplemental insecticide applications, but after 3 consecutive years of mating disruption, declining pest populations allowed a 25-percent reduction in pesticide use.

Reducing the use of broad-spectrum insecticide sprays in orchards through mating disruption also conserves beneficial insects that prey upon secondary pests such as mites, aphids, scale and leaf-miners. This further reduces the need for other insecticides, and can often eliminate those lesser pests after a few years. In orchards with insecticide-resistant codling moth or oriental fruit moth, mating disruption may be the most effective pest management option because the control is a result of behavioral changes, rather than killing individual moths.

Mating disruption does have its limitations. For example, it does not control nonmoth pests, such as apple maggot or stink bugs, which still have to be controlled with a separate pesticide spray. In addition, the cost of mating disruption is often high, even in comparison to multiple insecticide sprays. Finally, mating disruption is ineffective on female moths that mate elsewhere but fly in to lay eggs in the managed orchard. Limited border sprays can help mitigate this, but mating disruption is most effective in orchards of 10 acres or larger.

powders stay active longer in the field. Dusts and microencapsulated formulations also are active longer than other formulations, and they readily adhere to foraging bees (much like pollen). They may be carried back to the nest, where they can contaminate food stores for larval bees (Mason, 1986). For more details on the relative risks of formulations, see How to Reduce Bee Poisoning from Pesticides (Hooven et al. 2013).

Seed treatments

Insecticidal seed coatings also pose a risk to pollinators. Pesticide dust may be released during planting and should be managed as pesticide drift. To mitigate this potential hazard to bees, it is important to use seeds with high-quality coatings that are less prone to being removed during planting. If clients or their staff apply seed-coatings to seed, it is critically important that the best stickers are used, mixed correctly, and applied correctly. It is also important to properly vent pneumatic seeders. Bee kills have occurred when poor stickers were used and pneumatic seeders vented their exhaust up into the air. In this scenario, the seed coating dust drifted onto nearby honey bee hives or adjacent blooming fields, killing

many bees. To reduce this risk, pneumatic planting equipment should be modified to direct any vented dust down onto the ground, although recent research suggests that this may not be completely effective (Tapparo et al. 2012). It is important to note that this technique may reduce the drift of the dust offsite, but any dust in the field may still come into contact with bees.

Many bee-visited crops, such as corn, soybean, and sunflower, are now planted using seed treatments of systemic insecticides. As the plant grows, these insecticides are absorbed and may be expressed in the plant's pollen or nectar. Some evidence suggests that these levels may have negative impacts on bumble bee reproduction and honey bee foraging (Whitehorn et al. 2012), and questions still remain about the impact when millions of acres are treated across broad landscapes. Seed treatments should be used as part of an approved IPM plan, with appropriate scouting and monitoring to determine when treatment is actually necessary.

Consult the IPM specialist about the availability and use of untreated seed. Also ask about emerging technology for planting seed-treated crops and the availability of special planting equipment that minimizes the release or drift of insecticide-contaminated dust when planting seed-treated crops. Research is under way to develop planting equipment that reduces this risk.

Drift reduction

It is critically important that any IPM plan clearly explains how the client will reduce pesticide drift, including dust from planting insecticide-coated seeds. This will save money by ensuring that the majority of the pesticide that is applied ends up on the target plants or soil. It also helps reduce nontarget impacts caused by pesticide drift onto adjacent wildflowers, weeds, or wildlife nesting habitat. Several drift-reducing techniques may be incorporated into an IPM plan. They include the following:

- Weather conditions—The first step in minimizing drift is to apply pesticides when winds are calm, but not totally still. Ideally, winds are blowing at a gentle 2 to 9 miles per hour (mph). When conditions are too windy, the pesticide may be transported by wind currents offsite and onto adjacent habitat. When too calm, such as during a temperature inversion, the pesticide may linger in the air and float a longer distance offsite compared to gentle wind conditions. Temperature inversions occur naturally, typically in the early morning hours when the ground cools the air layer immediately above it. Inversion conditions result when warmer air above traps cooler air near the surface of the ground and are often characterized by fog. Such conditions facilitate pesticide drift. Drift that occurs over long distances (a mile or more) is most often the result of applications made during temperature inversions.
- Application method—To minimize drift, apply insecticides as close to the ground or target plant as possible. Spray nozzles should be calibrated regularly to ensure that the appropriate amount of pesticide is being applied. With traditional application equipment, proper nozzle selection is important in reducing drift losses. Several manufactures have specially designed nozzles to deliver spray patterns and droplet sizes that are less apt to drift. Additionally, adjuvants that reduce drift are also available to tank-mix.

  Specialized equipment also may help reduce drift. For example, using GPS systems to prevent overlapping applications is commonplace as a way of reducing the total amount of active ingredient applied as well as drift. In some cases, GPS systems control boom sections or even individual nozzles along the booms to avoid overlapping or applying outside of the field boundaries (e.g., on grassed waterways, filter strips, etc.).

  Farmers may also use new application technologies, such as electrostatic or image-responsive sprayers. The electrostatic sprayer uses special nozzles that charge the droplets, which are then electrically drawn to the plant surfaces. This technique typically reduces off-target application (i.e., to the ground or offsite drift) by over 50 percent. Image-responsive sprayers detect when a spray nozzle approaches a plant and are supposed to turn on only then.

  Another alternative is to use spray curtains or hooded sprayers that surround the nozzles and crop rows or plants. In this way, the spray is relatively contained around the application area and drift is reduced. Similarly, using tower sprayers in orchards reduces drift and better targets sprays compared to strong air blast sprayers.

- Unsprayed set-backs along crop edges—To minimize drift from the target area, applicators can leave a 30-foot-or-greater pesticide-free set-back around the edge of the application area (i.e., a buffer within the crop field that is untreated). In some cases, this will be easy to implement. In other cases, such as when a client is strategically scouting field edges to note when pests are coming into a field, it will be more appropriate to scout and treat targeted sections of field edges.

Application timing

Whenever possible, IPM plans should ensure that pesticides are applied at times and during environmental conditions that reduce or eliminate potential exposure to bees and other pollinators. Specific considerations include the following:

- Blooming plants—Avoid plants in bloom and application times when bees are active in the field. Insecticides that are toxic to bees should not be applied to a crop in bloom or to adjacent blooming plants. In some cases, insecticides that degrade very quickly may be applied over flowers when pollinators are not active, such as after dusk, immediately after bees stop foraging for the day. Check with local IPM experts for what applications are allowed for specific crops and pesticides, and how to schedule applications to minimize the exposure to bees.

  Keep in mind that most insecticides have a long residual toxicity and the residues left on the plants may kill later-visiting bees, especially smaller species. Careful timing of pesticide applications at night or outside of bloom also need to occur with crops that do not rely on pollinators, but whose flowers may be visited by bees and other pollinators collecting pollen (see fig. 2).
- Weather: Temperature and dew point—Temperature and dew also have a significant effect on the residual toxicity of most insecticides. In general, cooler temperatures result in much longer periods of toxicity, and dewy nights cause the insecticide to remain wet on the foliage and thus more available and toxic to bees the following morning.

Systemic insecticides

Systemic insecticides, such as the neonicotinoids and some carbamates and organophosphates (see table 1), pose a unique risk to bees. Plants treated with systemic insecticides through seed coatings, foliar sprays, trunk injections, or drenches can express the insecticide in their pollen and nectar, thus transferring these pesticides directly to bees.

Detailed information on the relationship between application rates and insecticide concentrations in pollen and nectar, and subsequent impacts on bees, is often lacking and the role of these products in bee deaths across the world is still being studied.

Many studies suggest that seed coated plants (e.g., sunflower, corn, or canola) result in less than lethal doses of insecticide in pollen and nectar (Hopwood et al. 2012 for review). However, newer research indicates that even these very low doses may have a negative impact (Whitehorn et al. 2012). Additionally, insecticide-laden dust from treated seeds is a threat during planting season. Extreme care should be taken during planting to prevent contaminated dust from drifting offsite. This dust should be treated as any other pesticide drift.

Approved agricultural application rates for foliar sprays or drenches are much higher than that approved for seed coatings (Stoner and Eitzer 2012, Dively et al. 2012), and resulting residue concentrations are at levels that have been demonstrated to negatively impact honey bees and bumble bees (Stoner and Eitzer 2012, Gill et al. 2012, Henry et al. 2012).

Beyond approved agricultural application rates treatments, several incidents have been reported on the lethality of pollen and nectar from trees treated with high doses of systemic insecticides as trunk injections or drenches (Hopwood et al. 2012). These applications were at rates approved for ornamental plants which are much higher than in food crops.

To reduce potential hazard to pollinators, work with IPM specialists to minimize applications prior to crop bloom of systemic insecticides known to be toxic to bees. Have clients talk with IPM specialists or extension about the smallest effective dose for treating a specific pest. Finally, discuss how to minimize contamination of weeds or cover crops growing under or adjacent to application areas.

Insect growth regulators (IGRs)

Some types of IGRs pose another unique risk to pollinators because they disrupt hormones in insects that control growth, molting, and fertility. Some products are specific only to hormones found in moths and butterflies (e.g., tebufenozide, methoxyfenozide, rynaxypyr, flubendiamide) and

have little or no effects on bees. Other IGRs that disrupt molting in all insects or cause sterility (e.g., diflubenzuron, fenoxycarb, azadirachtin, novaluron) can be as toxic as other insecticides to bees or beneficial insects at specific life stages. While generally considered safe to adult bees, a few IGRs are suspected of causing sterility in adults, and most can kill the larval or egg stages of pollinators if exposed. Therefore, to avoid poisoning bees, it is important to minimize contamination of flowers where bees may pick up IGRs and potentially bring them back to their nests. If a client wants to protect butterflies or other immature beneficial insects (e.g., hover fly larvae, lacewing larvae, lady beetle larvae), they should work with an IPM professional to develop a plan to apply the least toxic IGR in the most targeted manner.

Step 4b: NRCS conservation practices used to mitigate pesticide hazards to pollinators

NRCS planners can work directly with their clients to implement some of the following practices in order to reduce pesticide drift onto habitat adjacent to a crop field or to create pollinator habitat refuge areas that are protected from pesticides.

Create drift barriers (e.g., hedgerows and windbreaks)

Properly designed windbreaks and hedgerows can help contain or block drifting pesticides and contaminated dust. Tree and shrub layers provide a large surface area over which droplets or particles of pesticides may adhere, and the wind speed reduction at the application site reduces the movement of pesticides off their target. Details for designing pesticide-barrier windbreaks can be found in appendix B (excerpt from "Inside Agroforestry" (2012) volume 20, issue 1).

It is critical that such drift barriers are designed as barriers with little or no appeal to pollinators (fig. 6) and not as pollinator habitat (fig. 7). While NRCS encourages the creation of pollinator habitat hedgerows that provide pollen and nectar attractive to bees and other pollinators, **in the ca se of drift barriers, it is critically important to choose plants that are not attractive to bees or other beneficial insects.** Conveniently, the best plants for drift barriers are conifers that offer few or no resources for bees. For example, they could include paired rows of conifers, such as spruce, cypress, or juniper, separated by 12 to 20 feet and planted on 8- to 12-foot centers. See appendix B for details.

Since most drift originates from the edge of sprayed areas, when combined with an unsprayed in-field setback, properly designed windbreaks and other vegetative barriers can greatly reduce pesticide drift.

Reduce offsite movement of pesticides adhering to dust, soil, and sediment

Some pesticides may adhere to soil particles and be transported in eroded sediment. To determine if this is a potential hazard, check the WIN-PST Interaction Absorbed Runoff Potential (IARP) Hazard Rating. The Soil/Pesticide IARP is derived from the Soil Adsorbed Runoff Potential (SARP) and Pesticide Adsorbed Runoff Potential (PARP) output in WIN-PST.

If the IARP hazard rating is intermediate or above, then water erosion may move these products offsite into adjacent water sources used by honey bees, onto mud used by mason bees for nest construction, or onto areas of bare, undisturbed soil where ground-nesting bees may build their nests. If soil adsorption and transport of bee-toxic pesticides is possible, practices such as Residue and Tillage Management (e.g., CPS Codes 329 or 345) or CPS Code 328, Conservation Crop Rotation, should be installed that minimize the erosion and transport of pesticide-laden sediment.

In addition, clients could implement trapping or filtering practices, such as CPS Code 393, Filter Strip, to prevent pesticide contaminated sediments from moving offsite. However, care should be taken to prevent a situation where bees collect mud, construct ground nests, extract water, or otherwise come into contact with pesticide laden mud or sediment. Whenever possible, it is best to prevent sediment and pesticide residues from leaving the

Figure 6 Windbreaks designed to prevent pesticide drift site

pesticide application area rather than trying to trap contaminated soil at the edge of the field.

Pollinator refuges

NRCS planners can work with clients to create protected habitat areas away from where pesticides are sprayed or likely to drift. Ideally, such habitat is rich with flowers that bloom when the target crop does not, to attract bees and other pollinators away from the field.

A pollinator refuge should be located close enough to the field to attract crop pollinating bees, but far enough to allow for adequate pesticide protection. If honey bees or bumble bees are critical crop pollinators, such habitat could be located up to 1,000 feet away from field edges. If smaller bees (e.g., sweat or leafcutting bees) are important pollinators, the refuge habitat should be within the flight range of these insects (within approximately 250 feet of the fields). Note that closer is better, but it is critically important that such habitat is well protected from pesticide drift (fig. 8).

For help developing refuges for pollinators or other beneficial insects, visit http://www.xerces.org/pollinator-resource-center/, read NRCS TN 190-BIO-78, Using Farm Bill Programs for Pollinator Conservation, or see State and regional technical notes and job sheets developed by the NRCS and the Xerces Society Pollinator Conservation Program. The Conservation Stewardship Program and the Conservation Reserve Program both have enhancements specifically targeting pollinators.

Figure 7 Extreme care must be taken to prevent pesticide drift into pollinator habitat hedgerow and conservation cover such as this demonstration planting at the NRCS Plant Materials Center in Lockeford, CA

Pollinator habitat also may be contracted using CPS Codes 327, Conservation Cover, and 422, Hedgerow Planting, for example, through the Environmental Quality Incentives Program.

Supply clean source of water immediately adjacent to honey bee apiaries

Honey bees often use the damp edges of streams or shallow ponds to collect water to cool the hive or dilute honey. Those sources of water may be contaminated with pesticides in agricultural settings. Because honey bees collect water from the nearest source, clients and beekeepers should supply a clean source of water if other sources present a potential risk. To be used, the clean water source needs to be very close to an apiary and very shallow to allow bees to drink without falling in. Examples of possible watering devices include protected shallow stream or pond edges, dripping irrigation, or livestock watering valves (ideally dripping onto a board or into shallow pools upon which honey bees may safely land). If a client is interested, CPS Code 614, Watering Facility, could be adapted to create a water source for honey bees and a mud source for mason bees.

Figure 8 Aerial photo demonstrating placement of a pollinator refuge habitat protected from drift by adjacent forests, and windbreaks designed to prevent drift of pesticides either onsite or offsite

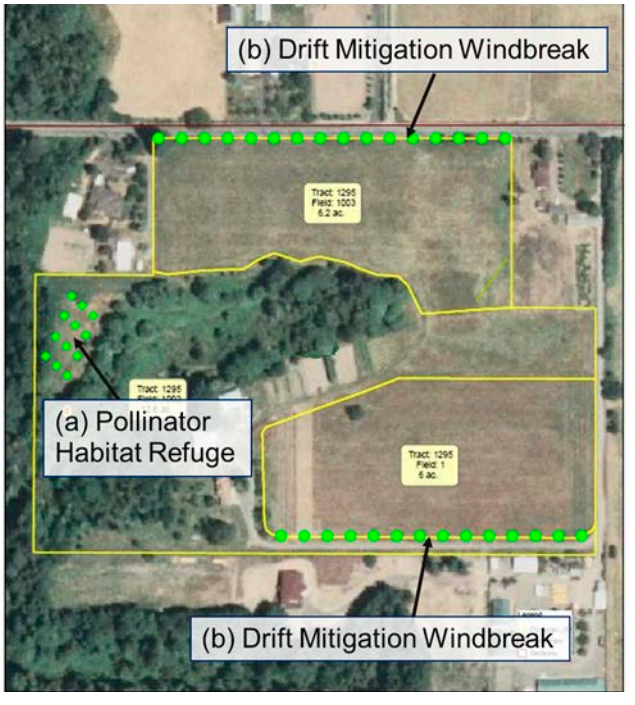


Table 2 Risk Mitigation Practices and Techniques for Pollinator Protection **Within Treatment Areas**. If a client, in collaboration with the NRCS or an IPM professional, identifies a pesticide risk to pollinators in a conservation plan, then the practices and techniques in the following table can be used to mitigate the potential impact that the product would have on pollinators within the treated areas. The blue shading indicates practices or techniques that are self-explanatory and can be selected, planned, and implemented by the client or NRCS employee. The grey shading indicates practices or techniques that require the expertise and guidance of an IPM professional in selection, planning, and implementation.

Risk Mitigation Practices and Techniques for Pollinator Protection Within Treatment Areas				
Mitigation Practices and Techniques	**Exposure Pathways Mitigated[2]**	**Treatment Requirements**	**Mitigation Index Value[3]**	**Comments**
CPS Code 327, Conservation Cover	a	Plant predominantly or exclusively grass species on field borders or in orchard and vineyard alleys so as to not attract pollinators during pesticide applications and for a period afterwards.	4	Care should be taken to ensure that the practice is not designed to attract pollinators when pesticides are being applied.
Application at Night: High to Moderate Toxicity and Long Residual Toxicity[4]	a, b	Apply pesticides when pollinators are least active, immediately after dark. **Required records**: record time of pesticide application and pollinator activity.	1	The effectiveness of this technique is based on the toxicity and residue half-life of the pesticide. This effectiveness score applies to the application of pesticides that are highly or moderately toxic to bees and have a residual toxicity greater than 8 hours.
Application at Night: High Toxicity and Short Residual Toxicity[5]	a, b	Apply pesticides when pollinators are least active, immediately after dark. Dewy nights may cause an insecticide to remain wet on the foliage and lengthen its toxic residual. **Required records**: record time of pesticide application and pollinator activity.	5	The effectiveness of this technique is based on the application of pesticides that are highly toxic to bees and have a residual toxicity of less than 8 hours and will be unavailable (and nontoxic) to bees if the product dries before dawn.
Application at Night: Moderately To Low Toxicity and Short Residual Toxicity	a, b	Apply pesticides when pollinators are least active, immediately after dark. Note that dewy nights may cause an insecticide to remain wet on the foliage and lengthen its toxic residual. **Required records**: record time of pesticide application and pollinator activity.	8	The effectiveness of this technique is based on the application of pesticides that are moderately toxic to bees and have a relatively short residue half-life and will be unavailable (and nontoxic) to bees if the product dries before dawn.
Application of Nonsystemic Insecticide When **Perennial** Crop is **Not** in Bloom	a, b	Apply pesticides when crops are not in bloom to reduce potential exposure of bees and other pollinators visiting the crop flowers. **Required records**: record time of pesticide application, crop stage, and pollinator activity.	4	The effectiveness of this technique is based on the application of nonsystemic pesticides to perennial crops, where understory weed pressure is typically higher.
Application of Nonsystemic Insecticide When **Annual** Crop is **Not** in Bloom	a, b	Apply pesticides when crops are not in bloom to reduce potential exposure of bees and other pollinators visiting the crop flowers. **Required records**: record time of pesticide application, crop stage, and pollinator activity.	8	The effectiveness of this technique is based on the application of nonsystemic pesticides to annual crops with few or no weeds.

Risk Mitigation Practices and Techniques for Pollinator Protection Within Treatment Areas				
Mitigation Practices and Techniques	**Exposure Pathways Mitigated[2]**	**Treatment Requirements**	**Mitigation Index Value[3]**	**Comments**
Application of Highly Toxic Systemic Insecticide After Perennial Crop Bloom	c	Do not apply systemic insecticides before or during crop bloom. **Required records**: record time of pesticide application, application rate, crop stage, and pollinator activity.	7	Systemic insecticides applied before crop bloom can contaminate pollen and nectar gathered by pollinators. In perennial orchards, berries, and vineyards, there also may be carryover from previous years' applications. The effectiveness of this technique is based on the application of systemic pesticides that are highly toxic to bees and have a relatively long residue half-life. IPM professional should confirm the efficacy of this technique.
Application of Moderately Toxic Systemic Insecticide After Perennial Crop Bloom	c	Do not apply systemic insecticides before or during crop bloom. **Required records**: record time of pesticide application, application rate, crop stage, and pollinator activity.	5	Systemic insecticides applied before crop bloom can contaminate pollen and nectar gathered by pollinators. Technique effectiveness is based on the application of systemic pesticides that are moderately toxic to bees and have a relatively short residue half-life. IPM professional should confirm the efficacy of this technique.
Application of Highly Toxic Systemic Insecticide with Relatively Long Soil Half-Life After Annual Crop Bloom[6]	c	Do not apply systemic insecticides before or during crop bloom. **Required records**: record time of pesticide application, application rate, crop stage, and pollinator activity.	8	Systemic insecticides applied before crop bloom can contaminate pollen and nectar gathered by pollinators. Technique effectiveness is based on the application of highly-toxic, long-lived systemic pesticides on flowering annual crops. IPM professional should confirm the efficacy of this technique.
Application of Moderately Toxic Systemic Insecticide with Relatively Short Soil Half-Life After Annual Crop Bloom	c	Do not apply systemic insecticides before or during crop bloom. **Required records**: record time of pesticide application, application rate, crop stage, and pollinator activity.	7	Systemic insecticides applied before crop bloom can contaminate pollen and nectar gathered by pollinators. Technique effectiveness is based on the application of systemic pesticides that are moderately toxic to bees and have a relatively short residue half-life. IPM professional should confirm the efficacy of this technique.
In-field Bloom Removal Prior to Application of Nonsystemic Moderately to Highly Toxic Insecticide in Perennial Crop	a, b	Mow weeds or cover crops in a field, vineyard, or orchard to prevent flowering and reduce attraction to bees when pesticides are applied. **Required records**: time of pesticide application, crop stage, field conditions (i.e., weed species and bloom status), and pollinator activity.	5	The effectiveness of this technique is based on the application of nonsystemic pesticides that are highly or moderately toxic to bees and have a relatively short residue half-life.

Risk Mitigation Practices and Techniques for Pollinator Protection Within Treatment Areas

Mitigation Practices and Techniques	Exposure Pathways Mitigated[2]	Treatment Requirements	Mitigation Index Value[3]	Comments
In-field Bloom Removal Prior to Application of Highly Toxic Systemic Insecticides	a, b, c	Prevent pollinator-visited weeds or cover crops from flowering if they come in contact with systemic insecticides. **Required records**: management plan (e.g. documentation of mowing or herbicide treatment) to prevent or remove bloom of weeds or other plants contaminated by systemic insecticides.	3	Contamination of weeds or other bee-visited plants within or adjacent to crop fields can contaminate pollen and nectar gathered by pollinators. There also may be carryover from previous years' applications. The effectiveness of this technique is based on the use of systemic pesticides that are highly toxic to bees and have a relatively long residue half-life.
In-field Bloom Removal Prior to Application of Moderately Toxic Systemic Insecticides	a, b, c	Prevent pollinator-visited weeds or cover crops from flowering if they come in contact with systemic insecticides. **Required records**: management plan (e.g., documentation of mowing or herbicide treatment) to prevent or remove bloom of weeds or other plants contaminated by systemic insecticides.	5	Contamination of weeds or other bee-visited plants within or adjacent to crop fields can taint pollen and nectar gathered by pollinators. The effectiveness of this technique is based on the use of systemic pesticides that are moderately toxic to bees and that have a relatively short residue half-life.
Electrostatic or Image-Responsive Sprayer Technology	a,d,e,h	Use electrostatic or image-responsive sprayers to deliver pesticide application to the target. **Required records**: original application equipment, new electrostatic or image-responsive application equipment.	5	Typical applications using this method achieve the same control with less active ingredient per acre, thus reducing risk significantly for pesticides that are moderately toxic or highly toxic with a relatively short residue half-life.
Formulation Substitution for Nonsystemic Insecticide (e.g., dust or liquid to granular)	g	Use liquid or granular bait formulations instead of dusts and fine powders that may become trapped in the pollen collecting hairs of bees and consequently fed to developing larvae. This method does not address risks posed by systemic insecticides that may contaminate pollen and nectar. **Required records**: original formulation, new formulation, and dates of application.	7	This technique will reduce the risk associated with the pesticide formulation that was traditionally applied, but any associated risk with the newly substituted pesticide should be adequately mitigated. This only applies to active ingredients available in multiple formulations. Note, alternative pesticide formulations must be approved by IPM professional and must be client-selected as NRCS employees do not make pesticide recommendations.
Product Substitution: Nonchemical	ALL	Replace the application of a pesticide that poses a significant risk to pollinator populations with an alternative cultural or mechanical pest suppression technique that poses no risk to pollinator populations. **Required records**: IPM professional or extension literature supporting the decision to substitute pesticide with nonchemical control.	10	This technique will prevent the risk associated with the pesticide and does not introduce any new pesticide risks.

Risk Mitigation Practices and Techniques for Pollinator Protection Within Treatment Areas				
Mitigation Practices and Techniques	**Exposure Pathways Mitigated[2]**	**Treatment Requirements**	**Mitigation Index Value[3]**	**Comments**
Product Substitution: Alternate Product	ALL	Replace the application of a pesticide that poses a significant risk to pollinator populations with an alternate product that poses less risk (Note: any new risk must be mitigated as well). Use of semiochemicals or kaolin clay barriers is included in this technique. **Required records**: IPM professional or extension literature supporting the decision to substitute pesticide with alternative pesticide.	10	This technique will prevent the risk associated with the pesticide formulation that was traditionally applied, but any associated risk with the newly substituted pesticide should be adequately mitigated. Note, alternative pesticides must be approved by IPM professional and must be client-selected as **NRCS employees do not make pesticide recommendations.**
Monitoring and Economic Pest Thresholds: Moderately to Highly Toxic Pesticide With Long Residual Toxicity	a, b	Monitor pest levels to determine when a pest population exceeds a previously determined economic threshold to reduce the total amount of pesticide applied, and only treat the areas exceeding this threshold. **Required records**: established economic threshold values, monitoring data, areas receiving treatment, and dates of application.	3	This is important in protecting foraging pollinator populations in the field from exposure to unnecessary pesticide applications. Sometimes, applications using this method achieve the same control with less active ingredient per acre, thus reducing risk significantly for pesticides that are moderately toxic or highly toxic with a relatively long residue half-life when pollinators are present
Monitoring and Economic Pest Thresholds: Low to Moderately Toxic Pesticide With Short Residual Toxicity	a, b	Monitor pest levels to determine when a pest population exceeds a previously determined economic threshold to reduce the total amount of pesticide applied, and only treat the areas exceeding this threshold. **Required records**: established economic threshold values, monitoring data, areas receiving treatment, and dates of application.	6	This is important in protecting foraging pollinator populations in the field from exposure to unnecessary pesticide applications. Sometimes, applications using this method achieve the same control with less active ingredient per acre, thus reducing risk significantly for pesticides that are moderately toxic with a relatively short residue half-life when pollinators are present.

2. See Table 1. Potential Exposure Pathways to Mitigate (pages 6-7) for detailed information on each exposure pathway.
3. IPM techniques or NRCS conservation practices with an index value of 1 to 4, by themselves, generally have a low potential to reduce negative impacts to pollinators. Techniques or practices with a mitigation index value of 5 to 7 generally have a significant potential to reduce impacts to pollinators. Techniques and practices having an index value of 8 to 10 are highly effective at reducing impacts to pollinators. Specifically, a value of 10 indicates that the selected technique or practice will eliminate the potential hazard or risk to an identified pollinator of concern through the noted exposure pathway. IPM specialists can fine-tune efficacy scores for specific situations if appropriate.
4. Long residual toxicity is defined as a residual toxicity where 25 percent of bees die upon contact (RT25) 8 hours or longer after application.
5. Short residual toxicity is defined as an RT25 of less than 8 hours.
6. Data is still lacking on residual carrover and buildup from one year to the next.

Table 3 Risk Mitigation Practices and Techniques for Pollinator Protection **Outside of Treated Areas**. If a client, in collaboration with the NRCS and an IPM professional, identifies a pesticide risk to pollinators in a conservation plan, then the techniques and practices listed below can help mitigate the potential impact that product has on pollinator populations outside of the treated area (e.g., from offsite drift). Several of the entries in this table come directly from TN 190-AGR-5, and many of those have the same mitigation index value reported in that document. Other entries from TN 190-AGR-5 differ in mitigation index value due to pollinator-specific design considerations described below. The practices and techniques selected should be incorporated into a farm IPM plan. The blue shading indicates practices that can be selected, planned, and implemented by the client or NRCS employee. The grey shading indicates techniques that require the expertise and guidance of an IPM professional in selecting, planning, and implementing.

Risk Mitigation Practices and Techniques for Offsite Pollinator Protection				
Mitigation Practices and Techniques	**Exposure Pathways Mitigated[7]**	**Treatment Requirements**	**Mitigation Index Value[8]**	**Comments**
Field Border (386)	a, b, c, d, e, f, g, h	Place field border between crop field and sensitive habitat. Field border used for drift mitigation should be at least 20' wide. It should not be planted with pollinator plants or the forbs and shrubs included should not be flowering when bee-toxic pesticides bees are applied to the adjacent crop.	5[9]	If primary purpose of this practice is to serve as a pesticide buffer, care should be taken to ensure that the practice is not designed to attract pollinators when pesticides are being applied.
Filter Strip (393)	a, b, c, d, e, f, g, h	Place filter strip between crop field and sensitive habitat. Filter strip should be at least 30 feet wide, and maintained predominantly as a grass stand. Weeds should be controlled prior to blooming.	10[9]	If primary purpose of this practice is to serve as a pesticide buffer, care should be taken to ensure that the practice is not designed to attract pollinators when pesticides are being applied.
Hedgerow Planting (442)	a, b, c, d, e, f,	In a hedgerow designed to reduce pesticide drift, plants should not be flowering when bee-toxic pesticides are applied to the adjacent crop field. Systemic pesticides should not be used adjacent to pollinator hedgerows because of potential contamination of pollen and nectar.	10[9]	If primary purpose of this practice is to serve as a pesticide buffer, ensure that the practice is not designed to attract pollinators when pesticides are being applied. If primary purpose of this practice is to serve as a drift barrier, see appendix B for further guidance.
Windbreak/Shelterbelt Establishment (380)	a, b, c, d, e, f, g	Planned trees and shrubs should not be flowering when chemicals that are toxic to bees are applied to the adjacent crop field. See appendix B for further guidance.	10[9]	If primary purpose of this practice is to serve as a pesticide buffer, ensure that the practice is not designed to attract pollinators when pesticides are being applied. If primary purpose of this practice is to serve as a drift barrier, see appendix B for further guidance.
Application Timing: Optimal Wind Speed	a, d, e, f, h	Apply pesticides only when wind speed is optimal to reduce pesticide drift. Optimal spray conditions for reducing drift occur when the air is slightly unstable with a very mild steady wind between 2 and 9 mph. **Required records**: date and time of the pesticide application, and wind speed and direction	10	Many labels explicitly require that the pesticide applicator monitor wind speed to either minimize or eliminate drift. This technique is most effective when wind direction during application events is away from pollinator habitat.

Risk Mitigation Practices and Techniques for Offsite Pollinator Protection				
Mitigation Practices and Techniques	**Exposure Pathways Mitigated[7]**	**Treatment Requirements**	**Mitigation Index Value[8]**	**Comments**
Adjuvants: Drift Reduction	a, d, e, h	Use specific drift-retardant adjuvants to reduce pesticide spray drift. **Required records**: name and purpose of adjuvants added to tank mix and how they reduced pesticide drift.	5	
Spray Nozzle Selection, Maintenance and Operation to Reduce Drift	a, d, e, h	Select appropriate nozzles and operating pressure for the application, with an emphasis on higher volume spray nozzles run at lower pressures where possible. Maintain proper nozzle spacing, boom height, and boom suspension, along with frequent calibration and replacement of worn nozzles and leaking tubing. **Required records**: a maintenance log detailing calibration, nozzle selection (original nozzle type and operational pressure and newly installed nozzle type and operational pressure), equipment setup, and application date and time.	10	Higher volume spray nozzles run at lower pressures produce larger droplets and a narrower droplet size distribution, which reduces spray drift.
Electrostatic or Image-Responsive Sprayer Technology	a, d, e, h	Use electrostatic or image-responsive sprayers to deliver pesticide application to the target. **Required records**: original application equipment, new electro-static or image-responsive application equipment.	10	This technology can significantly reduce drift onto offsite pollinator populations and habitat. Typical applications using this method achieve the same control with less active ingredient per acre and can reduce risk significantly for moderately toxic or highly toxic pesticides with a relatively short residue half-life.
Spray Curtain or Hooded Sprayer	a, d, e, h	Use spray curtains or hooded sprayers to help contain pesticide. **Required records**: original application equipment, new spray curtain or hooded sprayer equipment.	10	This technology can significantly reduce drift onto offsite pollinator populations and habitat. Typical applications using this method achieve the same control with less active ingredient per acre and can reduce risk significantly for moderately toxic or highly toxic pesticides with a relatively short residue half-life
Formulation Substitution for Nonsystemic Insecticide: Dust or Liquid to Granular	g	Use granular bait formulations instead of dusts and fine powders that may become trapped in the pollen collecting hairs of bees and subsequently fed to developing larvae. This method does not address risks posed by systemic insecticides that may contaminate pollen and/or nectar. **Required records**: original formulation, new formulation, and dates of application.	15	This technique will reduce the risk associated with the pesticide formulation that was traditionally applied, but any associated risk with the newly substituted pesticide should be adequately mitigated. Note: alternative pesticide formulations must be approved by IPM professional and must be client-selected as NRCS employees do not make pesticide recommendations.

Risk Mitigation Practices and Techniques for Offsite Pollinator Protection				
Mitigation Practices and Techniques	**Exposure Pathways Mitigated[7]**	**Treatment Requirements**	**Mitigation Index Value[8]**	**Comments**
Monitoring and Economic Pest Thresholds: Pesticide With Long Residual Toxicity	a, b	Monitor pest levels to determine when a pest population exceeds a previously determined economic threshold to reduce the total amount of pesticide applied, and only treat the areas exceeding this threshold. **Required records**: established economic threshold values, monitoring data, areas receiving treatment, and dates of application.	5	This practice helps protect foraging pollinators from exposure to unnecessary pesticide applications. Ideally, pest management using this method achieves the same control with less active ingredient per acre. This efficacy score is based on the use of pesticides that are highly or moderately toxic with a relatively long residue half-life, applied when pollinators are present.
Monitoring and Economic Pest Thresholds: Pesticide With Short Residual Toxicity	a, b	Monitor pest levels to determine when a pest population exceeds a previously determined economic threshold to reduce the total amount of pesticide applied, and only treat the areas exceeding this threshold. **Required records**: established economic threshold values, monitoring data, areas receiving treatment, and dates of application.	10	This practice helps protect foraging pollinators from exposure to unnecessary pesticide applications. Ideally, pest management using this method achieves the same control with less active ingredient per acre. This efficacy score is based on the use of pesticides that are moderately toxic with a relatively short residue half-life, applied when pollinators are present.
Product Substitution: Nonchemical	All	Substitute the application of a pesticide that poses a significant risk to pollinators with an alternative cultural or mechanical pest suppression technique that is not harmful. **Required records**: IPM professional or extension literature supporting the decision to substitute pesticide with nonchemical control.	20	This eliminates the risk associated with the pesticide and does not introduce any new pesticide risks.
Product Substitution: Alternative Product	All	Substitute the application of a pesticide that poses a significant risk to pollinators with an alternative product that poses less risk. Any new risk must be mitigated as well. Use of semiochemicals or kaolin clay barriers is included in this technique. Note: alternative pesticides must be approved by IPM professional and must be client-selected as NRCS employees do not make pesticide recommendations. **Required records**: IPM professional or extension literature supporting the decision to substitute pesticide with alternative product.	20[10]	This technique will prevent the risk associated with the pesticide formulation that was traditionally applied, but any associated risk with the newly substituted product or pesticide should be adequately mitigated.
Setback (30')	a, b, d, e, h	A 30-foot setback from the edge of the field into the crop will be used. No application of chemicals within 30 feet of the downslope or downwind edges of the field. **Required records**: map showing location of setback.	10	This is important in protecting offsite pollinator populations and habitat by providing a pesticide free buffer within the crop, along the crop edge. Most offsite drift emanates from crop edges.

Risk Mitigation Practices and Techniques for Offsite Pollinator Protection				
Mitigation Practices and Techniques	**Exposure Pathways Mitigated[7]**	**Treatment Requirements**	**Mitigation Index Value[8]**	**Comments**
Setback (100')	a, b, d, e, f, g, h	A 100-foot setback from the edge of the field into the crop will be used. No application of chemicals within 100 feet of the downslope or downwind edges of the field. Required records: map showing location of setback.	15	This is important in protecting offsite pollinator populations and habitat by providing a pesticide free buffer within the crop, along the crop edge. Most offsite drift emanates from crop edges.

7. See Table 1, Potential Exposure Pathways to Mitigate, (pages 6-7) for detailed information on each exposure pathway.
8. For drift mitigation (i.e., reducing offsite risk to pollinators), IPM techniques or NRCS conservation practices with an index value of 5 generally have the potential to reduce losses by 10 to 5 percent. IPM techniques or NRCS conservation practices having an index value of 10 generally have the potential to reduce losses by about 25 percent, and IPM techniques or NRCS conservation practices having an index value 15 generally have the potential to reduce losses by 50 percent or more. This is the same scale and rating process employed in TN 190-AGR-5 for drift losses.
9. True effectiveness of these practices is affected greatly by design height, width and porosity and can be significantly higher or lower than reported here for the generic conditions stated.
10. Complete product substitution will prevent the hazard associated with the original product and thus entirely satisfies the minimum mitigation criteria established in TN 190-AGR-5 associated with that product.

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Resources

Xerces Society Pollinator Conservation Resource Center (http://www.xerces.org/pollinator-resource-center/). Choose a region of the United States and Canada. Click on the Pesticide Guides for regional information (if available) on protecting bees from pesticide use.

Xerces Society. 2012. Organic Approved Pesticides: Minimizing Risks to Pollinators (http://www.xerces.org/wp-content/uploads/2009/12/xerces-organic-approved-pesticides-factsheet.pdf).

Xerces Society. 2012. Native Bee Conservation: Pollinator Habitat Assessment Form and Guide. http://www.xerces.org/wp-content/uploads/2009/11/PollinatorHabitatAssessment.pdf.

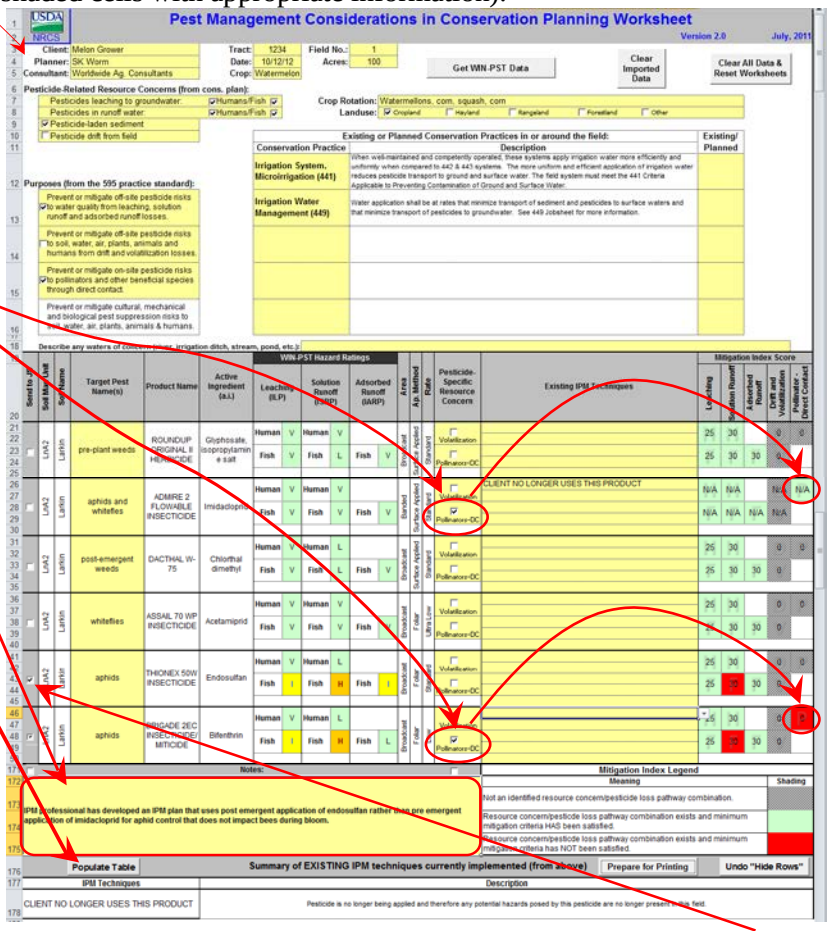
Pesticide Environmental Stewardship Web site (supported by the Center for Integrated Pest Management) http://pesticidestewardship.org/PollinatorProtection.

Pollinator Protection at Environmental Protection Agency (http://www.epa.gov/opp00001/ecosystem/pollinator/index.html).

APPENDIX A – GUIDANCE FOR USING THE 595 PEST MANAGEMENT CONSERVATION PLANNING WORKSHEET

Here you will find guidance for using a generalized version of the 595 Pest Management Conservation Planning Worksheet used to track the pollinator risk mitigation points associated with each adopted technique and/or practice. See your State eFOTG for a State-specific version of this Excel® worksheet or similar document. For example, contact NTSC agronomist for current version or see efotg.sc.egov.usda.gov/references/public/WA/595_js_0512.xlsm (WA) or efotg.sc.egov.usda.gov/references/public/AK/AK_595_IPM_Jobsheet_Dec2011.xlsm (AK).

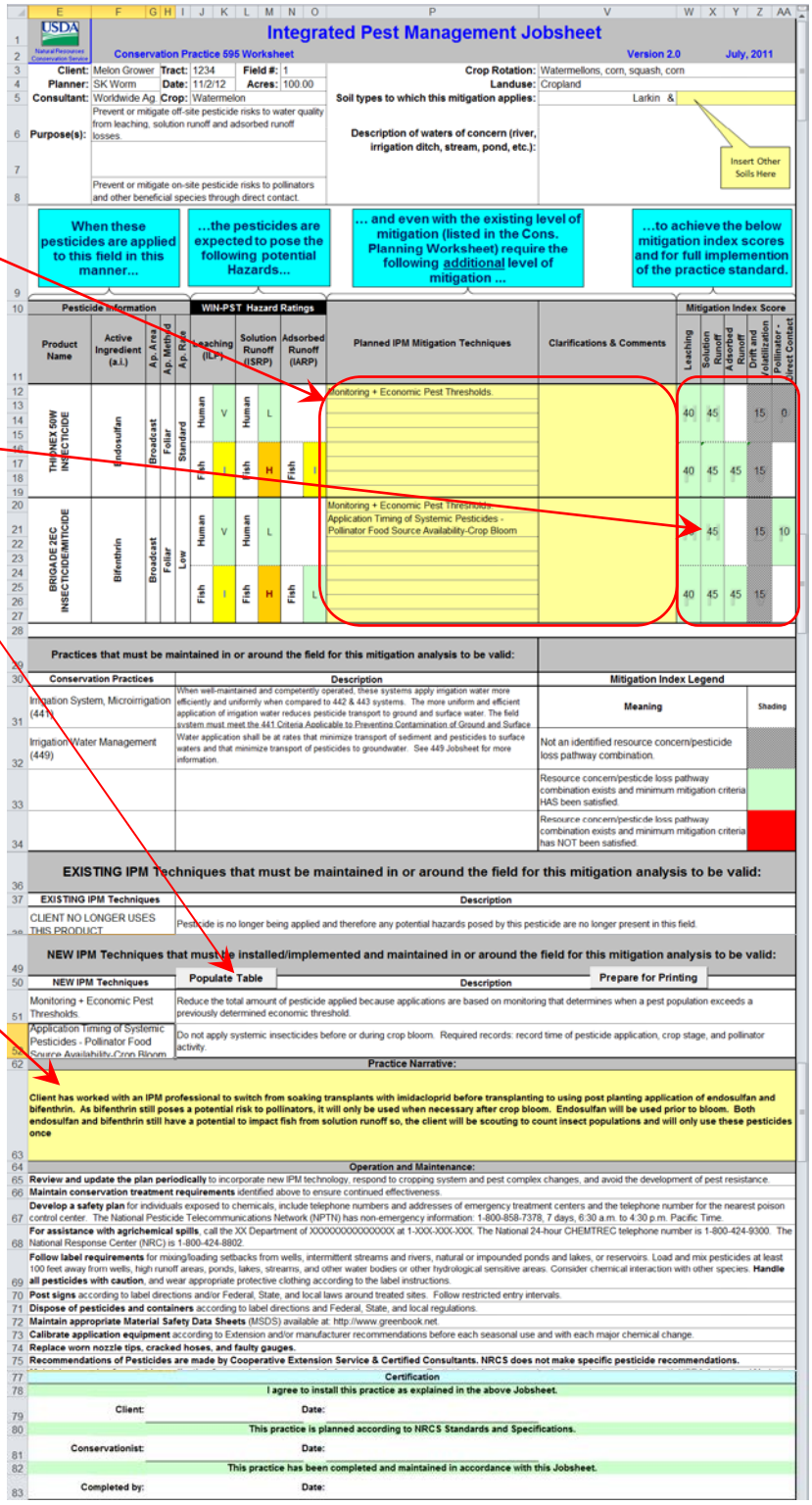
1. Enter all the general information about the field in the upper portion of the Conservation Planning Worksheet (i.e., fill in all yellow shaded cells with appropriate information).
2. To identify that a pesticide has a potential to impact pollinators visiting the field in question, check the *pollinator-DC* box in the table next to the pesticide in question. This will activate the appropriate mitigation tracking box.
3. Add additional information that can explain IPM prevention techniques adopted by the client as part of their current LGU-IPM plan in the "Notes" section.
4. Click "Populate Table" to summarize EXISTING IPM TECHNIQUES selected above and their accompanying descriptions.
5. Click "Prepare for Printing" to hide all empty rows in the Mitigation Tables and then save and/or print. If all mitigation index scores are green or shaded grey, you are done!



6. If there are not enough points to mitigate the potential hazards for some pesticides, select the check boxes of the pesticides still needing mitigation (they will have at least one Mitigation Index Score cell shaded in red) and proceed to the "595 JS-Multiple pesticides" worksheet.

> **Note**: The spreadsheet automatically matches the Hazard Ratings and the current level of mitigation with the value required by the Agronomy Tech Note 5 and the 595 Standard (e.g., 20 points for Intermediate hazard, 40 points for High hazard, etc.). If you have enough points to mitigate all the appropriate pathways, the appropriate Mitigation Index Score cells turn green indicating that the minimum criteria for the listed purposes of the 595 have been met. The "Conservation Planning Worksheet" worksheet can be used to document this condition.

7. After discussions with the client, pest management specialist (e.g., CCA or PCA) and pollinator specialist, populate the "Planned IPM Mitigation Techniques" and "Clarifications & Comments" columns of the job sheet until the required level of mitigation has been achieved (i.e., all the unshaded Mitigation Index Score cells will be shaded in green).
8. Click "Populate Table" to summarize NEW IPM TECHNIQUES selected above and their accompanying descriptions.
9. Enter a descriptive summary of what the producer will be required to perform as a fulfillment of this practice installation. Be sure to include any details that are not covered by the tables above. This is where the specificity of the pollinator protection actions is described for the client.
10. Click "Prepare for Printing" to hide all empty rows in the job sheet and then save and/or print.
11. Once you have printed the job sheet, acquire the appropriate signatures to indicate that client will implement the itemized techniques and file accordingly.



APPENDIX B – WINDBREAK DESIGN FOR PESTICIDE DRIFT REDUCTION

Excerpted and adapted from Adamson N, Ward T, and Vaughan M. 2012. Designed with pollinators in mind. *Inside Agroforestry*. Volume 20, Issue 1. pp: 8-10.
http://nac.unl.edu/documents/insideagroforestry/vol20issue1.pdf (a special issue on windbreaks).

PESTICIDE DRIFT PREVENTION

Windbreaks designed primarily to prevent pesticide drift may include trees and shrubs that are known to be exceptionally effective at capturing spray drift and, at the same time, provide little or no forage for bees and other pollinators. In this way, the maximum amount of spray drift is captured and bee losses are minimized. Research has shown that, because of their three-dimensional porosity, vegetative windbreaks are more effective in controlling drift than artificial windbreaks made of wood, cloth, or other materials. Overly dense windbreaks (greater than 60 percent), may lead to wall effects forcing wind up and creating eddies on their leeward side that could bring drifting material back down to the surface (an effect known as "downwash").

The best pesticide drift protection comes from multiple rows of vegetation that include small-needled evergreens. Small-needled evergreens are two to four times as effective as broadleaf plants in capturing spray droplets and provide year-round protection. The optimum for capturing spray drift is 40 to 50 percent porosity in several rows. Two rows of evergreens can provide 60 percent density (40 percent porosity). Spruce (*Picea* spp.), juniper (*Juniperus* spp.), fir (*Abies* spp.), and arborvitae (*Thuja* spp.) are recommended above pines (*Pinus* spp.) since pines are generally less dense and they tend to loose lower branches with age. In coastal plain areas, lowland species like wax myrtle (*Morella* spp.) and white cedar (*Chamaecyparis* spp.) may be more appropriate. While multiple rows of low porosity vegetation are better than a single row of dense vegetation, even a single row can substantially reduce drift.

Shape, structure, and width affect droplet capture effectiveness. Species with no low vegetation (branches or foliage) should be avoided or supplemented with low-growing species. Wind velocity reduction is proportional to windbreak height and density. While some crops benefit by being sheltered from wind, maturing more quickly, others may not thrive with less light, so structural design needs to balance wind reduction goals with consideration of shade effects.

Windbreak design will depend on site conditions and available land. Generally, windbreaks are aligned to intercept prevailing winds (commonly from the west) with one to five rows, starting with a shrub row and including an evergreen row. For pesticide drift prevention, they may also need to be placed on the leeward side of crop fields to prevent movement of chemicals offsite.

Spacing between rows should be 12 to 20 feet, guided by the mature width of plants and maintenance practices (4 feet wider than equipment used between rows). Where possible, spacing should be closest on the windward (shrub row) and leeward (evergreen row) sides, and farthest between the innermost rows (deciduous or evergreen trees). Designs with a mixture of shrubs, trees, and perennials, or fewer rows can be planted a little more densely. In drift prevention windbreaks, avoid nectar-producing perennials that might attract pollinators. If grasses are used, planting density should be very low to prevent competition with shrub and tree growth (until the shrubs and trees mature). Ideally, spacing within rows will be based on the average mature width of shrubs and trees, so they grow quickly and to their full extent (crowding

slows growth). Minimum height at maturity should be 1.5 times the spray release height (2 times the spray height if porosity is expected to be less than 40 percent).

Buffer zones—unsprayed areas around the edge of the crop field—are a complementary drift management technique. To protect pollinators, buffer zones can be mowed just prior to spray time if pollen or nectar producing plants are flowering within them.

While windbreaks for pollinators are designed to intercept pesticides, potential susceptibility of plants to herbicide drift should be considered where herbicides are regularly used. Windbreaks make up only one component of best management practices to minimize agrochemical drift. Timing (avoiding active times of pollinators and choosing times with lower wind velocities), nozzle adjustments (smaller droplets travel farther and are less easily captured by vegetation), and other spray systems and techniques can reduce potential drift impacts on pollinators and their habitats.

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