REPORT ON THE REVIEW OF AERIAL APPLICATION OF HERBICIDES FOR FOREST MANAGEMENT

PREPARED BY

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I. Introduction

In 2021, the Maine Legislature passed LD 125, An Act to Prohibit Aerial Spraying of Glyphosate and Other Synthetic Herbicides for the Purpose of Silviculture. This bill was subsequently vetoed, and Executive Order 41 FY 20/21 (EO) was issued. The EO directs the Board of Pesticides Control (BPC), in consultation with the Maine Forest Service (MFS) and other stakeholders and interested parties, to review and amend rules related to the aerial application of glyphosate and other synthetic herbicides for the purpose of silviculture, including reforestation, forest regeneration, or vegetation control in forestry operations. The major provisions for completing these directives include:

A. A review of the existing best management practices (BMPs) for aerial application of herbicides including:
  a. A review of the findings and recommendations of the independent assessment on aerial applications conducted in 2020.
  b. A review of the current international scientific literature regarding the aerial application of herbicides for forestry purposes, taking into account the species addressed in other states and countries.
  c. A review of Integrated Pest Management (IPM) guidelines as they apply to aerial application of herbicides for forestry purposes to assess the relative effectiveness and costs of other treatment methods.

B. Development of a surface water quality monitoring effort to focus on aerial application of herbicides in forestry to be conducted in 2022.

C. A review undertaken by the Department of Inland Fisheries and Wildlife to assess wildlife habitat impacts related to sites treated by aerial application of herbicides.

D. A review of the existing regulatory framework for aerial application of herbicides in forestry operations, to include:
  a. A proposal to amend the rules to expand the buffers and setbacks to further protect rivers, lakes, streams, ponds, brooks, wetlands, wildlife and human habitats, and other natural resources.
  b. A proposal to amend rules to expand the buffer for areas next to Sensitive Areas Likely to be Occupied (SALO) and other sensitive areas to include farming operations.

E. A series of public meetings to share and obtain public input on the results of the review before finalizing.

The full text of the Executive Order is provided in Addendum E.

A. Resource Considerations

Although the tasks laid out in the EO were ambitious, BPC staff made every effort to complete them in-house in the timeline directed in the EO. However, there are two areas where BPC staff determined they do not have specific expertise. These areas of expertise include: 1) current international scientific literature regarding the aerial application of herbicides for forestry purposes, considering the species addressed in other states and countries, and 2) IPM guidelines as they apply to aerial application of herbicides for forestry purposes to assess the relative effectiveness and costs of other treatment methods. There are entities within the State of Maine with this expertise, however, consultation services from these entities were not available during the timeline within which the work needed to be completed. BPC staff were fortunate to secure the services of a regional consultant, Dr. Harold Thistle, able to provide a data-driven response to parts 1A and D of the EO. A brief biography of Dr. Thistle, as well as a listing of the document contributors, is presented in Addendum F. BPC conducted the work outlined in the EO with existing financial resources. The Governor was also amenable to extending the report back deadline to February 18, 2022, to enable an adequate amount of time for stakeholder review and comment, both written and as contributed through a stakeholder outreach session, and to avoid having this review period overlap with the end of year holidays to ensure maximum public participation.

B. Associated Costs

The consultant work and completed water quality monitoring work required funding. BPC staff were able to leverage $30,000 in existing dedicated funding to cover the consultant work and $14,383 in federal funding to cover the preliminary water quality monitoring work.

Additional funding totaling $84,080 will need to be secured to cover the costs of the water quality monitoring work proposed for completion in 2022.

C. Summary of Efforts Completed

This report is a compilation of research and review work conducted by multiple entities—including Board of Pesticides Control (BPC) staff, contractors Drs. Harold Thistle and Jane Bonds, Maine Inland Fish and Wildlife staff, a nationwide survey prepared by BPC staff and distributed by the American Association of Pesticide Control Officials, and SCS Global Services. BPC staff worked with the listed collaborators to address the major provisions of the EO as follows:

Provisions I A and I D of the EO—A review of the existing best management practices for aerial application of herbicides.

Following discussion with collaborators at the Maine Forest Service (MFS), it was determined that provision IA of the EO would be best addressed by experts outside of the Department of Agriculture, Conservation and Forestry (DACF). The University of Maine School of Forestry and the Cooperative Forestry Research Unit were contacted and while both entities were interested in the subject matter, neither was able to accommodate the additional work on such a short timeline. However, DACF staff contacted the regional office of the U.S. Forest Service, and recently retired U.S. Forest Service employee, Dr. Harold Thistle was recommended.

Dr. Thistle's services were contracted to address all parts of IA and ID of the EO. His expertise in the construction, limitations, and application of the AgDISP model (modeling software for estimating drift from the aerial application) proved to be particularly beneficial to the successful development of the evidence-based reports provided in section II.

Dr. Thistle further secured the services of Dr. Jane Bonds to aid in the completion of a review of the international scientific literature regarding the aerial application of herbicides for forestry. This review considered the species addressed as well as the relative effectiveness and costs of other management methods. Brief biographies of Drs. Thistle and Bonds are provided in Addendum F.

Provision I B of the EO—Development of a surface water quality monitoring effort to focus on aerial application of herbicides in forestry to be conducted in 2022

In 2021, BPC staff used existing resources and federal funding to conduct a water quality scoping study of aerially applied herbicides in forestry. This study was used to inform a more comprehensive water quality monitoring project proposed for completion in 2022. The details of the completed scoping study and the proposed monitoring project are included in addendum D and section III of this report, respectively.

Provision I C of the EO—A review undertaken by the Department of Inland Fisheries and Wildlife (DIFW)to assess wildlife habitat impacts related to sites treated by aerial application of herbicides

BPC and MFS staff met with DIFW staff to discuss the scope of provision I C and reasonable reporting expectations are given available monetary and staffing resources and the timeline for completion. The DIFW literature review is included in section IV of this report.

Work conducted by DIFW and the DACF Maine Natural Areas Program (MNAP) frequently overlaps and results in a collaboration between these two programs. BPC staff met separately with MNAP to discuss a possible role for this program in the project.

Provision I D of the EO—A review of the existing regulatory framework for aerial application of herbicides in forest operations

Dr. Thistle reviewed existing Maine regulations and best management practices as well as national regulations relevant to aerial application of herbicides in forest operations. This review is discussed in section II A of this report.

BPC staff also conducted a nationwide survey of relevant regulations. This survey was distributed by the American Association of Pesticide Control Officials to state pesticide regulators. A summary of the results of this effort are included in section V of this report.

Additionally, BPC staff have compiled a narrative summary of regulations relevant to aerial application of herbicides. These as well as the BPC's best management practices for aerial application are included as addendums A and C, respectively, in this report.

Further, regulations relevant to aerial application of herbicides in Maine were compiled as a series of checklists as a part of the SCS Global assessment conducted in 2019. This report and the associated checklists are included in this report as addendum B.

Provision I E of the EO—A series of public meetings to share and obtain public input on the results of the review before finalizing

II. Report in Response to Directives I A and D of the EO

Herbicide Application in Site Preparation and Release in Plantation Forestry in Maine

Harold Thistle, PhD
Jane Bonds, PhD

Executive Summary

The State of Maine has commissioned this report on aerial spraying of herbicide in forestry plantation site preparation (to help clear a site for planting) and then again, a few years later, to release young trees from competition for light and other resources by non-crop plants. The report reviews the practice in Maine and discusses the physics of spraying in the context of these aerial application practices as conducted in Maine. The report then addresses specific concerns raised regarding these practices. Guidance from Maine BPC shows a modern and nuanced understanding of aerial spraying. The report generally shows that aerial spraying in forestry as practiced in Maine can be conducted with very low risk to human and ecological health when label guidance (federal law) and Maine BPC guidance (state law) is followed. Though aerial herbicide application as practiced in Maine is very low risk, it is impossible to assert that 'no drift' of herbicide occurs. It is demonstrated that drift amounts at long ranges are minute when present. Note that in a typical plantation, herbicide application will likely only occur twice in a tree growing rotation spanning decades. A review of alternative practices to accomplish vegetative control in site preparation and release on Maine plantations reveals that aerial herbicide application is used because it is the most economical, least damaging to the soil, has the lowest worker exposure, does not damage commercial species and can be performed in short windows of time dictated by forest phenology when compared to other spraying practices. It should be noted that all spraying practices have some (if often very low) potential for herbicide drift. Alternatives to herbicide application include fire (only for site preparation), hand clearing, and no treatment. These all have serious limitations and economic as well as other costs, such as air quality concerns with fire, labor shortage concerns with hand clearing, and loss of production concerns if no treatment is pursued. Recommendations for control of unwanted plant species are included as options for expanding BPC guidance. Existing industry and international operating procedures could be invoked as part of Maine guidance though it is thought that existing guidance is thorough. The following four recommendations are made:

1) Set a maximum wind speed during application at 10 mph for all cases.
2) Set a maximum extent of nozzles on the boom at 75% of helicopter rotor diameter.
3) Require that all anticipated buffers used in aerial application of herbicides in forestry be shown on all spray plan maps.
4) Require that all ISO standards regarding aerial application and all NAAA best management practices be used except where specifically overridden by regulation or direction from the State of Maine.

These recommendations are augmented with a list of suggested actions.

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Part I General Discussion and Spray Physics

Introduction

The State of Maine has requested a review of current scientific and technical understanding regarding aerial herbicide spraying in preparation and release of forest plantations after harvesting. The point of the report is to offer recommendations and options for best management practices (BMPs) that might augment existing guidelines. These practices directly influence (often determine) whether the activity of herbiciding in site prep and release can be accomplished without unacceptable risks to human health and the environment. The report demonstrates that practice, defined as how the application is conducted (equipment used, equipment set-up, and environmental conditions during application) can result in orders of magnitude difference in off-site movement of material as well as in the efficacy of the application.

The report assumes that pesticides used are registered, that all pesticides used are applied according to pesticide label guidelines (that is to say the pesticides are applied legally), and that applicators are trained and registered according to state requirements. The U.S. Environmental Protection Agency (USEPA) has determined that for registered pesticides, if the label guidance set forth in the pesticide labels is followed, the pesticides can be applied safely. However, the State of Maine has requested this report as an independent evaluation focusing on specific practices used in Maine for forestry site preparation and release of newly planted plantations from competing vegetation. The report will not attempt to summarize the body of toxicological literature available for the relevant active ingredients used in the various formulated pesticides sprayed in forestry site prep and release in Maine. This literature is generally summarized in risk assessments conducted by the USEPA and US Forest Service (Pesticide-Use Risk Assessments and Worksheets (fs.fed.us)). This report will not make any independent recommendations as to health risks but will provide absolute amounts of pesticides expected to be encountered at distance from site prep and release applications as presented in the literature and under a variety of modeled, hypothetical conditions.

The report will address alternatives to aerial application. In modern pest management it is always prudent to take an integrated pest management (IPM) approach and review all options, in this case, for vegetation management. The range of vegetation management practices available includes mechanical, cultural, biological, and chemical options. Chemical application methods may include aerial, heavy machinery, and backpack spraying. This type of general vegetation control is not generally approached with biological control, but all other approaches have been utilized. Since the option taken often comes down to a cost comparison, a discussion of relative costs will be included. Phenology, climate, or other factors may require an application occur in a specific (possibly short) time frame, so how quickly a treatment can be accomplished is often a deciding factor. The success or failure (efficacy) of an operation may also ultimately be expressed as a cost. Collateral environmental damage and such factors as impact to visual aesthetics and short- term inconvenience to the public (noise, restricted access, etc.) may be legitimate impacts of pesticide application but the costs of these impacts are harder to quantify.

As part of the review of BMPs, regulation of forestry practice in other US states, as well as internationally, will be reviewed. The review of existing BMPs and regulation will be utilized alongside the existing literature to make recommendations in the context of Maine forestry as to the safety of forestry aerial herbiciding in Maine and what additional measures (if any) are needed to ensure the safety of aerial herbicide application in Maine.

The State of Maine will use the report and associated recommendations to determine whether this activity can be conducted without undue risks to human health and the environment. If so, BMPs will be reviewed to determine the practices that should be recommended or regulated moving forward. Pesticide labels are considered legally binding documents. Since Federal law does not encourage state regulation that is more lenient than Federal regulation, recommendations will affirm pesticide label guidance, cover areas not currently discussed on pesticide labels or be more restrictive than existing pesticide label guidance.

Part I The Practice and Physics of Aerial Herbicide Application in Maine Forestry

1.0 General Discussion of Aerial Forestry Herbicide Application Operations

Herbicide application is conducted a few times (typically twice) in the cycle of plantation forestry which lasts decades (often 40 yrs. or more in northern forestry producing saw timber, typically shorter rotations in pulp harvests). After harvesting the previous generation, vegetation will be controlled (and residual logging debris leveled) prior to clear the site for the planting of the next generation. This both reduces resource competition for the saplings and removes obstacles to the physical work of planting. This practice is known as site preparation and is referred to in this report as ‘prep.’. The objective of this practice is to remove or reduce competing vegetation, remove or reduce logging debris, and/or prepare the soil to promote the growth and survival of desired tree species.

The second herbicide application occurs when the plantation is young (a few years old) and is called a ‘release’ treatment. This treatment is meant to reduce competition for light, water, and nutrients from competing non-commercial species. This practice ‘releases’ the young trees from vegetative competition. A notable difference between the two applications is that in release, the intention is not to damage the commercial species that has been planted.

1.1 Aerial Spraying for Plantation Site Preparation and Plantation Release in Maine

The commercial species most often reported in the spray plans examined for this study are various conifers as well as sugar maple (*Acer saccharum*) though there are other applicable commercial species in the diverse forests of Maine. As indicated above, treatment is described as site preparation or plantation release. The spray mixes that are used in the two treatments are similar but not the same. The formulated mixes are always applied as very dilute mixes with water as the carrier and active ingredient (AI) rates specified by the label. The formulated herbicide comprises less than 10% of the applied mix and the active ingredient is only part of the formulated herbicide (Table 1). For instance, a 2021 spray plan filed with the State of Maine shows 768 oz of water mixed with 66.5 oz of formulated herbicide yielding a mix of 92% water and 8% herbicide. Generally, the difference between prep and release applications is that a surfactant is used in prep applications to cause the spray to adhere to and spread on the target foliage. To protect the trees in a release application, the surfactant is replaced with an adjuvant (Penetron) to lower collection by the young conifers. This approach has been successfully used in Maine for decades. It is noted that there is a short window that release can be performed due to the phenology of the conifers being released, typically 4-5 weeks. Aerial spraying in Maine currently uses 'closed systems' so there is no on-site mixing as mix arrives in canisters which are connected into the aerial spray systems. 'Practice,' as described below, generally follows what is listed in the spray plans and data submitted to the State of Maine and from discussions with Ray Newcomb (JBI Helicopters) and Ron Lemin (Nutrien).

Aerial spraying is conducted with helicopters and typical application and equipment specifications are:

Bell 206B JetRangerIII

Forward Speed 60 mph

Nozzles set inside of 75% of rotor width every 6" resulting in 51 nozzles total

Nozzles dropped 6" and deflector plates used

AccuFlo .020 nozzles with VMD around 700 microns

Release Height 45'

Swath Width 45'

The active ingredients listed in the spray plans are glyphosate, triclopyr, imazapyr, sulfometuron- methyl and metsulfuron methyl.

Glyphosate is a non-selective herbicide that works by stopping the plant from producing an enzyme it needs to make protein for proper growth. Glyphosate is widely used in agriculture, industrial weed control, forestry, and in outdoor residential applications. It comes in a number of chemical forms but most of the formulated products contain the isopropylamine salt.

Triclopyr is a man-made herbicide used to control both broadleaf and woody plants. Broadleaf weeds include nettles, docks, and brambles. It mimics a plant growth hormone that causes uncontrolled growth and plant death.

Imazapyr is a systemic herbicide that moves throughout the plant tissue and prevents plants from producing a necessary enzyme, acetolactate synthase (ALS), which is not found in animals. Plant death and decomposition will occur gradually over several weeks to months.

Sulfometuron methyl is an herbicide in the sulfonylurea chemical family. Sulfometuron methyl is an organic compound used as a herbicide. It functions via the inhibition of acetolactate synthase enzyme.

Metsulfuron-methyl is an organic compound classified as a sulfonylurea herbicide, which kills broadleaf weeds and some annual grasses. It is a systemic compound with foliar and soil activity, that inhibits cell division in shoots and roots. It has residual activity in soils, allowing it to be used infrequently.

Table 1. Herbicides used in Aerial Herbicide Application in Maine since 2015 (BPC Spray Plans 2015-2021)

Formulated Herbicide	Active Ingredient	%AI (by weight)
Garlon	Triclopyr	60.45
Arsenal	Imazapyr	27.8
Escort XP	Metsulfuron-methyl	60
Oust XP	Sulfometuron-methyl	75
Accord XRT	Glyphosate	50.2
Mad Dog	Glyphosate	41
Chopper	Imazapyr	26.7

Rodeo	Glyphosate	53.8

Note that there are different versions of some of these brands. For instance, there are 7 registrations for Garlon in 2021 with differing % by weight.

1.2 Spray Drift Modeling

Modeling will be used in this report to illustrate the effects of individual variables in the physical discussion as well as to help develop options for forestry practice guidelines. The model used here is AGDISP. The AGDISP model was originally developed by the USDA Forest Service (FS) and has been progressively improved and updated over the past 35 years (Bilanin et al., 1989; Teske et al., 2003; Teske et al., 2019). It is a mechanistic model which uses the basic physics of aerial spraying to calculate the movement and landing position of spray droplets released from an aircraft. In technical terms it is a lagrangian model that calculates droplet trajectory through the aircraft wake and subsequently through the atmosphere beyond the wake. The model was developed by the FS using data from forestry spray trials (Teske et al., 1994) and then tested again as part of a development effort known as the Spray Drift Task Force (SDTF) which was a collaborative effort between the agricultural industry and the USEPA(Bird et al., 2002; Hewitt et al., 2002). The main value of the SDTF was the collection of dozens of spray trial data sets. This data was used to challenge and improve AGDISP (among other goals of the SDTF) and resulted in AGDISP being part of a modeling package that was reviewed and accepted by an EPA scientific advisory panel. (The original SDTF reports and data are now in the public domain and available to this effort.)

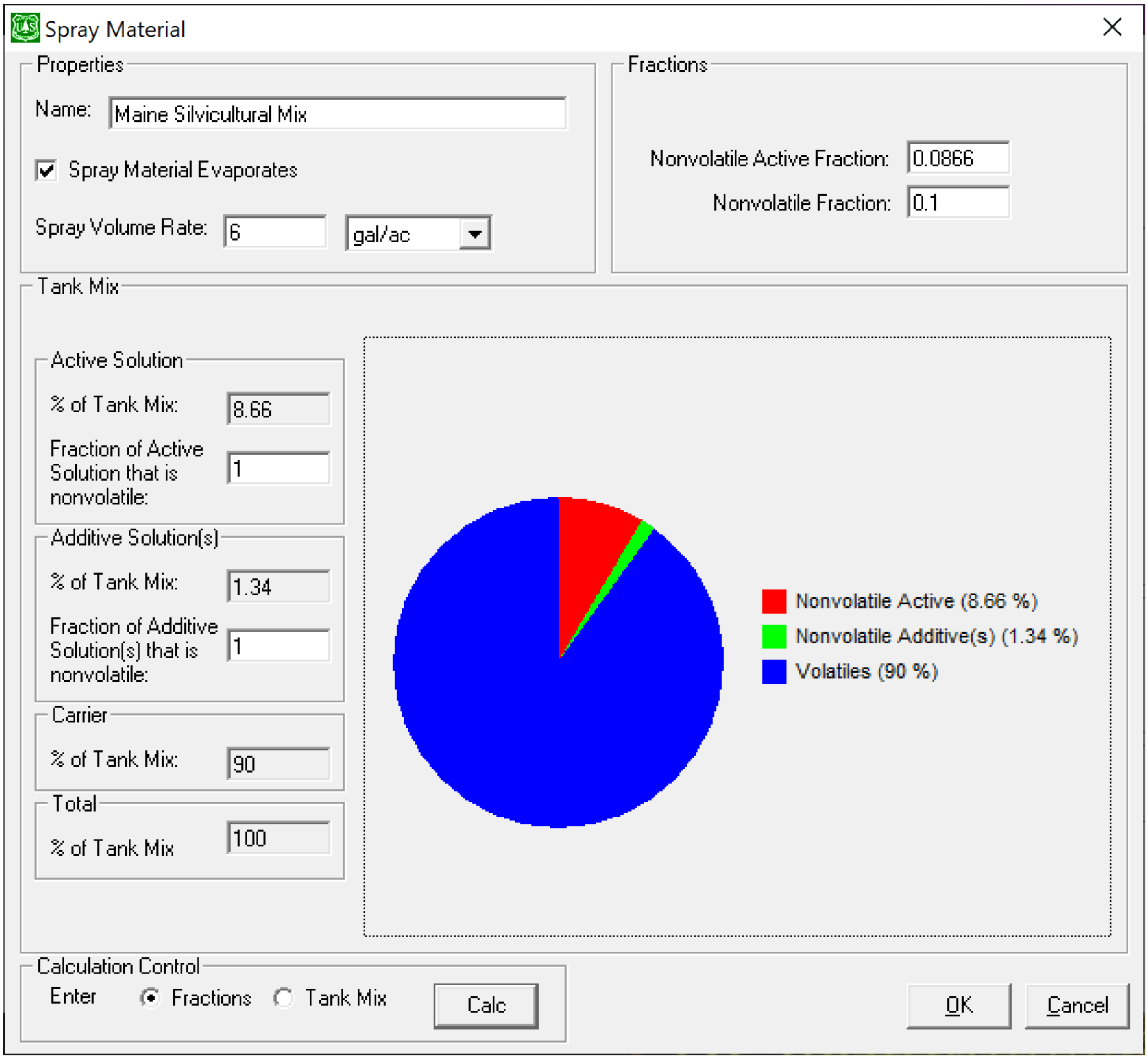
The complex physics of aerial spraying are discussed below. The model is a simplification of these physics, but it is still a reasonably comprehensive treatment. The model code is in the public domain and the techniques used are well referenced. AGDISP allows us to use the system physics and extend beyond individual data sets. However, the model has many limitations and model results given here will be provided with caveats as necessary.

With that said, forestry herbicide application practice in Maine provides an excellent scenario for AGDISP modeling. Larger drops, such as those that comprise the vast majority of the material sprayed in aerial forestry herbiciding are much easier modeling subjects than small drops, and herbiciding is generally easier to model than forestry insecticide application as efficacy is less dependent on the complex process of canopy penetration.

1.3 Spray Physics

The general physics of aerial application is known (Teske et al., 2003; Picot and Kristmanson, 1997), and are comprehensive treatments, among others as they will be discussed below. The detailed discussion of the physics of aerial spraying is presented to emphasize to readers new to this subject that it is an area of extensive research and is relatively well understood.

Generally the attributes of the mechanical systems can be fixed or monitored in a straightforward way, attributes of the vegetation, weather and other environmental factors vary on differing time scales and in space so questions of temporal and spatial averaging come into play. The continuous variability of these factors in time and space make them difficult to know exactly. It should be remembered within the context of this report and the design of BMPs, that monitoring is a cost item and it is often very difficult even with resources allotted to know certain factors exactly. This means that some important parameters in the anticipation of spray deposition and movement are not good candidates for required monitoring. All of the variables discussed below interact, so the discussion builds to describe a complicated system of interrelated factors. The detailed mathematics of this system are found in Teske et al. (2003). The below concepts are illustrated using the AGDISP model. A base case is set up using the application parameters as shown in Table 2. The material screen of the base case is shown in Figure 1.



Spray Material

Properties

Name: Maine Silvicultural Mix

☑ Spray Material Evaporates

Spray Volume Rate: 6 gal/ac

Fractions

Nonvolatile Active Fraction: 0.0866

Nonvolatile Fraction: 0.1

Tank Mix

Active Solution

% of Tank Mix: 8.66

Fraction of Active Solution that is nonvolatile: 1

Additive Solution(s)

% of Tank Mix: 1.34

Fraction of Additive Solution(s) that is nonvolatile: 1

Carrier

% of Tank Mix: 90

Total

% of Tank Mix 100

Calculation Control

Enter ● Fractions ○ Tank Mix

Figure 1. This is a screen capture of the Materials screen from AGDISP. The fractions option is chosen with all the active material (.0866) designated as non-volatile. The description used in the base case is typical of the mixtures used in herbicide application in Maine.

The modeling Base Case is shown in Table 2 and the parameters included in the table will be discussed in some detail below. In this discussion, deposition is presented as fraction of the applied application rate of the AI. To arrive at an absolute deposition, multiply the fraction of applied by the target application rate of AI.

Table 2. Modeling Base Case for Aerial Herbicide Application as Practiced in Maine

Aircraft	Bell 206B JetRangerIII
Airspeed	60 mph
Nozzle spacing	Every 6”, 75% of boom
Nozzle postion	Dropped 6”
Volume Median Diameter (VMD)	834 microns
Relative Span (RS)	.86
Release Height	45’
Swath Width	45’
Wind Speed	6 mph
Temperature	68 °F
Relative Humidity	60%
Stability	Neutral
Application Rate	6 gal acre
Material	.0866 non-volatile active, .1 non-volatile total

1.3.1 Droplet Size

A large body of spray drift literature (Bird et al., 2002) indicates that the most important variable in controlling aerially applied spray is the size of the applied droplets. Droplet size is also widely thought to affect efficacy. Forest herbicide application in Maine is at an advantage in this regard as prep and release treatments typically utilize very large droplets.

It is necessary to introduce certain terms and concepts in this discussion. Sprayed droplets always represent a spectrum of sizes termed the droplet size distribution (DSD). The droplet size in this spectrum, or DSD, where half the spray material is in smaller droplets and half is in larger droplets is termed the volume median diameter (VMD). A required droplet size may be specified on the pesticide label. When the label states apply as a Coarse drop, for instance, it is referencing the American Society of Agricultural and Biological Engineers (ASABE) droplet size standard. ASABE defines a DSD with a VMD of 658 microns as an 'Extra-coarse to Ultra coarse' DSD. The DSDs sprayed in Maine are in this category or larger. Keep in mind the cubic relationship between droplet diameter and mass; an 800 micron droplet has a mass 1.8 times that of a 658 micron droplet.   This bodes well for spray control in terms of hitting a target area. A critical point here is that the DSD does represent a droplet spectrum so there are always some fine drops that are susceptible to drift. For instance, in the case of ASABE Extra-coarse to Ultra-coarse DSDs, the DSD shows .007 of the total volume in droplets less than 105 micron diameter.

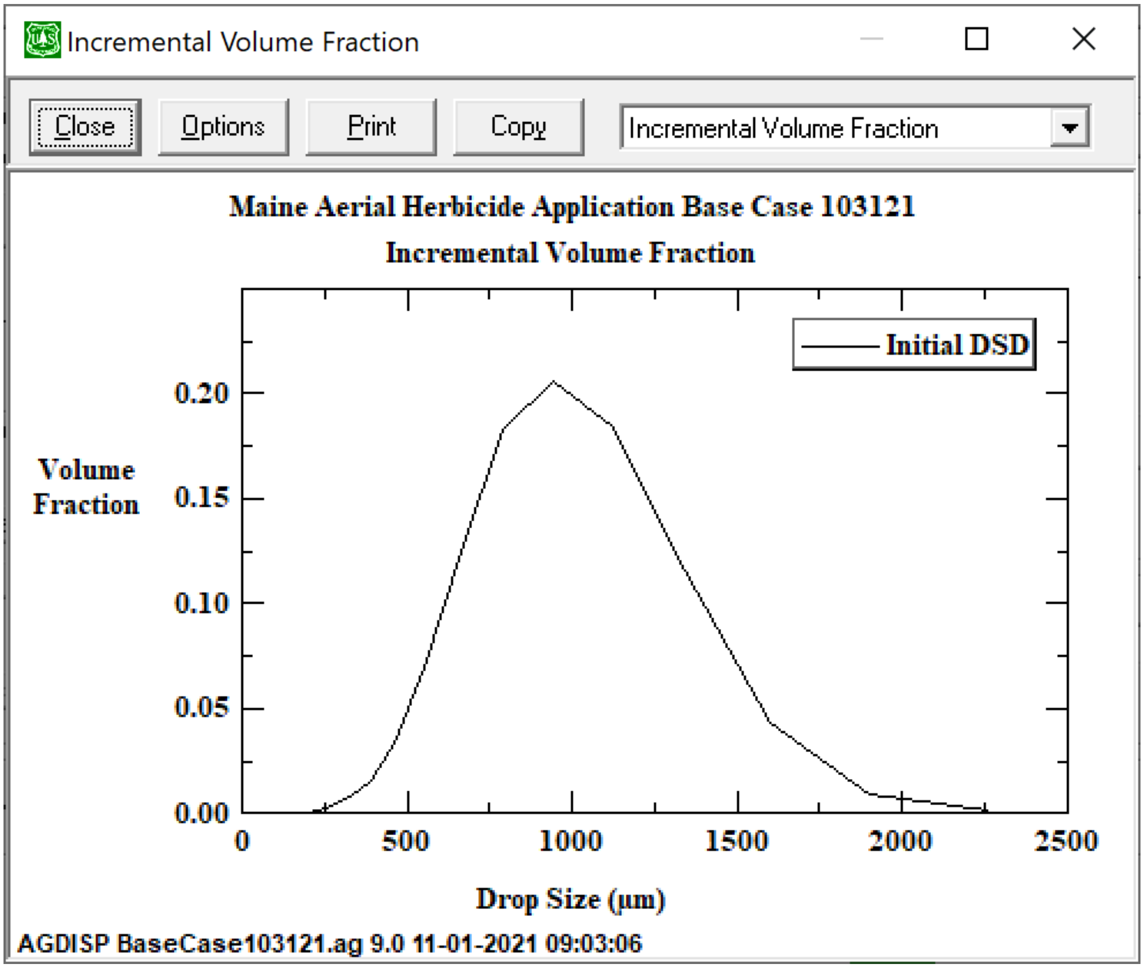


Figure 2. Base case droplet size distribution (DSD) for aerial herbicide application in Maine.

A further metric of the DSD is the relative span (RS). RS is defined as:

RS= $(D_{V0.9} - D_{V0.1}) / D_{V0.5}$

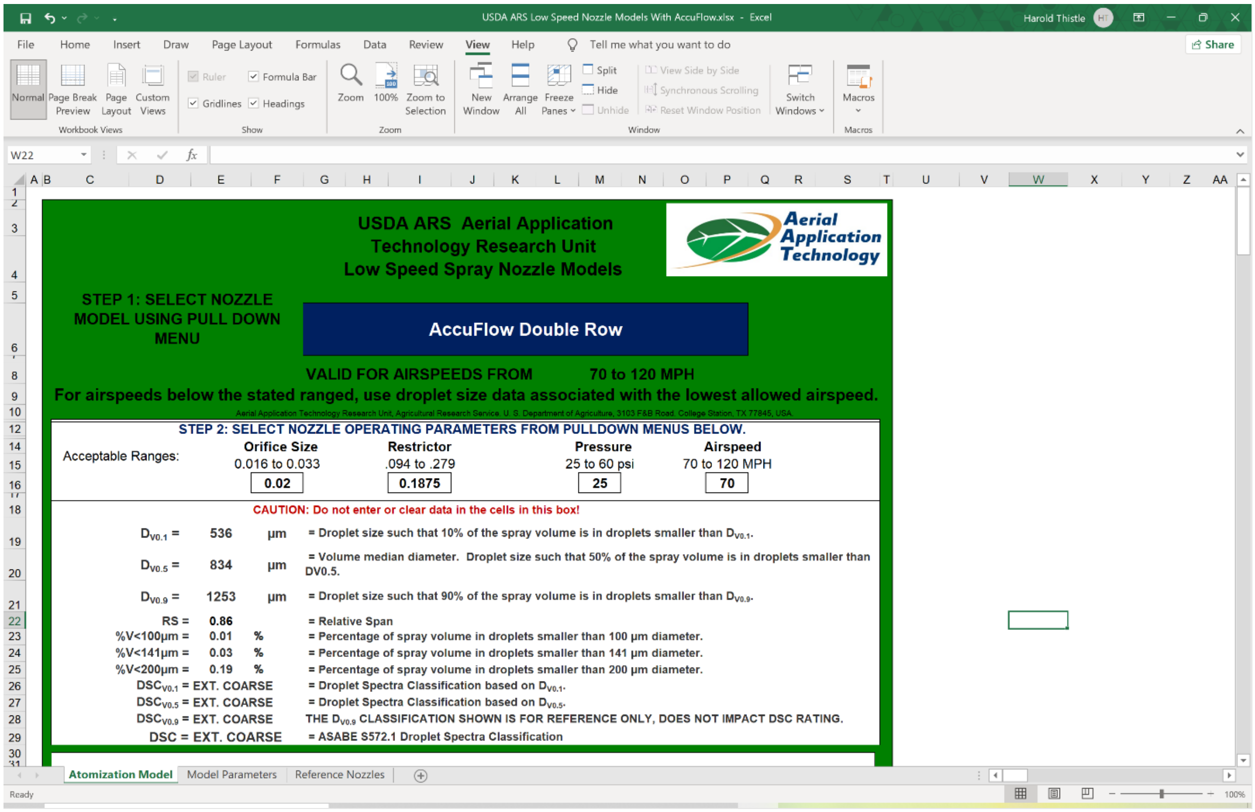
where

$D_{V0.5}$ = VMD

$D_{V0.9}$ = The droplet size where 10% of the volume is in droplets larger and 90% of the droplet volume is in droplets smaller.

$D_{V0.1}$ = The droplet size where 90% of the volume is in droplets larger and 10% of the droplet volume is in droplets smaller.

The RS describes the kurtosis or peakedness of the DSD. The base case RS is set as .86. A lower RS indicates a narrower DSD implying fewer fine droplets. The importance of this will be seen in the discussions below. An analysis of the .020 Accu-Flo nozzles conducted at the USDA Aerial Application Laboratory in College Station, TX has produced a set of curves that can be used to model the DSD of these nozzles. A screen shot of this empirical model is shown in Figure 3.



USDA ARS Aerial Application
Technology Research Unit
Low Speed Spray Nozzle Models

STEP 1: SELECT NOZZLE MODEL USING PULL DOWN MENU

AccuFlow Double Row

VALID FOR AIRSPEEDS FROM 70 to 120 MPH
For airspeeds below the stated ranged, use droplet size data associated with the lowest allowed airspeed.

Aerial Application Technology Research Unit, Agricultural Research Service. U. S. Department of Agriculture, 3103 F&B Road. College Station, TX 77845, USA.

STEP 2: SELECT NOZZLE OPERATING PARAMETERS FROM PULLDOWN MENUS BELOW.

	Orifice Size	**Restrictor**	**Pressure**	**Airspeed**
Acceptable Ranges:	0.016 to 0.033	.094 to .279	25 to 60 psi	70 to 120 MPH
	0.02	**0.1875**	**25**	**70**

CAUTION: Do not enter or clear data in the cells in this box!

$D_{V0.1}$ = 536 µm = Droplet size such that 10% of the spray volume is in droplets smaller than $D_{V0.1}$.
$D_{V0.5}$ = 834 µm = Volume median diameter. Droplet size such that 50% of the spray volume is in droplets smaller than DV0.5.
$D_{V0.9}$ = 1253 µm = Droplet size such that 90% of the spray volume is in droplets smaller than $D_{V0.9}$.
RS = 0.86 = Relative Span
%V<100µm = 0.01 % = Percentage of spray volume in droplets smaller than 100 µm diameter.
%V<141µm = 0.03 % = Percentage of spray volume in droplets smaller than 141 µm diameter.
%V<200µm = 0.19 % = Percentage of spray volume in droplets smaller than 200 µm diameter.
$DSC_{V0.1}$ = EXT. COARSE = Droplet Spectra Classification based on $D_{V0.1}$.
$DSC_{V0.5}$ = EXT. COARSE = Droplet Spectra Classification based on $D_{V0.5}$.
$DSC_{V0.9}$ = EXT. COARSE THE $D_{V0.9}$ CLASSIFICATION SHOWN IS FOR REFERENCE ONLY, DOES NOT IMPACT DSC RATING.
DSC = EXT. COARSE = ASABE S572.1 Droplet Spectra Classification

Figure 3. USDA ARS droplet size calculator run for the .020 Accu-Flo nozzle used in aerial herbicide application in Maine forestry.

The nozzle manufacturer states a VMD of 600-800 microns with no specific RS listed. After extensive discussion with Dr. Brad Fritz (USDA-ARS, College Station, TX) who is one of the designers of the calculator shown in Figure 3, the output of the calculator (VMD= 834 microns, RS=.86) was deemed backed by substantial data so was used in this study.

The basis of droplet size effects largely resides with the relationship between aerodynamic drag and gravity. For very fine droplets (< 30 microns depending on droplet density) a relationship known as Stoke's law determines settling velocity. For sizes up to 100 microns, Stoke's Law is used with a correction factor (Hanna et al., 1982). Stoke's Law states that settling velocity of these small droplets is a function of gravity, droplet size and droplet density divided by the viscosity of air. These small droplets are considered 'driftable' and though they represent a very small fraction of the spray volume released in the forestry practices described here, they are the most prone to drift. The settling velocity of a 100 micron diameter water droplet is 0.24 m/s while a 800 micron diameter water droplet has a settling velocity of 3 m/s. Considering this, a 100 micron water droplet will be displaced laterally 40 meters when released from 10 meters in a 1 m/s wind while a 800 micron droplet will be displaced approximately 3 meters. In a 5 m/s wind, these displacements increase to 200 meters and 15 meters respectively. This kind of linear reasoning for the movement of droplets in air is more valid for larger droplets. Smaller droplets are more likely to be influenced by atmospheric turbulence, so their trajectories follow the vagary of the wind as it rolls and eddies through the near surface atmosphere. The result of this tortuous trajectory is that there may be more opportunity to encounter foliage but conversely there is more time for the droplet to get even smaller through evaporation. Droplets below 40 microns or so are not strongly driven down by gravity and their movement is often treated as if they were a cloud of gas. Droplets in the VMD size ranges in prep and release in Maine are driven down by gravity and are less effected by small scale turbulence. These topics are explained in more detail below.

It should be noted that, most importantly in insecticide application but also to a lesser degree in herbicide application, the targeting advantages gained through larger droplets are partially off-set by losses in coverage and canopy penetration that may affect efficacy. Experience indicates that large droplets are efficacious as used in Maine plantation prep and release work while also reducing drift.

To illustrate the effect of droplet size, Figures. 4a., b., and c. were generated. The axes on these plots is downwind distance from the edge of the last downwind swath on the x-axis and fraction of the target application rate deposited on the y -axis.

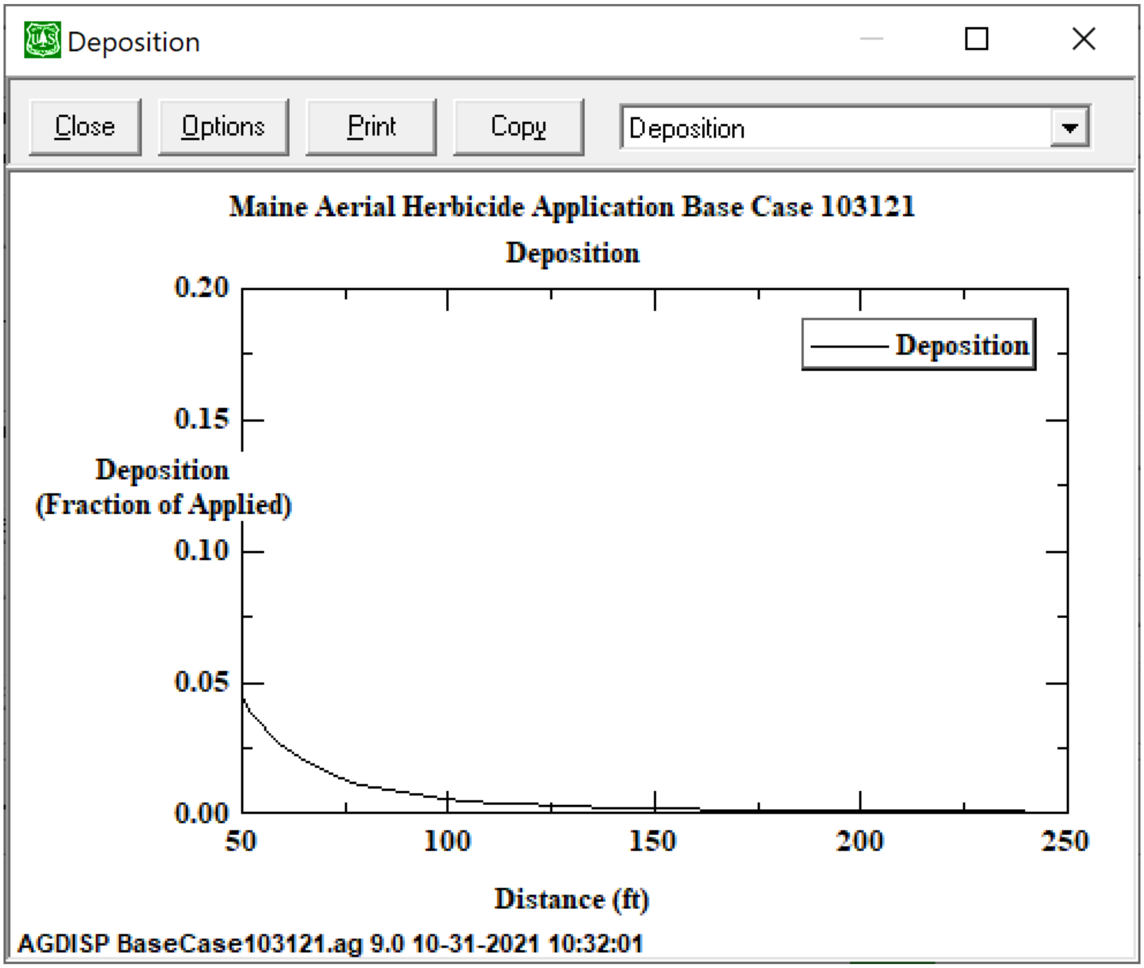


Figure 4.a. Graph of downwind deposition using the base case with VMD of 834 microns.

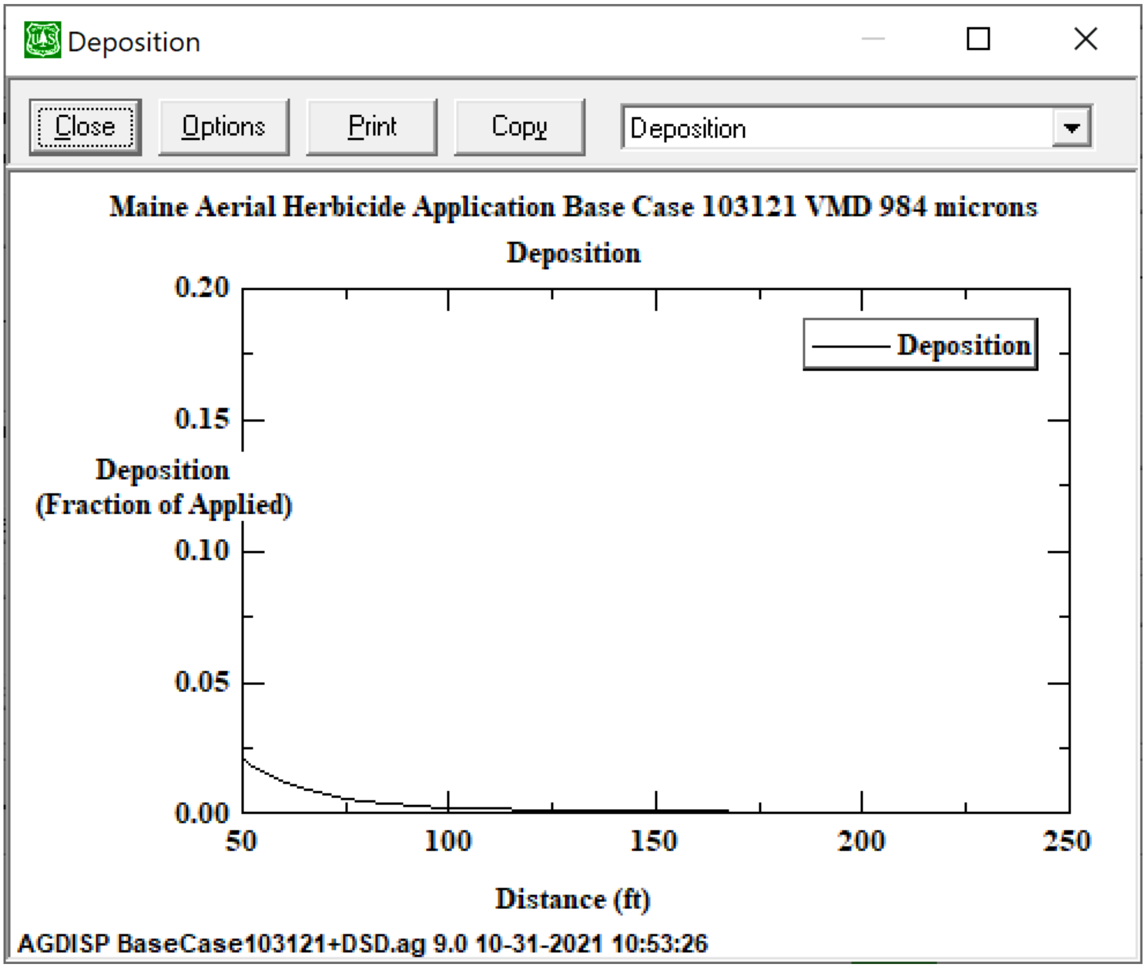


Figure 4.b. Graph of downwind deposition using the base case with VMD of 984 microns.

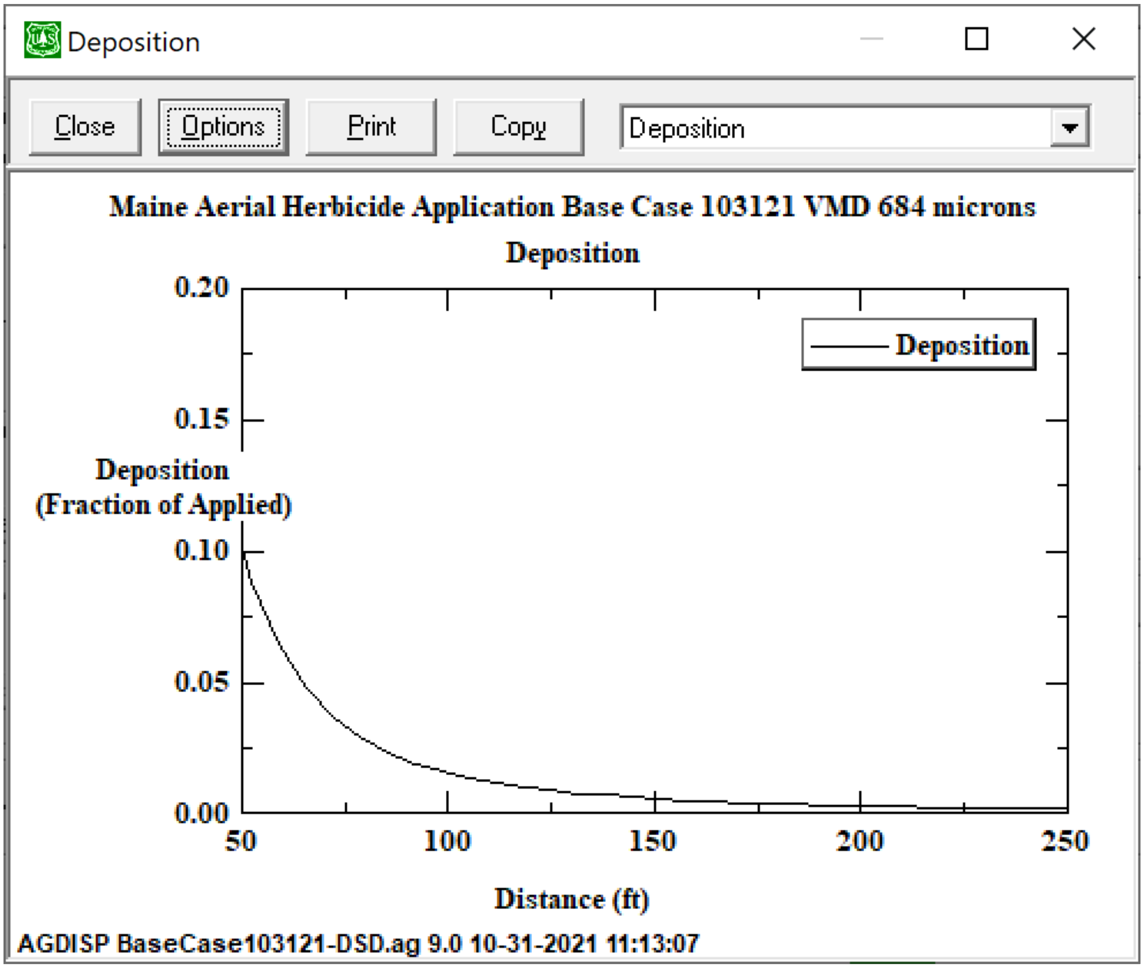


Figure 4.c. Graph of downwind deposition using the base case with VMD of 684 microns.

Table 3. Effects of Droplet Size

Feet from downwind edge of downwind swath	Base Case (684 micron VMD) (fraction of applied)	Base Case (834 micron VMD) (fraction of applied)	Base Case (984 micron VMD) (fraction of applied)
50	0.1	0.042	0.021
75	0.032	0.0127	0.0055
100	0.015	0.0054	0.00232
150	0.0055	0.0019	0.00093
200	0.00285	0.00098	0.000495
2600	0.000011	.0000054	0.0000026

The modeling clearly reflects the understanding of the role of droplet size discussed above. The amount of deposited spray at 50’ downwind more than quadruples as droplet size is decreased from a VMD of 958 microns to a VMD of 684 microns.

To continue the discussion of droplet size effects, we again model the base case but in Figs. 5.a. and 5.b. RS is varied.

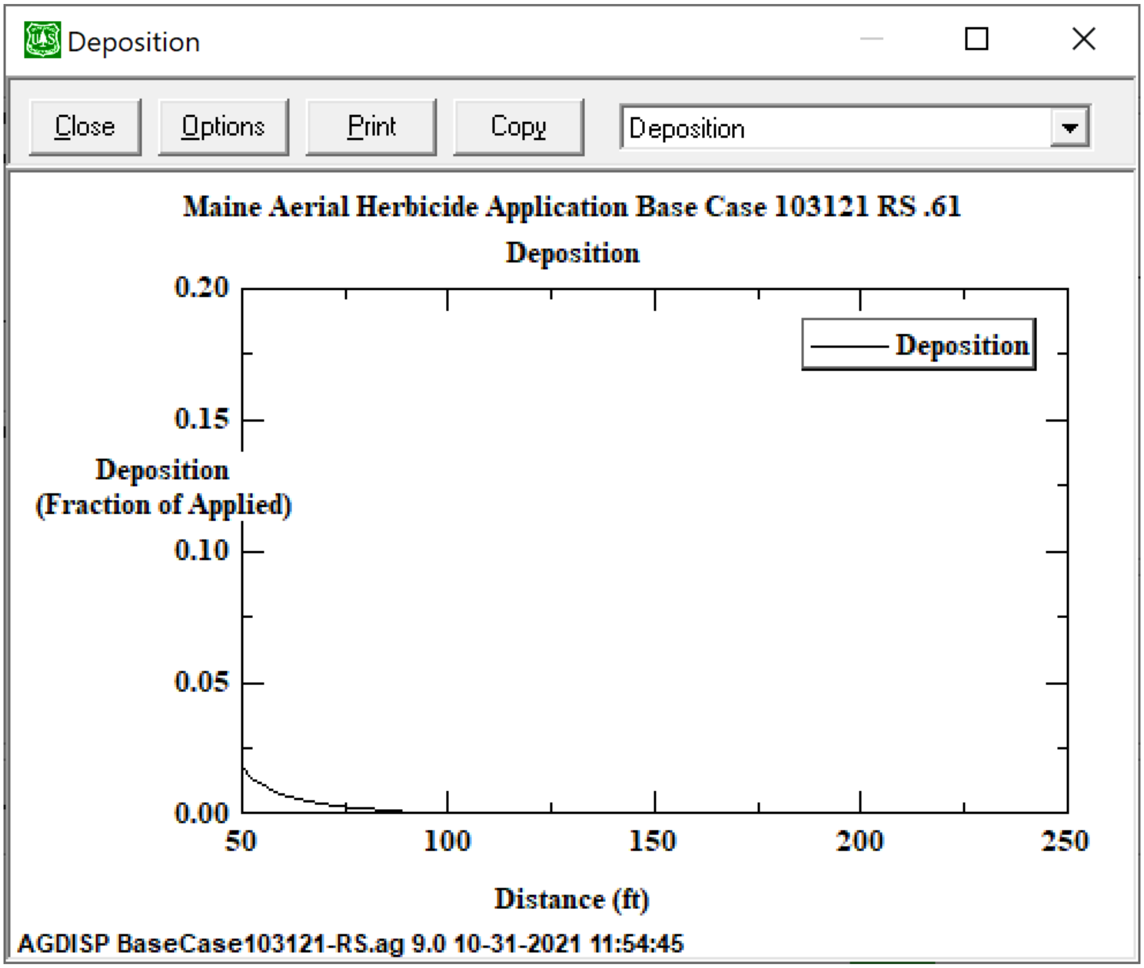


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Figure 5.a. Base case with RS decreased to .61.

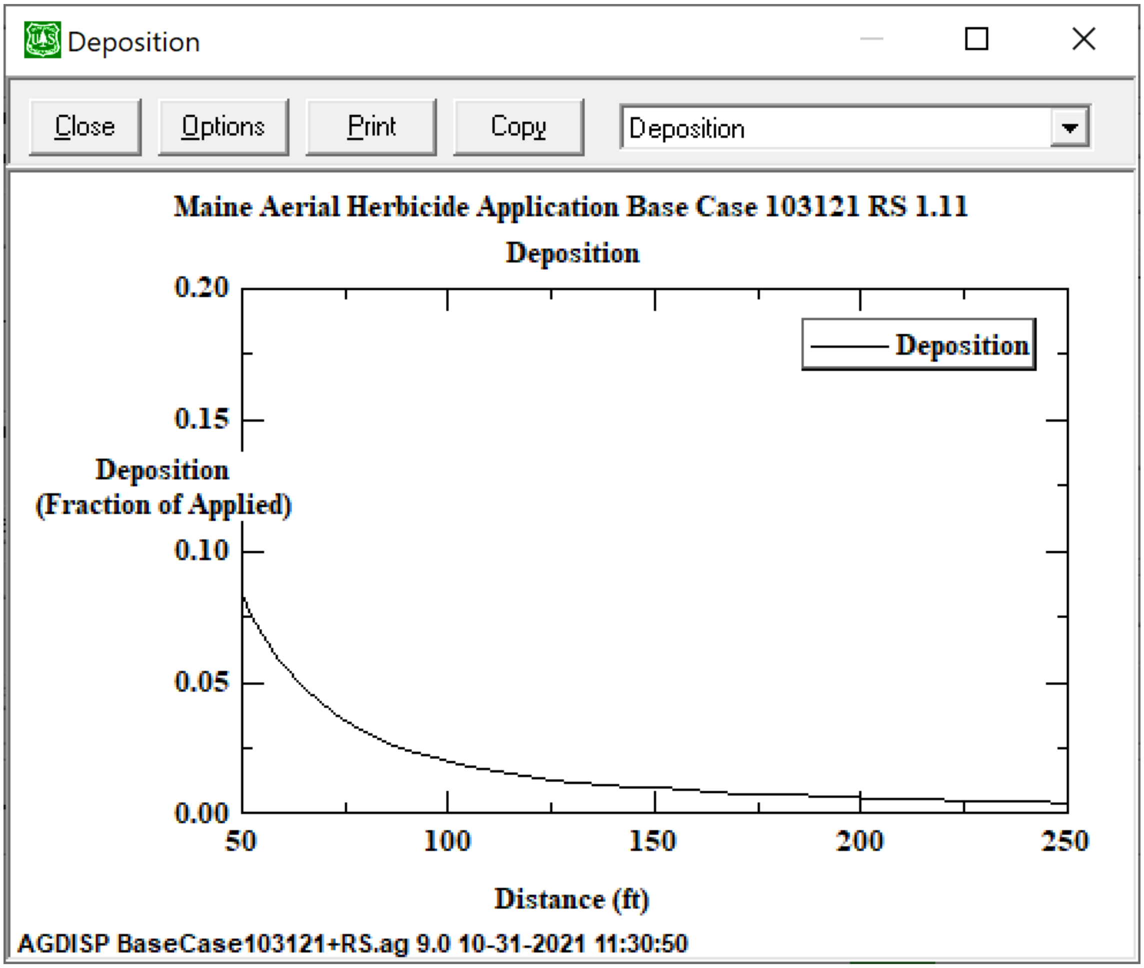


Figure 5.b. Base case with RS increased to 1.11.

Table 4. Effects of RS

Feet from downwind edge of downwind swath	Base Case (.61 RS) (fraction of applied)	Base Case (.86 RS) (fraction of applied)	Base Case (1.11 RS) (fraction of applied)
50	.01	0.042	0.083
75	.0021	0.0127	0.0349
100	.00044	0.0054	0.0195
150	.000084	0.0019	0.0096
200	.000036	0.00098	0.0067
2600	0	.0000054	0.000086

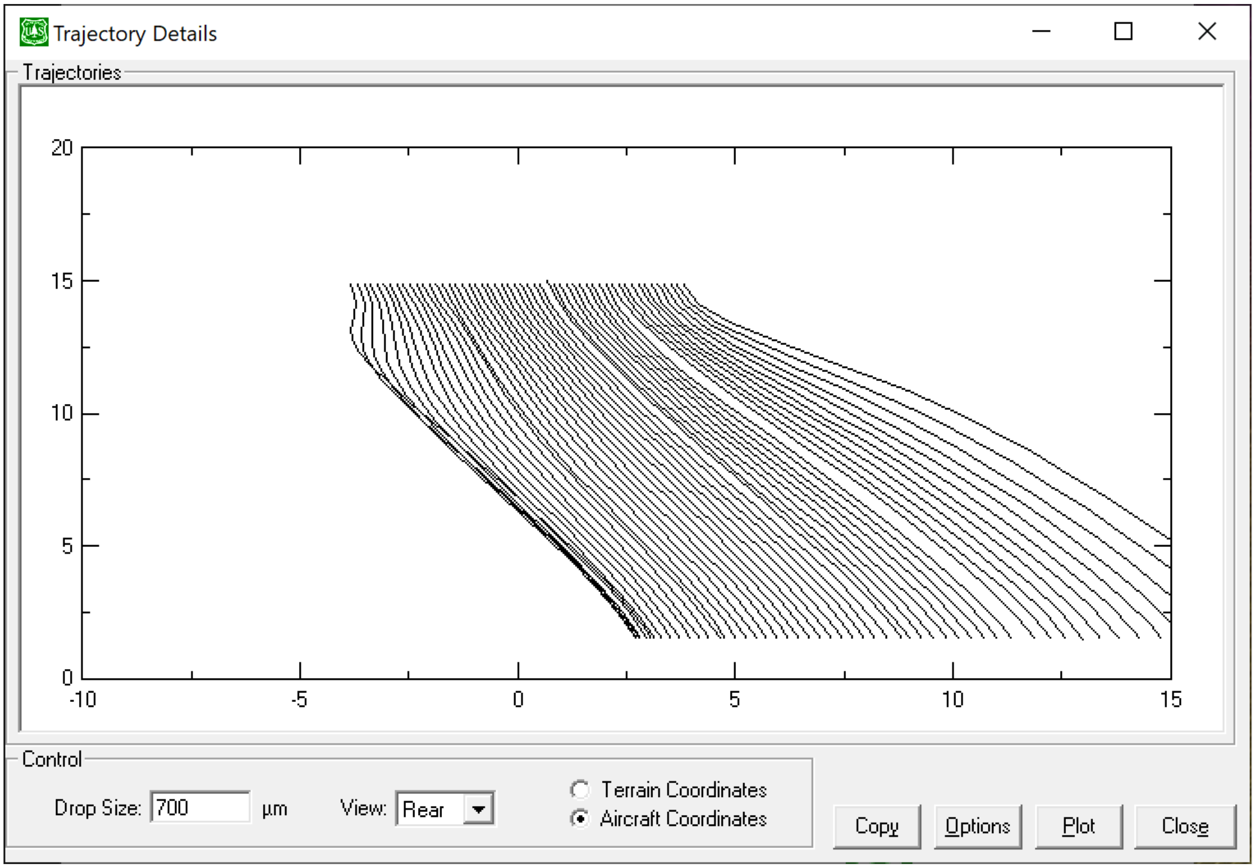
The effect of RS shows up in Table 4 more strongly as the spray moves away from the target as the larger drops deposit and it is only the fine fraction influencing drift. At 200’, there is over a factor of 15 difference between an initial RS of .61 and 1.11.

1.3.2 The Effects of the Helicopter

An aircraft requires substantial energy to remain airborne. This energy is supplied by the aircraft engines and the forward propulsion or rotor spin results in a pressure gradient across the wing or propeller surfaces known as lift. The discussion here will focus on rotary aircraft (helicopters). The upward force of lift pushes upward on the rotors allowing flight but it also results in air streaming off the rotor tips and forming rotor tip vortices that descend. Interestingly, by two or three aircraft lengths behind the flying helicopter, the rotor tip vortices and wing-tip vortices that characterize fixed wing aircraft will look very similar and both exist in a geometric plane perpendicular to the ground surface. If a spray droplet is released into the rotor wash vortex, it is carried along by the vortex. The vortices do descend and are used in certain types of aerial application to bring fine droplets down but the initial vortex motion is upward, followed by descent over the fuselage. This initial upward motion and the general airplane wash allows some droplets to escape the vortex at greater height than the initial release height and data has shown that releasing into the vortex actually increases drift (Teske et al., 1998). This effect is mitigated by restricting the nozzle placement to a percentage of the rotor width so that droplets are not released directly into the rotor wash. This is often mandated on the label and in Maine, the practice is generally not to place nozzles outside of 75% of the rotor diameter.

The other direct effect of the aircraft beyond wake effects is the potential effect of droplet shearing at the nozzle due to forward speed. For large droplets such as those utilized in prep and release in Maine, the secondary atomization effect of wind shear at the nozzle orifice can shift the droplet DSD three or four categories from a coarse spray to a fine spray. This effect is mitigated in practice in Maine by pointing the nozzles ‘straight back’ or parallel with the forward motion of the aircraft, pointing toward the tail. Deflectors are also used to shield the nozzles from the direct effects of air shear.

To evaluate the practice of positioning the nozzles inside 75% of the rotor radius and dropping the nozzles, we plot the mean trajectories of a 700 micron droplet and a 100 micron droplet in Figures 6.a. and 6.b. where the Y-axis is release height and the x-axis is downwind distance.

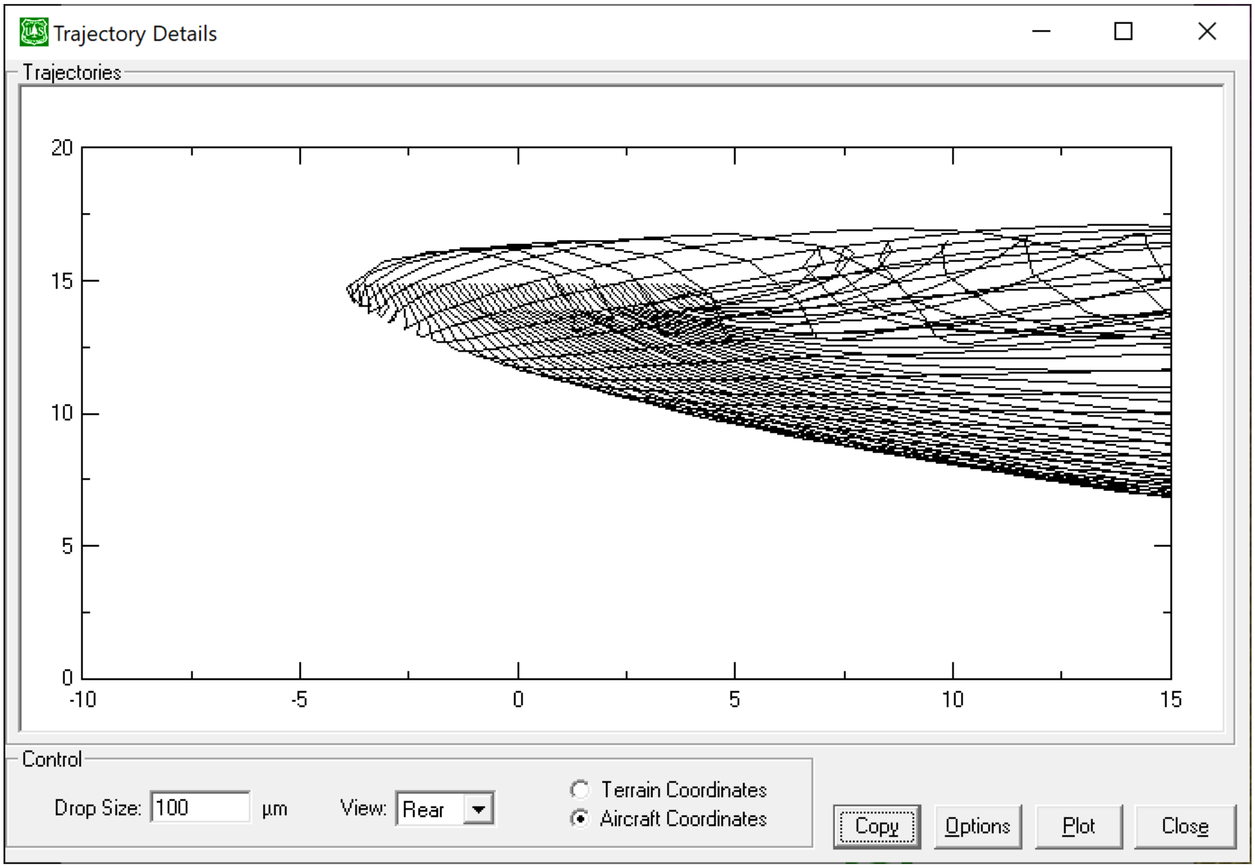


Drop Size: 700 µm

View: Rear

○ Terrain Coordinates
● Aircraft Coordinates

Figure 6.a. Average trajectory of a 700 micron droplet released using the base case. The graph assumes a crosswind with the aircraft flying into the page.



Drop Size: 100 µm

View: Rear

○ Terrain Coordinates
● Aircraft Coordinates

Figure 6.b Average trajectory of a 100 micron droplet using the base case.

1.3.3 Release Height

The effects of release height are intuitive. The higher the aircraft is off the ground, the more time the atmosphere has to move droplets laterally as well as for evaporation to make droplets smaller and more drift prone. General practice in prep and release work in Maine is conducted at release heights of 13-16 meters (40-50 feet). Flying height is a safety issue and must be left to the discretion of the pilot based on circumstances. In forestry spraying, a common type of vertical obstacle that may be encountered is dead snag that can rise above the canopy top. Often silver in color, these can disappear against clouds or in sunlight and are notorious aviation hazards. The retention of dead snags for wildlife can exacerbate this problem. A further issue to consider is that, especially with large orifice, large VMD nozzles, deposition to the ground surface may become ‘striped’ resulting in strips of over application within the stripes and lower efficacy in the rest of the swath if release height is too low.

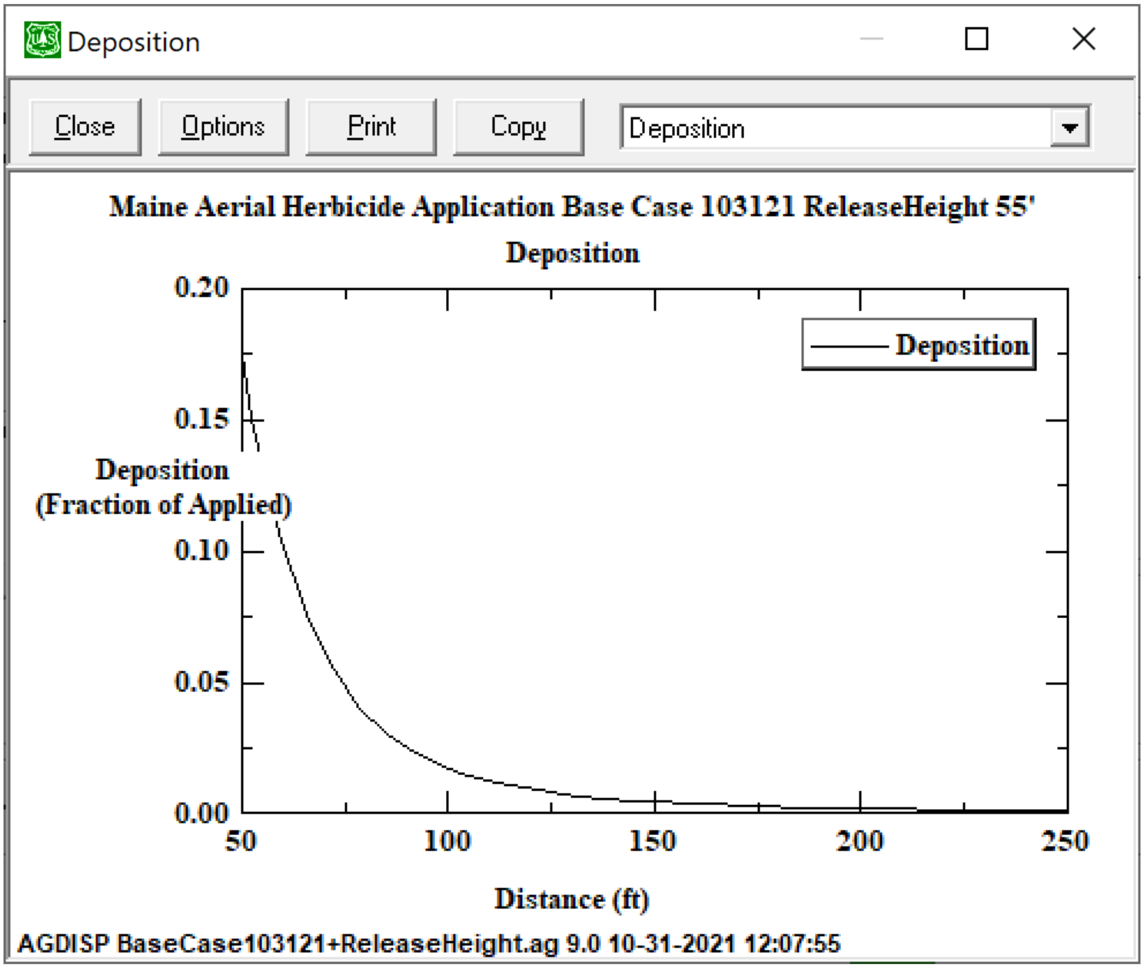


Figure 7.a. Base Case with release height raised to 55’.

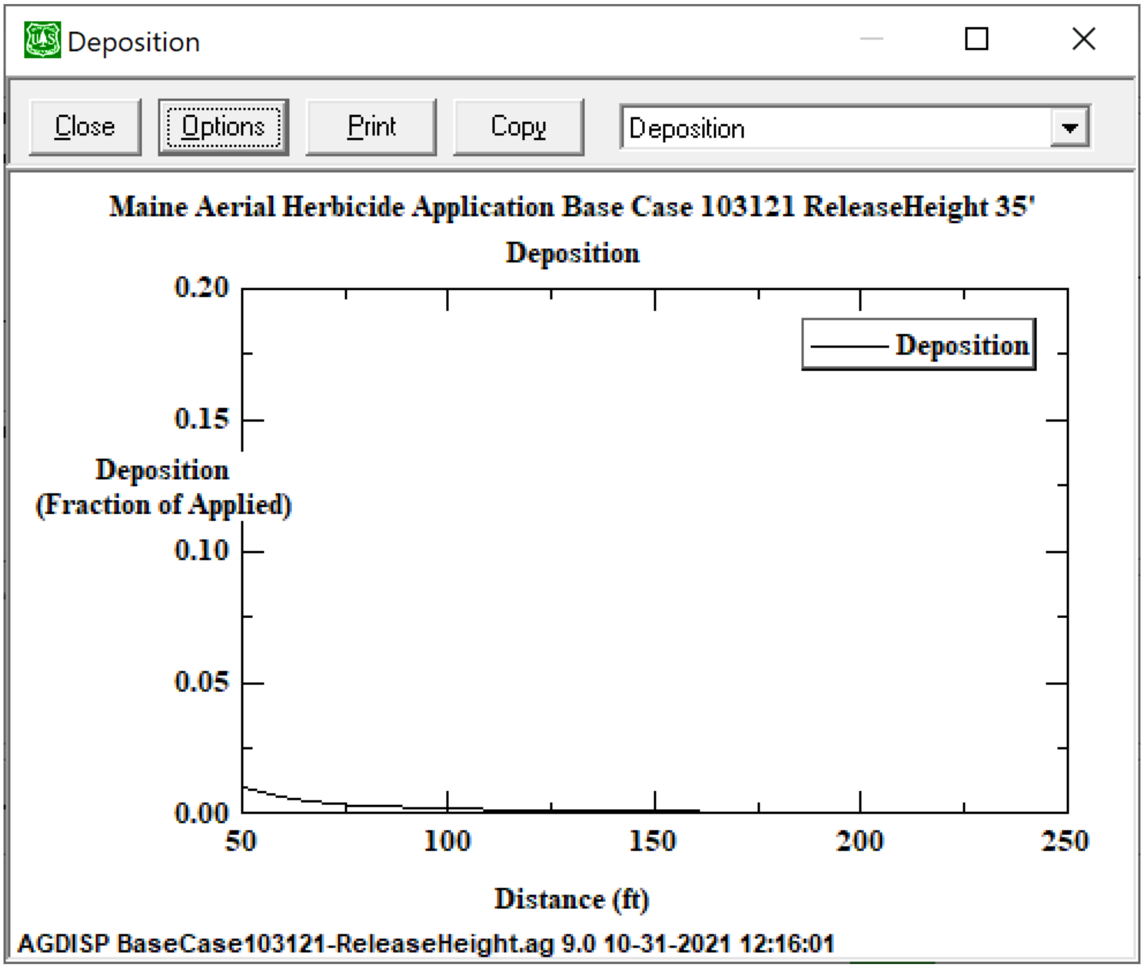


Figure 7.b. Base Case with release height lowered to 35’

Table 5. Effects of Release Height

Feet from downwind edge of downwind swath	Base Case (Release Height 35’) (fraction of applied)	Base Case (Release height 45’) (fraction of applied)	Base Case (Release height 55’) (fraction of applied)
50	0.01	0.042	0.2
75	0.0035	0.0127	0.048
100	0.0018	0.0054	0.0169
150	0.0008	0.0019	0.0044
200	0.00047	0.00098	0.002
2600	0.0000039	.0000054	0.0000075

Table 5 indicates that as release height is raised from 35’ to 55’, deposition at 50’ downwind increases by a factor of 20 and increases by over a factor of four at 200’. At 50’ downwind, some of the large droplets are still airborne and available to be displaced. The DSD distribution shifts with distance as larger droplets fall out nearer the spray line so the distribution of airborne droplets shifts to smaller droplets with distance downwind. This is demonstrated in Fig. 8.

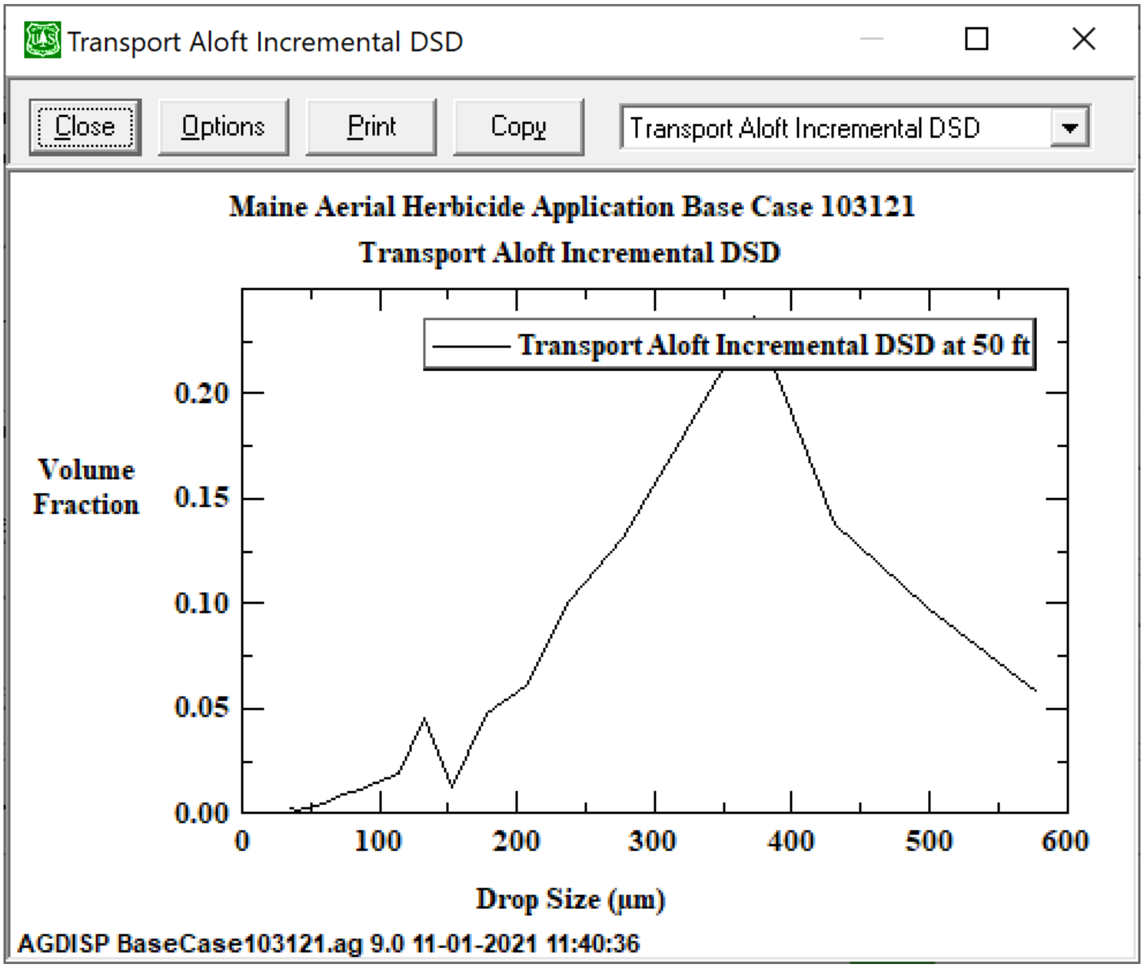


Figure 8. The droplet size by volume fraction of drops remaining aloft at 50’ downwind of the block edge. The airborne VMD has shifted from over 800 microns at release to less than 400 microns 50’ downwind. This graph is from the Base Case for aerial herbicide application in Maine forestry.

1.3.4 Wind Speed and Direction

Wind speed and direction have strong effects on the movement of aerially released spray. The wind moves spray laterally from the release point in the downwind direction of the prevailing wind. The stronger the wind, the greater the displacement. Wind effects are lessened for larger droplets which are not displaced as much. Pesticide labels typically dictate maximum and minimum wind speeds for application. Label requirements regarding wind speed are used as practice in Maine. Some managers require buffers around blocks or will offset upwind or use one-half swath inside the block edge as the sprayed edge. These practices are all to counter swath displacement and mitigate off-target deposition due to the wind. It is also noted that ambient wind dilutes the energy of and displaces the rotor wash. Generally, the wash near the aircraft is powerful enough so that ambient effects are minimal but, in still air, coherent vortices may linger for a large distance. The higher the ambient wind, the more quickly the vortical energy is diluted. This effect is captured in the AGDISP model.

Minimum wind speeds are specified on the labels for a few reasons. Some motion and turbulence (discussed below) are considered desirable to mix herbicide into the canopy thus improving efficacy. Wind direction is often variable when wind speeds are low and low wind speeds may be an indication of a stability condition known as ‘inversion’ which raises the potential for off-target effects. Low wind speed prevents application in conditions that would otherwise be advantageous to targeting and control of sprayed material.

Discussions of wind speed and direction often revolve around the variability of these quantities both spatially and temporally. As much attention in aviation is given to meteorology, pilots are generally aware of conditions and can ‘feel’ the variability in wind speed and direction. Many aerial application projects will use smoke, either generated by smokers on the aircraft or from deliberately set ground fires to assess wind speed and direction. To follow label requirements regarding wind speed, assumptions must be made regarding how appropriate a given point measurement of meteorology is in space and how often meteorology should be measured. The pilot is responding to nearly instantaneous effects of these factors on his aircraft as well as anticipating the effects of changing conditions on the movement of released spray. If a pilot uses a wind speed measurement at the aircraft, this results in a conservative application window as the windspeed will almost always be lower near to the surface due to the drag of the surface and vegetation on the airflow. If weather from a reporting station several miles away is used, conditions could be substantially different where the application is occurring. Not much formal, regulatory guidance is typically given on these points.

As a final note on this topic, there is technology now that calculates the position of depositing drops in the cockpit in near real-time (Thistle et al., 2020). This technology can then set a light bar, which is mounted on the center of the aircraft dashboard to indicate how closely the pilot is flying a pre-programmed spray line, and position the aircraft to compensate for swath displacement by the wind. Most aerial applicators already have the light bar in-cockpit, so this calculation plugs into existing technology. The swath displacement technology is off-the-shelf and not completely mature or widely used. It does point out that aerial spraying is fully engaged with precision agriculture.

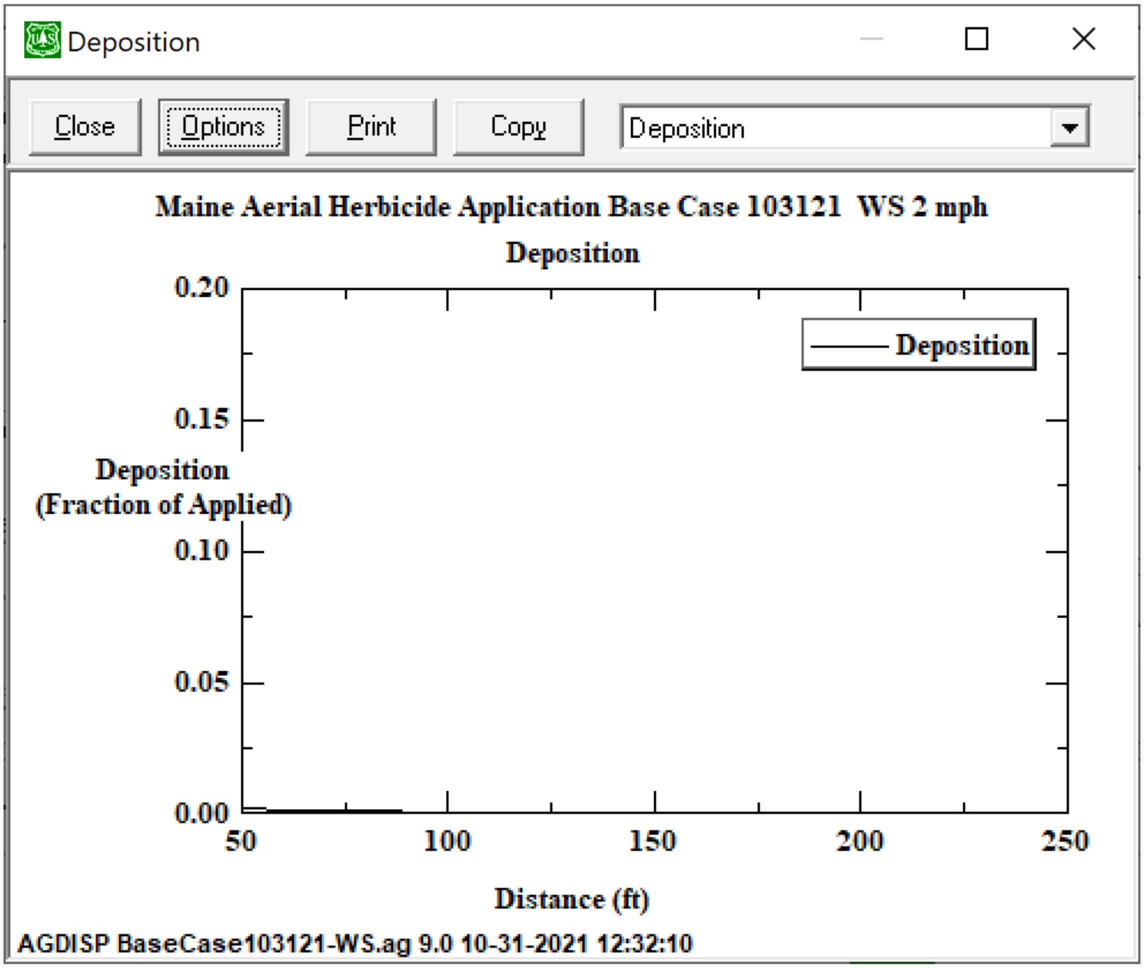


Figure 9.a. Base Case with wind speed reduced to 2 mph.

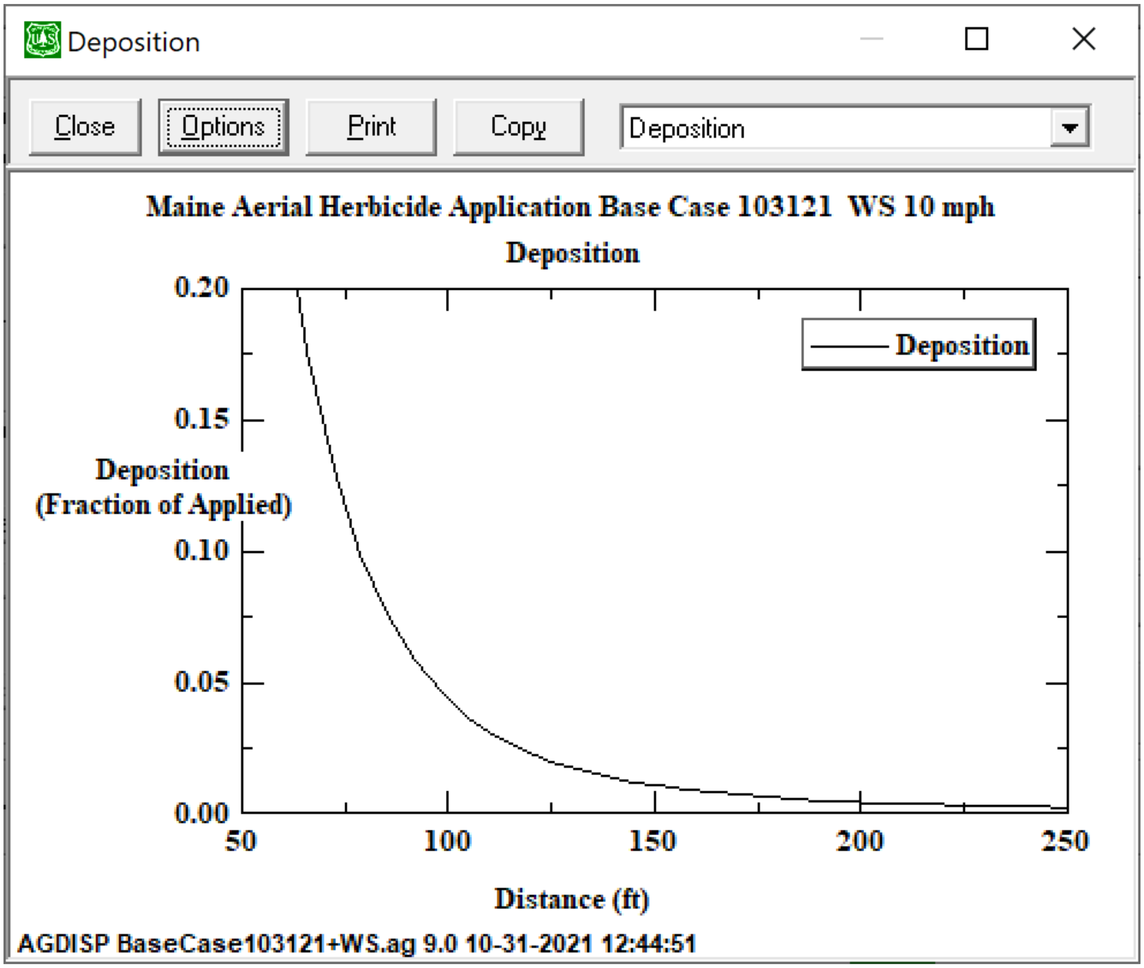


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Figure 9.b. Base case with wind speed raised to 10 mph.

Table 6. Effect of Wind Speed

Feet from downwind edge of downwind swath	Base Case (Wind speed 2 mph) (fraction of applied)	Base Case (Wind speed 6 mph) (fraction of applied)	Base Case (Wind speed 10 mph) (fraction of applied)
50	0.002	0.042	0.35
75	0.00078	0.0127	0.1
100	0.000375	0.0054	0.042
150	0.00018	0.0019	0.01
200	0.000109	0.00098	0.0043
2600	0.00000155	.0000054	0.00001

The effect of wind speed is seen clearly in Table 6. Deposition increases by a factor of over 1005 at 50’ as wind speed increases from 2 to 10 mph. By 200’ the increase is well over a factor of 35.

1.3.5 Turbulence

Turbulence is defined here, simply, as the variability in a mean fluid flow. Due to the drag of the surface of the earth and the complex surfaces offered by plant canopies and uneven terrain, the wind field near the surface is almost always turbulent. This idea is introduced here because turbulence impacts many aspects of the subsequent discussion. It is worthwhile to note that the equations that describe turbulent fluids (such as the near surface atmosphere) can be written down but cannot be explicitly solved. Modern science has quantitative approaches to this problem and makes very good approximations but it is not possible to say that if the wind speed is exactly (x) at time (t) at a point on a spray plot, it will be x +2 at t +1. There is an inherent variability in the wind field on the time and spatial scales of interest to us in this problem that will always lead to some variability in application.

The nature of the turbulent flow field can be conceptualized as a wind field composed of rolling motions, as fluid drags along the surface it slows and the faster fluid above ‘trips’ over the slower air below and comes down. Since air cannot accumulate at the surface, when the faster air in the overlying layer comes down it displaces the surface air. This ‘roller’ analogy has to be used carefully as the air in the flow is actually composed of fluctuations at all time scales, constrained between vertical motions 1000s of meters in length at the long end and motions less than .01 meters in length, dictated by the viscosity of air, at the short end (A detailed discussion of this topic emphasizing plant canopies is given in Finnegan (2000)). This ‘turbulent’ motion results in mixing which is both useful in getting material onto and into plant canopies but can also be responsible for moving fine droplets off-target. Again, as indicated above, large droplets have the inertia due to their mass and settling velocity to move through turbulent fluctuations (this propensity can be stated as having a long relaxation time), while very small droplets will move with every little turbulent fluctuation (short relaxation time). The consequences of turbulence are seen in the various discussions below.

1.3.6 Humidity

Humidity can be a very important factor in aerial application. The effect of humidity is dependent on two factors: 1) The value of relative humidity (RH) itself, as low humidity facilitates the evaporation of water, and 2) The chemical propensity of the spray mixture to evaporate (known as 'volatility'). If the volatility of the spray mixture is high and the humidity is low, small droplets evaporate very quickly (this is known as 'flashing'). High volatility is not, generically speaking, considered a good attribute of an herbicide that is meant to be sprayed and deposited on plants, though some herbicides are relatively volatile. Most of the aerial herbicide applications performed in Maine use water as a carrier. One scenario from the spray plans consisted of 6% herbicide and 94% carrier. It should also be noted that the formulated herbicide is not pure active ingredient, so less than 6% of what is sprayed is active ingredient. The effect of a large amount of volatile carrier is that, in low humidity conditions, the droplets become smaller after release, increasing the number of droplets in driftable size ranges. Another consideration is that in the aerial applications discussed here, a large amount of fluid is released. This large volume of evaporating fluid will raise the ambient humidity in the immediate vicinity of the spray. This will have a counter-balancing effect of slowing evaporation (Teske et al., 2017).

Since herbicide application in Maine is not generally conducted in extreme humidity conditions (as might be encountered in the Western U.S.), it would be unlikely that humidity would be a controlling factor. Also, in large droplet applications with relatively low release heights, most of the volume is on the ground quickly and not prone to droplet evaporation effects. However, since we are interested in small amounts of drift, and spraying mostly water droplets, droplet evaporation will occur. Note that glyphosate has a very low vapor pressure (a *vapor pressure* of 9.8X10-8 mm Hg at 25 °C) indicating that it does not evaporate at a significant rate after application.

The model was run for the Base Case with humidity ranging from 80% to 40% and the modeled differences were not large enough to merit further analysis.

1.3.7 Atmospheric Stability

The term atmospheric stability refers to the change in temperature with height in the atmosphere. In what is known as a 'neutral' atmosphere, the temperature decreases with height in conjunction with the Gas Laws reflecting the fact that lower in the atmosphere, there is more air overhead and the pressure is higher causing the temperature to be higher. However, there are two other states of atmospheric stability that are important to us in the context of pesticide application. 1) The temperature decreases with height at a rate higher than the neutral gradient. This is known as an 'inversion', and 2) The temperature decrease with height is lower than the neutral gradient, this is known as an 'unstable' atmosphere. A detailed discussion is given by Thistle (2000).

Unstable atmospheres form at the surface under relatively still, sunny conditions when the sun heats up the Earth's surface causing warmer lighter air to be under heavier cooler air; the warm air rises in what are known as 'thermals', creating lofting and these are the thermals that can jostle aircraft. Unstable conditions can loft fine droplets and deposit them off-site but unstable atmospheres tend to consist of large energetic motions that create disperse drifting. In fine droplet applications, this can impede efficacy because it is hard to get small drops down in an unstable atmosphere, but this may not have major effects on aerial herbicide application with large droplets because the droplets fall through the convective turbulence and the small volume of the spray in fine drops may drift but will be widely dispersed with negligible off-target impacts.

Inversion conditions also form under still, clear conditions, generally between times close to sunset and just after sunrise before significant surface heating, when the Earth's surface can lose heat to space. The cool surface causes a layer of colder air to form under the warmer air above. This denser air just sits under the warmer air as it is heavier and 'stable', (a stable layer is synonymous with an inversion layer). The problem with inversions is the stable situation suppresses mixing so fine droplets can just hang in the air in relatively concentrated form. The colder, heavier air can slump downhill or be pushed by light winds and can carry a concentrated droplet cloud off-site. Many non-target damage claims are related to inversions. Again, in our scenario, it is only the small fraction of very fine drops that are susceptible to drift in an inversion situation, but these may remain in a relatively concentrated cloud.

Many labels warn against applying in an inversion and the minimum wind speed dictates are meant, among other concerns, to prevent spraying in an inversion. In practice, inversions are often encountered because, in many situations, it is preferred to conduct aerial application in the morning when humidity is often high and wind speeds low. Early morning spraying can mean spraying before a nocturnal inversion has been completely destroyed by surface heating.

1.3.8 Terrain and Large Water Bodies

The effects of terrain and large bodies of water on wind fields is a large area of ongoing research which is only peripherally important to this discussion. The main effect of large terrain features on aerial application is that differential heating of slopes during the day and drainage of cold air off of cold surfaces at night can cause diurnal cycling of wind direction. Heating of slopes during the day can cause hot air to rise off the slopes and an upslope flow of replacement air, at night cooling off of surfaces can cause down slope flow of cooler denser air. The implication is that the wind direction can rather abruptly change 180° causing spray drift to reverse direction. The transition in regimes is often in the morning when aerial application may be occurring.

Large lakes and the ocean can also drive diurnal wind regimes as the water temperature lags the temperature of the land. During the day, when the surface heats more rapidly, colder, over water air flows on-shore, this shifts at night as the land cools more quickly and the denser air on the land flows towards the water. Again, applicators may get caught in a transition where wind direction shifts dramatically and abruptly.

These terrain and water effects are actually atmospheric stability effects and are strongest in clear weather when the atmosphere is otherwise calm.

1.3.9 Canopy Density and Penetration

The physical interaction of droplets with the target organism depends on many things. A coarse droplet (800 microns, for instance) has a high settling velocity, as described above, resulting in a largely vertical trajectory as it falls through the turbulence and impacts a surface. If the target canopy is not closed, that is to say there are gaps and the ground surface is exposed to the sky in places, these large droplets may fall to the ground and not impact the plant. The smaller droplets in a given droplet size distribution (a commonly used rule is that droplets <140 microns in diameter are considered driftable though this is widely debated) have a more horizontal trajectory as they are displaced by the wind and also follow a turbulent trajectory as they move with the smaller turbulent eddies. This gives them more of a chance to penetrate a canopy and more of a chance to land on foliage. This is a critical factor in much forest insecticide application where the insecticide must be ingested by the target pest so it needs to deposit inside the canopy where feeding is occurring. As mentioned above, this is less important with most herbicide application as, in the case of systemic herbicide, material deposited on the upper leaves will be absorbed into the plant system. There is still some evidence that some penetration does help efficacy in any plant canopy. This may be because fewer small droplets go straight through the canopy to the ground, that absorption is better with many small droplets as opposed to a few very large droplets, or other issues of plant physiology.

The basic system can be considered as one of encounter and collection of droplets. The droplet first needs to encounter a canopy element. Canopy density is described as the amount of canopy per area or volume. Various measures have been used for this, the most common is leaf area index (LAI). LAI is usually stated as area of canopy surface (one side) per area of ground surface (m^2/m^2) vertically. So LAI of 3 indicates that if you dropped a plumb bob straight down through a canopy, you would encounter 3 canopy elements (on average). Thick blackberry, for instance, might have an LAI of 1 or 2. An oak-hickory forest might have a LAI of 2-3, an 8 meter high red maple stand might have an LAI of 5 (Teske and Thistle, 2004). The higher the LAI, the more likely a droplet that enters the canopy will encounter a canopy element. The second part of this system is collection. A droplet has what is referred to in this context as 'impaction energy' but would more generically be called inertia. A large droplet of the VMD size used in Maine has large impaction energy and will smack onto the surface of the first leaf or twig it encounters and deposit there. A very fine droplet has low impaction energy and may encounter the air flow which is bypassing the element and move with that flow (short relaxation time) instead of impacting on the element. The propensity to collect a droplet is called collection efficiency and if the collection efficiency of a surface is low, a small droplet might encounter many surfaces before it is deposited. The collection efficiency of a given foliar surface depends on roughness, hairiness, waxiness etc. A final consideration, especially relevant to large droplet spraying is that droplets might shatter upon contact with a canopy element creating small drops (Schou et al., 2012) though once these drops are in the plant canopy (whether a mature forest or a low shrub canopy), they are unlikely to escape and drift.

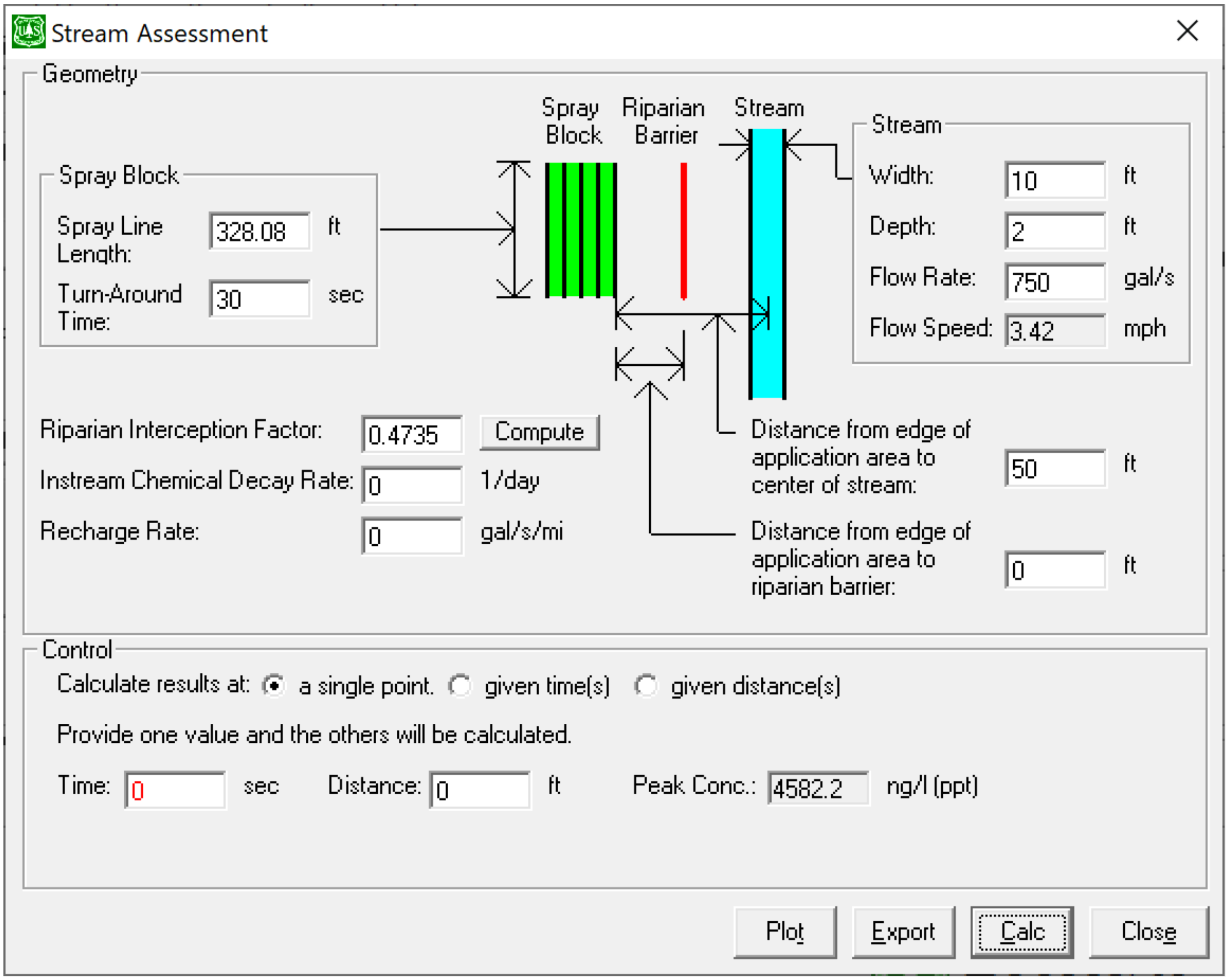
1.3.10 Scavenging and Basic Canopy Micrometeorology

It is worthwhile to revisit the ideas of wind and turbulence and the role they play in droplet deposition on and in a plant canopy. As mentioned above, the wind can be conceptualized as rolling along the surface of the earth and across the top of a plant canopy. Though this motion is not typically periodic, the occasional strong downward pushes of wind (gusts) push air from higher in the atmosphere into plant canopies and force the surface air that is in the canopy out. This is a critical exchange process for scalar quantities such as moisture, CO_2, O_2, etc. and has major implications for spraying (Finnegan 2000; Thistle et al., 2020). The turbulence associated with this process lengthens the trajectories of droplets, thus allowing more opportunities for canopy deposition, instead of a linear trajectory, the droplets are moving in non-linear motions greatly lengthening the trajectory in and near the canopy. Resulting droplet deposition is known as canopy scavenging of droplets. Another important related factor is that there is a hysteresis in energy between the downward wind motions and the return flow. An analogy (imperfect as all analogies are) might be the motion of waves breaking on a beach. The incoming wave is a coherent, identifiable entity that rears up and crashes on the beach, the outgoing water returns in a relatively low energy sheet. Though the downward motions in the atmosphere are not typically periodic, they can gain momentum through a large depth of atmosphere and bring faster moving air from higher levels down to the surface in a relatively coherent gust, this gust penetrates the foliage introducing fresh air into the canopy. The return flow is filtered back through the foliage and is known as diffusive, much of the kinetic energy in the downward gust has been lost to friction, so the diffusive return flow is much less energetic. The importance of this to this discussion is that it results in stronger downward pushes which help push spray down into the canopy and a weaker return mechanism that is less capable of pushing spray up where it might be re-entrained by the wind. This flow complexity is not captured in models like AGDISP and is a reason AGDISP is thought to be very conservative for long range drift, especially over forests (Richardson et al., 2017).

1.3.11 Riparian Barriers and Edges

Riparian buffer strips can be used in forestry as a means to protect forest streams. If trees are left in buffers they can provide a physical barrier to scavenge spray and lessen herbicide deposition to streams. Forest edges and windbreaks have been studied in some detail. It has been found that the flow disruption is a function of the density of the foliage and the thickness of the barrier in the case of windbreaks. In the case of a riparian buffer, the mean wind will adjust to the obstacle with the mean flow being displaced upward while an eddy will form in front of the trees and a lee eddy in the lee of the trees. The basic relationships of wind, density and shape of windbreaks was studied in detail by Wang et al. (2001) in the context of livestock sheltering on the Great Plains. The effects of a riparian buffer on spray drift was studied in Thistle et al. (2009). They showed that both 100’ and 75’ buffers as used in Oregon forestry practices provide substantial protection of streams from spray deposition (the average reduction in this study was 92% over all twenty trials and all barriers). Very small amounts of spray did either loft over or move through the barriers.

Based on the above work, a tool was developed to calculate stream concentrations beyond a riparian barrier. Using our base case, peak concentration in a stream 50’ downwind of a spray block and immediately behind a riparian barrier is calculated as 4.6 ppb. This tool is inside AGDISP but is not widely used, primarily because the riparian interception factor is hard to know and the algorithm is largely based on the single set of trials referenced above.



Spray Block

Spray Line Length: 328.08 ft

Turn-Around Time: 30 sec

Stream

Width: 10 ft

Depth: 2 ft

Flow Rate: 750 gal/s

Flow Speed: 3.42 mph

Riparian Interception Factor: 0.4735

Instream Chemical Decay Rate: 0 1/day

Recharge Rate: 0 gal/s/mi

Distance from edge of application area to center of stream: 50 ft

Distance from edge of application area to riparian barrier: 0 ft

Calculate results at: ● a single point. ○ given time(s) ○ given distance(s)

Provide one value and the others will be calculated.

Time: 0 sec Distance: 0 ft Peak Conc.: 4582.2 ng/l (ppt)

Figure 10. AGDISP screen used to calculate deposition to a stream behind a riparian barrier.

1.4 Long Range Drift

The question of long range drift is a difficult one. Thistle et al. (2012) aerially released *Bacillus thuringensis* (Bt) upwind of a 2 km grid in the desert of Utah. The Bt was used as a tracer in this experiment and is detectable at near single spore level. The release rate was 9.4 x 10^6 spores m^{-2}. At 2000 meters, 85% of the samples over 17 trials showed no Bt while the maximum sampled at that distance was .0001 of the applied rate and that sample was an outlier. In the case of a basically non-volatile herbicide, these results give at least an idea of the amount of herbicide that might travel longer distances. It would be expected that in the vegetated landscape of Maine, a much lower percentage of material would move that far downwind. Also, the VMD of around 105 microns used in the Utah work comprises less than one percent of the total volume of a Maine aerial herbicide application spray. In terms of fraction of applied, the maximum at 2000 meters would be expressed as 0.000001 of the applied rate.

AGDISP is not well suited to long range modeling. There is an approach to modeling vector control where clouds of very fine droplets are released at heights ranging up to 100m. This approach is not deemed appropriate here. The standard lagrangian approach in AGDISP was run and deposition at one-half mile downwind distance is noted in Tables 2-5. The base case shows .00014 of the applied rate at 2600’. This translates to around .000032 gal ac^{-1} AI at that distance or about 1/40th of a teaspoon ac^{-1}. This modeled number is believed to be extremely conservative as that transport distance does not consider scavenging by intervening foliage as discussed above. A further complication of measuring long range drift of an herbicide such as glyphosate is that the chemistry to detect at very low levels is complicated and expensive. Also, some of the herbicides of concern, such as glyphosate, are widely used garden chemicals and domestic weed killers that are sold locally all over America. It is difficult to be certain that other smaller but closer sources of such herbicides are not contaminating samples when we discuss sampling at thousands of meters downwind.

Part II Discussion of Impacts, Environmental Fate, Economics and Use

Introduction

In timber management, herbicides are used to control vegetation that may compete with more valuable tree species. Aerial application is the preferred approach in many cases, and is occasionally used in Maine, on less than 4% of harvested acres each year. But critics point to evidence that certain herbicides can be toxic to humans and animals. Recently, glyphosate, the most widely used herbicide in the United States since 2001 has come under increased scrutiny due to concerns regarding its safety (Sharon, 2021). This attention has drawn increased scrutiny to the practice of aerial application of herbicides in forestry in

Maine. Within this report the objective is to address some of these concerns via a review of available, and in general peer reviewed literature.

- Does aerial herbicide spraying reduce food and habitat for wildlife?
- Does aerial herbicide spraying result in chemical persistence in the environment?
- Have scientists made a legitimate effort to test non-chemical alternatives?
- What are the cost and benefits associated with aerial herbicide applications?
- What is the comparison between herbicide use, other interventions, and no intervention?
- Are herbicides harmful to humans and wildlife?
- What are the use patterns for aerial pesticide application in other areas?

2.1 Question: Does aerial herbicide spraying reduce food and habitat for wildlife?

Meeting future demands for wildlife habitat and biodiversity conservation will require that society's growing demand for wood be satisfied on a shrinking forestland base. Increased fiber yields from intensively managed plantations will be a crucial part of the solution. As integrated pest management (IPM) is pursued, properly conducted herbicide application will remain a tool in the IPM toolbox. Current research indicates that the negative effects on wildlife usually are short-term and that herbicide use can be part of meeting wildlife habitat objectives (Wagner, Newton, Cole, Miller, & Shiver, 2004).

Sullivan and Sullivan (2003) reviewed more than 60 published studies on glyphosate in forestry, considering potential effects of this management practice in forest ecosystems on biodiversity. The authors concluded that species richness and diversity of vascular plants, songbirds and small mammals were either not affected or affected to only a minimal degree by glyphosate treatments. The degree of change observed in all cases was considered to be within natural fluctuations. Temporary declines were observed for avian and some small mammal species, whereas in other species, abundance increased in treated sites. For species whose preferred habitat is removed by the herbicide treatment the typical response is a transient reduction in populations, followed by return when these habitat features become re-established. Studies on terrestrial invertebrates covered a wide range of taxa with variable responses in abundance to glyphosate treatments. The authors noted that management for a mosaic of habitats, which provides a range of conditions for plant and animal species, are likely to ameliorate any short-term changes in species composition which might occur on specific sites treated with glyphosate to enhance regeneration success and plantation growth rates following forest harvesting (Thompson, 2011). It is important to note that in the state of Maine such a mosaic approach could be considered to occur as areas no greater than 250 contiguous acres can be harvested.

Interestingly some studies have shown that low levels of glyphosate have led to stimulation of growth of some plant species. Glyphosate induces hormesis in crops and plant species as different as *Sorghum* spp., soybean, coffee, eucalyptus, *Arabidopsis thaliana*, maize, and *Pinus* spp. In general, the hormetic response was more pronounced in woody genera such as *Eucalyptus* spp. (Duke, 2006). Others have observed hormesis with glyphosate in maize and barnyard grass (Schabenberger, Tharp, Kells, & Penner, 1999; Wagner, Kogan, & Parada, 2003).

2.2 Question: Does aerial herbicide spraying result in chemical persistence in the environment?

Unintended damage from herbicides is typically seen when a compound bio accumulates or travels from the site. Accumulation is unlikely in forestry considering that applications are infrequent. After aerial herbicide applications in deciduous forests of Oregon, Michigan, and Georgia, residues were found to be highest in the overstory reducing exposure of the understory vegetation and streams with residues in streams at or under the detection limit in 3-14 days. All residue concentrations in foliage water and soil were below levels known to be biologically active in non- target fauna (Newton, 1994). In boreal forest sites of central Canada, more than 95% of the total herbicide residue after an aerial application was found in the upper organic layer with no evidence of lateral movement either in runoff water or subsurface flow (Roy et al., 1989).

It is noted here that due to the widespread use of glyphosate over the last 50 years, much of the literature focuses on glyphosate. In general, it is known that glyphosate is susceptible to rapid microbial degradation and thus non-persistent. It binds strongly to any organic substrate including organic matter and clay particles of sediments and soils, and thus shows no tendency to leach or move laterally with surface runoff even though it has relatively high solubility in water (Thompson, 2011). Glyphosate generally has a favorable environmental profile with minimal ecological impact in forest ecosystems, including strong binding and immobility and rapid biodegradation in most soils, water and sediments (Rolando, 2017). Glyphosate acid itself is zwitterionic, carrying both a positive and negative charge under typical environmental pH conditions but in different proportions depending upon the exact pH (Borggaard Gimsing, 2008; Piccolo, 1996). It is the zwitterionic character of the glyphosate molecule which is responsible for its tendency to adhere strongly to organic matrices or clay minerals. In soils with macropores and pronounced preferential flow, glyphosate can move to groundwater, but it has a relatively short environmental half-life especially in soils with high organic matter content. Vertical mobility was not observed in forest sites across several regions in the USA. Glyphosate is not volatile, so there is no secondary atmospheric contamination (Duke & Powles, 2008).

Tatum (2004) provides a simple comparison of the toxicity, transport, and fate of a number of various forestry herbicides. To begin, as mentioned above, glyphosate is strongly adsorbed to soil, resulting in low mobility and virtually no leaching from the application site, in soils and sediments and is primarily degraded through metabolism by bacteria and fungi. The reported half-lives of glyphosate in soil in field studies ranged from 1.2–197 days, with an average of 32 days (Giesy, Dobson, & Solomon, 2000). In most soils hexazinone is only weakly adsorbed and is thus highly mobile; because hexazinone is very water soluble and highly mobile in soil, it has potential to move offsite through leaching and runoff. The hydrophilic nature of hexazinone however, means it’s not likely to bioaccumulate. The reported half-lives for hexazinone in soil in field studies range from 24 days–1 year (Michael et al., 1999). Imazapyr is not strongly adsorbed to soil, so has potential to be highly mobile, but residues tend to be low because it is rapidly photodegraded in water with a half-life of 2-5 days. Degradation of imazapyr in soils occurs primarily through microbial metabolism with half-lives ranging from 25–142 days. Metsulfuron is weakly adsorbed to soils which can make it mobile, dissipation from soil is due to microbial degradation and hydrolysis with half-lives ranging from 7–42 days. Dissipation from water is due to hydrolysis meaning metsulfuron does not produce significant or persistent contamination of surface groundwater. Sulfometuron does not adsorb strongly to soil but is only moderately soluble in water and thus does not appear to be highly mobile. Degradation of sulfometuron in soils occurs via microbial metabolism, hydrolysis, and photolysis with soil half-lives ranging from 12–65 days. Although triclopyr is not strongly adsorbed to soil, leaching does not appear to be a concern and only small quantities have been detected in runoff in field studies. This is likely due to triclopyr residues remaining in plants until foliage is shed or the plant dies and tissues begin to decay (Tatum, 2003).

Oregon Department of Forestry, Forest Practices Monitoring Program (1992) has been sampling water from various areas over the past 16 years. Results from three different studies indicate that the majority of the 24-hour-average composite samples contained either no detectable residue or less than 1.0 ppb of the applied pesticide. The first sampling routine spanned from 1980 to 1987, to assess the effectiveness of the then forest practice rules at protecting the waters of the state. Of the 153 samples analyzed, a representative subset of their total pesticide applications, 86 percent (132 samples) resulted in no detectable pesticide residue. A subsequent study was carried out from 1989 to 1990 where of 52 samples analyzed, 83 percent (43 samples) resulted in no detectable herbicide. In Washington the Timber Fish and Wildlife Program (TFW) monitored six operations during 1991 (Rashin & Graber, 1993). Of the 6 operations, 83 percent (5 samples) contained 0.13 to 0.56 parts per billion (ppb) of the applied herbicide. Results of these three studies indicate that under most conditions, water concentrations greater than 1 ppb are relatively rare as a result of forest operations (Dent & Robben, 2000). In 1997, the Oregon Department of Forestry commissioned a study to monitor herbicide levels in streams. In particular, the goal of this study was to test the effectiveness of the forest practice rules in protecting fish-bearing and domestic use streams from unacceptable drift contamination during aerial applications of forest pesticides (Dent & Robben, 2000). No pesticide contamination levels at or above 1 ppb were found in any of the post-spray samples analyzed. Seven of the 25 post-spray samples (for 2 of 5 sites) were found to contain trace levels of the applied pesticide lower than 1 ppb (mdl 0.5 to 0.04 ppb). Contamination levels ranged from 0.1 to 0.9 ppb. The contaminants included hexazinone from site 22 and 2 4-D ester from site 25. Current literature indicates that thresholds of concern for human health and aquatic biota start at levels much higher than 1 ppb. The surface water quality criteria for hexazinone are 2500 for human health, 3200 for trout health, and 52,000 ppb based on daphnia mortality. The surface water quality criteria for 2 4-D ester are 300 ppb for human health, 7 ppb based on bluegill health, and 100 ppb based on daphnia mortality (Dent & Robben, 2000).

Direct effects to terrestrial fauna residing in forested areas treated with glyphosate from exposure to glyphosate via direct spray, spray drift or secondary exposure through the ingestion of flora and fauna food sources containing glyphosate residues are low. In addition the risk of bioaccumulation through secondary exposure to glyphosate is known to be low, based on its low octanol-water partition co-efficient (Table 7), well below the octanol-water partition co-efficient of 5.0 or greater suggested by Mackay and Fraser (2000) as a threshold for the onset of bioaccumulation.

Table 7 Numbers extracted from Extoxnet and PubChem two web based resource and Neary, Bush, and Michael (1993)

Herbicide	Solubility at 25C mg/L	Half Life days	Photo deg	Microbial deg	Hydrolysis	Volitization	Kd	Log Know 25C	Vapor pressure mm Hg	LD50 rat	LD50 sunfish
2,4-D	3,000,000	28	minor	yes	yes	yes	0.5	2.81	1.86X10-2	375	168
Dicamba	4,500	25	no	yes	no	no	0.1	2.21	3.75X10-3	757	135
Glyphosate	12,000	47	minor	yes	no	low	16.5	-3.40	9.80X10-8	5,600	120
hexazinone	33,000	30	yes	yes	no	low	0.2	1.85	2.25X10-7	1,690	370
Imazapyr	15,000	30	yes	yes	no	no	0.3	0.22	1.79X10-11	5,000	120
Picloram	430,000	60	yes	yes	yes	no	0.6	0.30	6.0X10-16	8,200	21

Sulfometuron-methyl	300	20	no	yes	yes	no	0.5	1.20	5.48X10-16	5,000	12
Triclopyr	430	45	rapid	yes	no	low	1.5	-0.42	1.26X10-6	630	148
Metsulfuron-methyl	2,790	30	no	yes	no	low	1.4	2.20	2.5X10-12	5,000	150

Alvarez et al. (2021) measured the degradation and mobility of sulfometuron-methyl and potential degradates were evaluated under field conditions in the United States following application of Oust herbicide to bare ground at the maximum labeled rate. Sulfometuron-methyl degraded rapidly at the four test sites; calculated half-life values ranged from 12 to 25 days. Sulfometuron-methyl residues were below the limit of quantitation (10 ppb) beyond 90 days after treatment at all test sites. Sulfometuron-methyl and its degradants were immobile under field conditions. The photolysis half-life for sulfometuron is reportedly 1 to 3 days (Robertson & Davis, 2010). Harvey, Dulka, and Anderson (1985) showed that photolyzed sulfometuron poses little further threat to the ecosystem because resulting compounds are herbicidally inert and ecologically harmless. Russell, Saladini, and Lichtner (2002) showed that it is capable of moving into aquatic systems and could thereby be moved off-site, although little or no damage is done to those systems because most residues are quickly photolytically or hydrolytically degraded. Harvey et al. (1985) analyzed the hydrolysis of the active ingredient under various pH conditions and found that at pH 5.0, the half-life of sulfometuron was approximately 14 days. Conversely, measurements taken 30 days after treatment for pH 7.0 and 9.0 in another study showed 87% and 91% of the active chemical remaining, respectively (Anderson & Dulka, 1985). In plants sulfometuron had a half-life of 1-12 days in the soil and aqueous residues of metsulfuron methyl showed halflives ranging between 84 and 29 days with the lower time period associated with a more realistic application rate (Thompson, MacDonald, & Staznik, 1992).

Imazapyr is active over a range of rates and is recommended at rates up to 1.68 kilograms acid equivalent per hectare (kg/ha). Imazapyr was observed to move offsite in streams principally in stormflow and dropped to near background levels within 40 days for the worst case studied. The highest observed stream concentration occurred during a period of aerial application where a flight over the stream channel resulted in direct deposition of imazapyr in the stream. One sample taken approximately 2 hours after completion of application contained 15 ppb of imazapyr. Subsequent samples did not contain quantifiable residues until the first post application precipitation (Michael, 1989). The persistence of imazapyr however can be highly variable. Three different Argentinian soils had half-life values of 121, 75, and 37 days. The half-life of imazapyr was negatively associated with soil pH and iron and aluminum content, and was positively related to clay content (Gianelli, Bedmar, & Costa, 2014). Tran, Harrington, Robertson, and

Watt (2015) investigated relative persistence of commonly used forestry herbicides in NZ. The treatments can be approximately ranked in the following order from most to least persistent: triclopyr/ picloram > high rate of clopyralid > high rate of hexazinone > terbuthylazine/hexazinone > low rate of hexazinone > low rate of clopyralid > high rate of terbuthylazine > triclopyr > high rate of metsulfuron-methyl > low rate of terbuthylazine > low rate of metsulfuron-methyl.

2.3 Question: Have scientists made a legitimate effort to test non-chemical alternatives?

Canadian Federal and provincial government scientists and academics across Canada have expended a tremendous amount of time and energy to investigate and develop non-chemical alternatives that would be effective in forestry scenarios. These efforts have focused on everything from natural regeneration and mulch mats, through biocontrols to using grazing livestock. The Vegetation Management Alternatives Program established by the Ontario Ministry of Natural Resources (MNR) in the early 1990s showed that while some of these techniques have potential for application under very specific conditions, none match modern herbicides, in terms of general utility, effectiveness, reliability, low cost and documented environmental acceptability (Thompson & Pitt, 2011).

Due to long histories of human intervention, the elimination of predators, clearance of land for agriculture, introduction of domestic grazing stock, utilization of forests for wood products, and the introduction of invasive and nonnative species have all disturbed natural cycles of woodland regeneration. As a result, natural regeneration of forests is now less likely to succeed without some form of human intervention. One of the key problems facing young regenerating tree seedlings is competition from weed vegetation for light, water, and mineral nutrients.

Symplastically translocated herbicides (e.g., glyphosate, imazapyr, sulfometuron, and metsulfuron) are rapidly taken up by the plant following application of the formulated product and thereafter translocated to active growing tissues in both the aerial and root structures. As such, they are particularly effective for control of biennial or perennial species which self-propagate from basal sprouts, roots or rhizomes. Plants with this type of reproductive strategy are often the most problematic in forestry, particularly because they tend to be very poorly controlled by mechanical techniques. Often mechanical cutting actually stimulates more extensive growth, thereby exacerbating rather than alleviating competition with more desirable crop species (Thompson, 2011). One potential issue is damage to the crop, triclopyr showed visual symptoms (45% of trees) and glyphosate (17% of trees) was associated with 0.1 – 0.2 m reductions in first-year height (Harrington, Wagner, Radosevich, & Walstad, 1995).

The Fallingsnow ecosystem project conducted in the boreal forest of northwest Ontario is one of the few studies to comparatively examine the ecological consequences of herbicide treatments, including glyphosate, with other methods of vegetation management. In this experiment, treatments included aerial applications of triclopyr ester (Release) at 1.9 kg a.i./ha or glyphosate (Vision) at 1.5 kg a.i./ha with direct comparison to mechanical cutting using either brush saws or tractor-mounted cutting heads. Lautenschlager, Bell, Wagner, and Reynolds (1998) concluded that herbicide treatments had relatively inconsequential effects on most ecological response parameters examined in this boreal forest site. As part of this multidisciplinary study, Simpson et al. (1997) observed no substantial treatment-related differences in the movement of selected nutrients such as total organic N, NH4+, NO3-, K, Ca. Woodcock, Ryder, Lautenschlager, and Bell (1997) assessed the effects on songbird densities as determined by territory mapping, mist netting, and banding and observed 20 to 38 species breeding within various treatment blocks. First year post-treatment assessments revealed that mean densities of the 11 most common species increased by 0.35/ha on the control plots. In contrast, densities on treated plots decreased by 1.1/ha (brush saw), 1.6/ha (Silvana Selective), 0.14/ha (Release) and 0.72/ha (Vision). A point of emphasis here is that essentially any effective vegetation management technique will alter available habitat to some degree. In at least this one study, songbird densities were relatively less impacted by herbicide treatments as compared to mechanical treatments. Response to these habitat changes will vary with species, favoring certain species while resulting in out-migration of other species at least for some period of time. As a single species example, chestnut-sided warbler (Dendroica pensylvanica) had lower ($p < 0.05$) mean densities on the brush saw treated and Silvana Selective-treated plots than on the control plots and fewer ($p < 0.05$) female birds were captured in the first post-treatment year.

Escalating controversy on clear-cutting, herbicides, burning, and grazing has led to a number of different research programs that aim to better understand the relative impacts of each of these interventions. P. M. McDonald and Fiddler (1996) with 40 studies, begun in 1980, compared vegetation management techniques used for enhancing growth of 1- to 3-year-old conifer seedlings. The studies included: manual manipulation, mulching, herbicides, and grazing for releasing conifer seedlings from undesirable vegetation. The authors found that manual release and mulching are effective but expensive. Herbicides are effective, applicable to almost all plant communities, and relatively inexpensive. Grazing is good for cattle and sheep but does not significantly enhance conifer seedling growth. Their conclusions were that, in most instances, productive forests cannot be managed economically without herbicides. A general ranking of the treatments from biologically effective to ineffective following herbicides are large mulches and large-area manual grubbing, mechanical, grazing, small mulches, small grubbed areas, (P. M. McDonald & Fiddler, 2010). If the goal is to create a forest with several age-classes and variable structure, but with slower seedling growth, longer time to harvest, and less species diversity, then it is possible to accomplish this without herbicides and other means of vegetation control (P. M. McDonald & Fiddler, 1996).

Vegetation management practices are an integral component of forest management. Fiddler and McDonald (1990) report results of stand-level benefit–cost analyses of 12 vegetation management treatments applied at six study sites in northern Ontario. The Forest Vegetation Simulator (FVSOntario) was used to project gross total and merchantable volumes to 70 years of age, and BUCK-2 was used to optimize potential products. Net present value (NPV), benefit–cost ratio (BCR), and internal rate of return (IRR) were calculated using 2009 constant dollars and variable real discount rates. Aerial herbicide treatments produced the highest NPV, BCR, and IRR. Internal rates of return of 4.32%, 2.90%, 2.82% and 2.50% for aerial herbicide, manual brush cutting, ground-applied herbicide, and brush cutting plus herbicide treatments, respectively, indicated that all of the vegetation management alternatives evaluated are economically viable (Homagain, Shahi, Luckai, Leitch, & Bell, 2011). Manual release, primarily accomplished using service contracts, is increasingly used by silviculturists for controlling competing vegetation in the West, particularly in California. Over 60 recent manual release contracts on four National Forests and one Bureau of Land Management Resource Area in California were analyzed for production rate and cost relationships. Mean number of acres completed per workday was 0.11-0.50 and the average cost of release was $174-$310 per acre. Grubbing or cutting costs were $0.44-$0.86 per seedling regardless of radius treated. Cutting and grubbing combined cost $0.63-$0.71 per seedling for 3-5 ft radii, and $1.19 for a 6-ft radius. The increased costs resulting from more realistic bidding and the projected unavailability of crews to do the work mean that many acres needing manual release will go untreated (Fiddler & McDonald, 1990).

2.4 Cost and Benefit Assessment

In forest vegetation management programs, herbicide applications are typically made during the establishment phase, considered as the first two to three years of a rotation or until canopy closure occurs. Unlike repetitive applications to the same area year over year in many agricultural cropping scenarios, glyphosate-based herbicides are typically applied only once or twice to the same area of planted forest over a period of ~8 years (e.g., *Eucalyptus* plantations in South Africa) to more than 50 years (e.g., *Picea* plantations in Canada). Most forest regeneration efforts around the world would fail or be severely delayed without effective Forest vegetation management. Worldwide, the influence of competing vegetation has been shown to have both short- and long-term negative impacts on timber production (Wagner et al., 2006). Risk estimates are generally expressed based on probability of occurrence either quantitatively or categorically as low, moderate, or high. What constitutes a low or acceptable risk probability is a matter of judgement and requires consideration not only of risk, but also of benefit (Klaassen, 2013) and is to some degree at least inherently subjective. In the case of glyphosate, a multitude of independent scientific reviews and regulatory risk assessments exist and commonly conclude that glyphosate-based herbicides, when applied in accordance with the product label and applicable best management practices, do not pose a significant risk to human or environmental health (Rolando et al., 2017).

Following harvest, numerous pioneer plant species, which are well-adapted to disturbed sites and open growing conditions, easily outcompete newly planted crop tree seedlings. Reduced crop growth or outright crop failure will occur if weeds are not controlled effectively. Of course in contrast to the home garden, the scale at which forestry operations occur makes hand-weeding highly impractical (Thompson & Pitt, 2011). Wagner et al. (2006) recently reviewed results from 60 of the longest-term studies in Canada, the USA, South Africa, Brazil, New Zealand, and Australia, documenting that the majority of studies show 30% to 500% increases in wood volume as well as reduced rotation periods from effective vegetation control treatments. Positive outcomes are reflected in significantly enhanced regeneration success and overall sustainable management of forest resources.

2.5 Comparison between herbicide use, other interventions, and no intervention

2.5.1 Volume gains in northern forests

MacLean and Morgan (1983) in northern New Brunswick reported on one of the earliest studies on herbicide release in northern forests. Phenoxy herbicides were used to release young balsam fir compared with those that were manually cleared and with those that received no treatment. The herbicide treatments were applied in 1953 and the plots remeasured in 1981. The total stem volume of balsam fir was 265% and 157% greater for 2,4-D and 2,4,5-T respectively in herbicide treated plots and 64% for manually treated plots compared to control plots.

Pitt, Wagner, and Towill (2004) investigated ten-year growth responses of planted black spruce and associated vegetation were studied for 10 years following several competition release treatments on two sites in northeastern Ontario. Five growing seasons of annual vegetation removal using repeat applications of glyphosate herbicide produced nearly complete domination by spruce with 111% and 477% increases in individual tree stem volume relative to that of untreated plots. The degree of stem volume gain among treatments was positively correlated with the level of vegetation control during the first few years after treatment.

Daggett (2003) examined the effects of aerial herbicide application and Pre-Commercial Thinning (PCT) on long term stand development of red spruce and balsam fir in Maine. This study, initiated in 1977, was an examination of the commonly used herbicides (glyphosate and triclopyr) in North America. The proportion of wood volume in 29-year-old balsam fir and red spruce was substantially increased by herbicide treatment. Among 14 herbicide treatments tested, softwood composition was 74% in herbicide-treated plots compared with 23% in untreated plots. Softwood volume was increased by 171% in herbicide-only plots relative to untreated plots. When including only glyphosate and triclopyr, merchantable softwood volume increased 264% above untreated plots. The effect of the herbicides was enhanced further if the stands were later subjected to forest stand improvement practices such as selective cutting. When herbicides and stand improvement were used in combination, merchantable softwood volume at 29 years was 411% greater than the untreated controls.

Ramsey, Jose, Brecke, and Merritt (2003) investigated the use of herbicides and fertilizer to accelerate the emergence of longleaf pine seedlings out-of-the-grass stage to replace prescribed fire as the preferred management practice in plantations. Longleaf pine survival was highest for the weed control (84%) and lowest for the fertilizer (53%) treatments. This pattern was repeated for root collar diameter (RCD) and height growth. Seedling height for weed control and control treatments were 33.4 and 13.4 cm, respectively, at the end of the second growing season. Herbaceous weed control during the early establishment phase appears to be critical in accelerating height growth of longleaf pine seedlings.

Nicholson (2007) reports that herbicide use was discontinued by Stora Enso 1998, raising concern about the performance of Stora Enso plantations in the absence of chemical weeding. Competition in plantations in Nova Scotia can be severe and the growth and survival of planted seedlings can be adversely affected if not released. The performance of plantations also has implications on future wood supply projections. The intent of this report was to summarize how these plantations have performed. Unfortunately, only 3% of the area surveyed met both the stocking and free-to-grow criteria for a successful plantation. Another 10% met the criteria of an adequately stocked plantation but requires maintenance. The remaining 87% of the area surveyed were considered unsuccessful plantations.

Dampier, Bell, St-Amour, Pitt, and Luckai (2006) reports on research conducted in the Fallingsnow Ecosystem Project in northwestern Ontario, Canada. The objective was to determine the relationship between release treatment costs and planted white spruce stem volume ($ m^{-3}) ten years after alternative release treatments. Treatment cost estimates for 2003 were calculated by applying 1993 time-study data to estimated 2003 market costs for each treatment component. The most cost-effective treatment was the aerial application of herbicide Vision ($12.16 m^{-3}), followed by the aerial application of herbicide Release ($12.18 m^{-3}), cutting with brushsaw ($38.38 m^{-3}) and mechanical tending ($42.65 m^{-3}). No cost differences were found between the herbicide treatments ($p = 0.998$) or between the cutting treatments ($p = 0.559$). The herbicide treatments were three-fold more cost-effective than the cutting treatments ($p = 0.001$).

2.5.2 Volume gains in Pacific north-western forests

Brodie and Walstad (1987), conducted long-term projections of yield enhancements associated with herbicide treatments. The results were presented in a series of four unreplicated case studies involving Douglas-fir (*Pseudotsuga menziesii*) plantations in western Oregon. Growth and yield projections from herbicide-treated and untreated sites indicated that early differences in stand development translated into 60 % increases in merchantable volume at the end of a typical Douglas-fir rotation (60 – 75 years) for three of the four cases. The increase in merchantable volume at 60 years for the fourth case was 15% greater than for untreated sites.

Monleon, Newton, Hooper, and Tappeiner (1999) showed herbaceous vegetation control was achieved by a single application of glyphosate following planting, with shrub seedlings covered and demonstrated a doubling of Douglas fir stem volumes at year 10 in western Oregon; removal of herbaceous vegetation after planting significantly increased tree diameter, height, and volume. Stein (1995) found that site preparation using herbicides on four sites in the Oregon Coast Range resulted in a 272 % increase in the Douglas-fir stem volume per hectare after 10 years when survival was taken into account. Powers, Young, and Fiddler (2005), examined 28 years of growth response by ponderosa pine in northern California following herbicide treatment and nitrogen fertilization. Results from the same experiment on two soil types revealed a 580% and 78% increase in stand volume from vegetation removal alone. Lanini and Radosevich (2003), examined 21 years of growth for three conifer species after three site preparation treatments and 2 years of follow-up release treatments in northern California. Brush raking followed by up to 2 years of herbicide release increased the volume growth of ponderosa pine and California white fir by 3035% and 1712%, respectively, relative to the control, a hydro-ax site-preparation treatment and no release.

Powers and Reynolds (1999) conducted another study with ponderosa pine (*Pinus ponderosa*) on three northern California sites, known as the ‘Garden of Eden’ experiment, where they Compared the effect of various combinations of herbicide, insecticide, and fertilizer treatments on 10-year volume growth. Herbicide application had the strongest influence on plantation growth among the three treatments, increasing volume by 270%, 173% and 59% above the untreated control on each of the three sites.

Hanson (1997) Used 14-year measurements from a southwestern Oregon study, investigating the impact of herbicides on the stem volume of individual ponderosa pines. The volume was approximately 464% higher on plots without vegetation than when shrubs and hardwoods were maintained at a high density.

2.5.3 Volume gains in south-eastern forests

Michael (1980) provided one of the first reports of long-term gains 20 years after 2,4,5-T aerial release to longleaf pine. Treated plots, had significantly greater tree diameter (10%), taller trees (17%), and more merchantable tree volume/ha (40%). Merchantable tree volume differences 20 yr after treatment represent an 8 yr growth advantage for treated plots.

Martin and Shiver (2002) conducted another region-wide site preparation study with loblolly pine (*Pinus taeda*) including 25 locations across South Carolina, Georgia and Alabama. The treatments included total vegetation (woody and herbaceous) control with herbicides, a typical site preparation treatment including herbicides and two other mechanical treatments. Average 12-yr-old merchantable volumes (ft^3/ac) across all locations by treatment were: burn (846); chop and burn (1,445); shear, pile, and disk (1,740); chop, herbicide, and burn (1,669); herbicide and burn (1,919); and herbicide, burn, and complete vegetation control (2,546).

A set of comprehensive studies examining yield enhancements from Forest Vegetation Management was conducted (Miller, Zutter, Newbold, Edwards, & Zedaker, 2003; Miller, Zutter, Zedaker, Edwards, & Newbold, 2003; Zutter & Miller, 1998; Zutter et al., 1999). The same experimental design was replicated in 13 plantations across seven southern states and four physiographic provinces of the region. Loblolly pine plantations were monitored for 15 years (or over 60 %) of the typical 24-year pulpwood rotation. A combination of two woody control treatments (no woody control vs complete woody plant control) and two herbaceous control treatments (no herbaceous control vs complete herbaceous plant control) was established. Herbicides were used before planting and annually through crown closure (3 – 5 years after planting) to establish and maintain the treatments. Controlling both woody and herbaceous vegetation increased merchantable wood volumes by 67 % (range among sites was 30 – 148 %) above that on plots that were only site prepared. Control of only woody vegetation increased merchantable pine volume on 11 sites by 14 – 118 % and gains on treated plots increased as hardwood and shrub abundance increased on the check plots. Gains from early control of only herbaceous vegetation (leaving woody vegetation) were somewhat less, increasing only 17 – 50 % on 10 sites (Miller, Zutter, Zedaker, et al., 2003).

Borders and Bailey (2001) studied intensive treatments for loblolly pine plantation management at six sites in Georgia. After intensive mechanical site preparation and planting high-performance seedlings, continuous vegetation control increased merchantable volume through ages 10 – 12 years from 37 – 122 %. Adding repeated fertilization further enhanced yields. With such interventions the authors concluded that growth rates were comparable to those obtained at other high biomass production areas for loblolly pine throughout the world (e.g., South Africa, Brazil, and Australia).

Glover, Creighton, and Gjerstad (1989) found that regularly controlling herbaceous vegetation using herbicides from planting to crown closure in young loblolly pine stands increased merchantable volume after 12 years by 33, 96 and 131 % on three sites in Arkansas and Mississippi.

2.5.4 Volume gains in Australasia

Effective weed control is an essential management task in establishing commercial tree plantations. Much of current weed control strategy employed in Australian forestry relies on the use of available herbicides. However, given community concern regarding the use of herbicides, investigation of alternative weed control methods is warranted. George and Brennan (2002) tested the ability and cost-effectiveness of mechanical (hand weeding and inter-row slashing), mulching (sawdust over newsprint, woodchips, and jute), cover crops and herbicide applications for weed control in establishing eucalypt plantations. Jute matting and herbicide treatments reduced weed competition and increased seedling growth to age 2 years in plantations of Eucalyptus in northern NSW, Australia. Growth increased by 269% with both treatments, 196% with the Jute and by 216% in the Herbicide treatments when compared to the control at 2 years age. The Jute material deteriorated, after nearly 2 years, weed cover increased and there were significantly more weeds present in the Jute treatment compared to the Herbicide treatment. Jute matting costs approximately 15 times more than the herbicide regime used and, therefore, could not presently be considered a viable option for weed control in commercial *Eucalyptus* plantations. Other weed control treatments included: hand weeding, sawdust, woodchip mulches, slashing and sowing cover crops, all of which did not effectively control weeds and did not improve survival or increase seedling growth to age 2 relative to the control. The authors conclude that herbicides remain the most cost-effective weed control option available to commercial growers of *Eucalyptus* plantations.

2.6 Question: Are herbicides harmful to humans and wildlife?

The degree to which a toxicological effect is expressed depends on exposure or dose, both in terms of the actual amount and the time frame over which it occurs. In simple terms, if there is no exposure, there can be no dose, and therefore no effect. One of the most important parameters is exposure. Best management practices are designed and used such that application rates, techniques, and mitigation strategies (e.g., buffer zones) ensure a high probability that exposure levels for wildlife species are below toxicological effect thresholds while at the same time sufficient to achieve silvicultural objectives (Thompson & Pitt, 2011).

Herbicides are used only a few times over a 15–30 year rotation in commercial forestry, often- causing exposure to be generally be low. This means that acute toxicity and teratogenicity are the endpoints of greatest concern, as these endpoints can be affected by a single exposure or exposure for a short period of time. Endpoints associated with chronic toxicity, reproductive effects, and carcinogenicity are less relevant to silvicultural herbicide use because they are more likely to be associated with multiple exposures occurring over a longer period of time (V. L. Tatum, 2004). In addition, where the low toxicity of these products and their metabolites combined with consistent dissipation and low mobility suggest that toxic hazard of their use need not be a matter of serious concern to humans, terrestrial wildlife, or aquatic systems. They are safe for use in management and rehabilitation of boreal forests when used properly (Newton, Cole, & Tinsley, 2008). Honeybees are classified as a beneficial insect and U.S. EPA requires manufacturers to evaluate toxicity of their products to honeybees. Glyphosate, hexazinone, imazapyr, metsulfuron, sulfometuron, and triclopyr are all considered nontoxic to honeybees (Kamrin, 1997). A recent review (Belsky and Joshi 2020) identified the need to fill knowledge gaps for additional bee species, more realistic exposure scenarios, sublethal effects, and indirect reduction of floral resources.

In oral acute toxicity tests with mammals, U.S. EPA considers pesticides with LD50 values of greater than 5,000 mg/kg body weight to be practically nontoxic and those with LD50 values of 500–5,000 mg/kg body weight to be slightly toxic (Table 7).

However, the International Agency for Research on Cancer (IARC, 2015) declared that glyphosate has a potential risk to humans. This declaration has been challenged by numerous scientists and regulatory risk assessment agencies worldwide. The European Food Safety Authority (2017, 2015) assessments concluded that the weight of evidence indicates that glyphosate does not have endocrine disrupting properties through oestrogen, androgen, thyroid, or steroidogenesis modes of action (EFSA, 2015, 2017). Accordingly, the Canadian Pest Management Regulatory Agency (PMRA) and the US Environmental Protection Agency found that products containing glyphosate do not present unacceptable risks to human health or the environment when used according to the proposed label directions (EPA, 1993; PMRA, 2915). Analysis of a comprehensive toxicology database by a special joint working group of the Food and Agriculture Organization of the United Nations and the World Health Organization (JMPR, 2016), all concluded that glyphosate uses are unlikely to pose an actual risk of carcinogenicity or any other toxic effect to humans.

The mechanism of action for glyphosate involves blockage of a specific enzyme (5- enolpyruvyl-shikimate-3-phosphate synthetase or EPSPS) in the synthesis of aromatic amino acids. This biosynthetic pathway exists in both plants and microorganisms but not in higher animals. Owing to its highly plant-specific mode of action, direct effects of glyphosate on animals generally require much higher dose levels than would be typically encountered, thus conferring a substantial level of safety for many wildlife species that may be potentially exposed (Thompson, 2011).

Glyphosate has an innately low toxicity to animals and is one of the least toxic pesticides to animals. Accordingly, it is used for weed control throughout the world in urban and recreational areas, as well as on industrial and agricultural land. Glyphosate is less acutely toxic than common chemicals such as sodium chloride or aspirin, with an LD50 for rats greater than 5 g kg−1. Some formulation materials and cationic salt ions used with glyphosate are more toxic than the glyphosate anion. Glyphosate is not a carcinogen or a reproductive toxin, nor does it have any subacute chronic toxicity (Duke & Powles, 2008). In a lengthy review, (Williams, Kroes, & Munro, 2000) conclude that, when used according to instructions, there should be no human health safety issues with glyphosate.

Thompson (2011) shows results of a tiered research program indicating that aerial applications of glyphosate (Vision), as typically conducted for conifer release in forestry, do not pose a significant risk of acute effects to the most sensitive aquatic life stages of native amphibians in forest wetland environments. The conclusion was consistent with specific risk assessments for formulated glyphosate products in aquatic systems (Solomon & Thompson, 2003).

Glyphosate is used at infrequent intervals in planted forests and at rates not exceeding 4 kg ha^{-1}. It is used within legal label recommendations and applied by trained applicators. While the highest risk of human exposure to glyphosate is during manual application (not aerial) when applied according to label recommendations, the risk of exposure to levels that exceed accepted toxicity standards is low. Based on the extensive available scientific evidence it is concluded that glyphosate-based herbicides, as typically employed in planted forest management, do not pose a significant risk to humans or terrestrial and aquatic environments (Rolando et al., 2017).

2.7 Use Patterns

In countries with large areas of natural forests (e.g. Canada, Russia, USA), pesticides are applied to only a very small proportion of the forest land base that is managed for commercial production of high value products such as sawn wood, panels or pulp and paper. In other countries (e.g., New Zealand, Australia, Finland, Sweden, and southeastern USA) relatively more intensive “plantation” management may be employed for the same general purpose and some situations of more intensive management occur in most countries (Thompson, 2011). It needs to be noted that use statistics are snapshots in time and use patterns change annually.

Herbicides are applied under two different strategies, either prior to planting (chemical site preparation) or after seedlings are planted (tending or release). Owing to the remoteness and difficult access characteristic of many treatment sites, and the cost-effectiveness of the technique, aerial application using either fixed-wing, or rotary wing aircraft, is the most common method of applying herbicides to target sites. Typically herbicides are applied within the first five years postharvest and any given site receives one or maximally two treatments in a rotation period of 50-80 years depending upon crop species and site quality (Thompson & Pitt, 2011).

Glyphosate-based herbicide use in planted forest management varies with region or country internationally. Actual rates of glyphosate use in planted forest management internationally (mainly as formulated products containing the isopropylamine salt) range from 0.3 to 3.5 kg active ingredient (a.i.)

per hectare. Higher rates are typically applied only on particularly difficult to control competitor species or on particularly productive sites where competitive advantage goes to pioneer plant species that establish quickly following opening of the canopy and/or site disturbance (C. A. Rolando et al., 2017).

Application rates reported in forestry were very low, in the range of 0.0001 – 0.6 kg active ingredient (a.i.) ha^{-1} yr^{-1}. By comparison, average application rates in agriculture were in the region of 0.3 – 1.84 kg a.i. ha-1 yr^{-1}. Use in forestry was usually less than 1 % that of agriculture on an annual area basis (Willoughby, Balandier, Bentsen, Mac Carthy, & Claridge, 2009).

2.7.1 New Zealand

New Zealand has a land area of 26.7 x 10^6 with almost 28% of its land area forested including 1.2 x 10 ^{6} ha of plantations. Plantation forestry is mainly radiata pine 1.1 x 10^6 ha, the second species is Douglas-fir followed by other conifers and eucalyptus (Richardson, 1993). An estimated 7% of the total area planted to forestry (1.8 million ha) was treated annually with herbicide (125,000 ha). This equates to a use rate of herbicides across the forest sector of 0.25 kg $ha^{-1}$$year^{-1}$with the predominant active ingredients being terbuthylazine (40%), glyphosate (39%) and hexazinone (10%). In a 2002-2003 study, authors indicated herbicides were the most common pesticide used in forestry, with an estimated 405 tonnes of active ingredient (a.i.) applied, followed by fungicides, with an estimated 54 tons of copper applied (Manktelow et al., 2005)

Glyphosate is one of the most important herbicides used for the management of competing vegetation in forests prior to commercial tree planting, with very limited use post-planting(i.e., it is typically applied once in a rotation of 25 to 30 years). Glyphosate is applied, almost exclusively, aerially in late summer and early autumn, in combination with metsulfuron methyl, at respectively ~3.5 kg a.i. ha^{-1} and ~0.12 kg a.i. ha^{-1} in 150 L water. Fourty-two percent of total glyphosate use is associated with management of vegetation in planted *Pinus radiata* forests, with the remainder used in the horticultural and pastoral farming systems. This equated to an annual loading of ~0.27 kg a.i. ha^{-1} yr^{-1}, and was the second lowest in terms of intensity across four sectors (pastoral farming, arable farming, forestry and horticulture), with much higher annual loadings recorded for horticulture and arable farming (13.19 kg a.i. ha^{-1} yr^{-1} and 2.43 kg ha^{-1} yr^{-1}). Similar figures for annual herbicide use in forestry were estimated by Rolando, Garrett, Baillie, and Watt (2013) with the three most intensively used herbicides identified as terbuthylazine, glyphosate and hexazinone.

Rolando et al. (2013) conducted a survey of pesticide use in planted forests showing that glyphosate was the most widely used active ingredient in pre-plant weed control with terbuthylazine and hexazinone used most widely for post-plant weed control. Together these herbicides comprise 90% of active ingredient that is annually used. Average aerial application rates for these three active ingredients were estimated at 3.3 kg ha^{-1}, 7.0 kg ha^{-1} and 1.8 kg ha^{-1}, respectively. Use of terbuthylazine and hexazinone is restricted on FSC-certified forests subject to derogation.

Environmental certification has resulted in a shift from broadcast application of terbuthylazine and hexazinone to greater use of spot weed control in the first year after tree planting. Spot weed control can reduce the amount of active ingredient used by up to 89%. Non-chemical weed control is not widely used by the forest industry as it is not as cost-effective as current herbicide regimes. A review of the literature indicated that, when used operationally and according to label registrations, these herbicides are unlikely to have any negative impacts on the planted forest environment. Although they have been detected in groundwater, under multiple land uses, concentrations were at levels below documented safe drinking standards. There are limited data for forest soil and no data on the effects of these herbicides on aquatic biota in New Zealand. (Rolando, Baillie, Withers, Bulman, & Garrett, 2016) Pesticides are used in forests because they generally represent the most cost-effective tool for managing insect pests, diseases and weeds. An economic assessment was conducted of the potential financial impact to the industry of a switch to non-chemical methods of weed control, including manual and mechanical. The substantial cost to industry of non-chemical weed control highlighted in that assessment provided justification for the continued use of herbicides and the need to find alternatives to those listed as highly hazardous (Rolando, Watt, & Zabkiewicz, 2011).

2.7.2 Australia

Australia covers an area of almost 770 x 10^6 ha and has approximately 5.3% of its land area covered in forests of which 942,000 ha are planted forests; most are comprised of conifers the primary species is *radiata pine* (70%) (Richardson, 1993). Pesticide use in plantation forestry in Australia accounts for only 0.7% of the total annual national expenditures on pesticides. The latter report presents detailed analysis of pesticide expenditures in agricultural crops as compared to forestry. Results emphasize the dramatically higher use frequency and hence expenditures associated with pesticide use in agricultural crop production. To a large degree, this reflects the common practice of multiple pesticide applications on an annual basis to much of the agriculture land base. In contrast, individual forest stands rarely, if ever receive annual pesticide treatments and frequency of use is typically quite low. Even under intensive forest management regimes, the total number of pesticide applications during a rotation period is unlikely to exceed four; that is two herbicide treatments in the early regeneration phase and two insecticide treatments when trees are semi-mature to mature. However, rotation periods vary markedly with forest crop species ranging from as little as 8 to 10 years. For example, in short rotation *Eucalyptus* plantations of Australia, to 80 years or more for spruce stands in the boreal forests of Canada (D. Thompson, Chartrand, Staznik, Leach, & Hodgins, 2010).

In Australia, glyphosate is principally used in pre-plant vegetation control operations in both softwood and hardwood planted forests, with limited use post-planting. The herbicide is mainly broadcast via ground based machine or by helicopter, with use of hand-spraying limited to buffers, right-of-ways, and sensitive boundaries (Jenkin & Tomkins, 2006). The maximum label rate is 3.36 kg a.i. ha^{-1}, with use rates generally not exceeding 2.88 kg a.i. ha^{-1}. While no published data on the total amount of glyphosate used in planted forests in Australia was available it was estimated that use of glyphosate in Australian planted forests was in the range of ~200 to 250 tonnes annum (Rolando et al., 2017).

2.7.3 South Africa

In 2017-18 herbicide information was obtained from 46 timber plantations owned by six forestry companies, comprising 343,872 ha surveyed. A total of 188,288 kg (or 0.55 kg ha−1) of herbicide active ingredient (a.i.) was applied in the area surveyed. Glyphosate-based products accounted for 97% of all the herbicides applied, and metazachlor and triclopyr butoxy ethyl ester accounted for 2% (Roberts, Little, & Rolando, 2021). Competing vegetation in South Africa is controlled through a combination of physical control (manual hoeing or slashing) and application of herbicides. The predominant herbicide used is glyphosate, where in South Africa, forestry accounts for 4% of the total glyphosate used (Gous, 2014). Glyphosate applied as a pre-plant spray may be sprayed aerially (seldom), or manually using knapsack sprayers (more common) at 1.76 to 2.32 kg a.i. ha^{-1} (Little & Rolando, 2012). All post-planting applications of glyphosate are via knapsack sprayers, either as a broadcast or directed/spot application depending on the size of the trees (Little & Rolando, 2008; Rolando & Little, 2009). Between planting and canopy closure (<2 years), a eucalypt pulpwood stand will typically receive one broadcast application of glyphosate (with cones for tree protection), followed by two to three directed applications (Little & Rolando, 2008). The duration of vegetation control in pine compartments is typically longer due to slower initial tree growth, requiring an additional two directed spot sprays in years three to five (Rolando & Little, 2009).

2.7.4 Canada

Half of Canada (418 million ha) is covered by forest and currently holds about 10 per cent of the world's forest area and 30 per cent of the world's boreal forest (Natural Resources Canada, 2004). Approximately 28 per cent (119 million ha) is currently managed for timber production. Canada for the 2015 reporting year, national use statistics demonstrate that approximately 765,269 ha (~0.2% of the productive forest land base) was harvested to derive economic benefits. More than half of this harvested area (436,715 ha) was replanted, with the remainder being allowed to regenerate naturally. In this same year, only 105,811 ha were treated with a chemical herbicide, 94% of which was treatment with the herbicide glyphosate and almost entirely on the planted forest area (Silviculture, 2015)

Herbicides are typically used in Canadian forest vegetation management only where conifer crops (e.g., spruce and pine species) are to be regenerated and grown for products such as lumber, paper, and wildlife habitat. Herbicides, play an important role in maintaining a viable wood supply for economic purposes and also contribute to an appropriate balance of conifer, deciduous, and mixed stands across the forest landscape (Thompson, Martin Del Campo, & Constenla, 2020). There are five herbicide active ingredients registered for use in Canadian forestry (glyphosate, triclopyr, hexazinone, 2,4-D and simazine) and of those glyphosate-based herbicides account for more than 96% of the forest area treated in the past decade.

Recent trends in operational practice include a move toward more intensive management on higher quality sites and adoption of innovative approaches (e.g. nutrient loaded seedlings, larger planting stock) and advanced technologies (e.g. electronic guidance in aerial herbicide applications). The lack of long-term growth response data and economic analyses demonstrating positive cost/benefits remain as shortcomings, however continued development of the program will undoubtedly enhance sustainable wood supply and minimize impact on the forest environment.

The total proportion of the productive forest land base treated is also an important consideration in ecotoxicological risk assessments. Again, on a comparative basis, agricultural food crop production often involves essentially 100% of the land base receiving at least one pesticide treatment each year, whereas production of fiber typically involves pesticide application to only a very small proportion of the commercial forest land base annually. While these statistics vary with jurisdiction, year and pesticide type, the point is well exemplified by herbicide use in Canadian forestry where <1% of the commercial forest land base is treated in any given year (Thompson, 2011). In Ontario, which has historically treated the most forest area of any province on an annual basis, ~ 70,000 ha are treated each year, an area essentially equal to the area planted. This equates to approximately one-third of the area harvested annually or about 0.28% of the total productive forest land base in the province. The typical use rate for glyphosate in conifer release programs in Ontario was 1.9 kg /ha (Thompson & Pitt, 2011).

Campbell (1990) found that in 1988, 217,825 ha were treated with herbicide for forest management purposes, 76% of the herbicide was applied aerially and 85% of that was for release. If only herbicides with an aerial registration (2,4-D and glyphosate) are considered, the percentage increases to 81. Tending, rather than site preparation, was the most common reason for herbicide treatment (85% vs 15%). In New Brunswick, 100% of the application was aerial. In Ontario, 97% of the 2,443 and glyphosate was applied aerially. Clearly, aerial application is the preferred method of applying herbicides for forest management in Canada. Glyphosate was used by all of the provinces that used herbicides and accounted for 81% of the total. The fact that glyphosate controls a wider range of species, plus the lack of controversy associated with it at that time, allowed it to capture much of the forestry market previously held by 2,4-D. In addition to odor, two other factors have made 2,4-D controversial: it was a component (along with 2,4,5-T) of Agent Orange, and there have been studies purporting to demonstrate health effects on workers. In Ontario, from 2001-2005, the area of Crown forest regenerated ranged from 180,381 to 240,435 hectares per year but only 32.6 to 38.4% of the area received a chemical tending treatment.

Interestingly, Quebec banned the use of glyphosate in forestry in 2001 and replaced herbicide use with thinning crews. Eight out of the 10 provinces in Canada have some form of restriction on the use of glyphosate. Vancouver banned private and public use of glyphosate, and in June of 2019, New Brunswick officials announced that the province would reduce glyphosate spraying in certain areas with more regulation to follow. It is not clear however what that means for forestry considering its widespread use.

2.7.5 United States

One-third of the land area in the United States of America (302 million ha) is covered by forest (Smith et al., 2001). Forty-two percent of US forestland is publicly owned, either by individual states or the federal government. Of the total forest area, 67%(204 million ha) is classed as timberland capable of producing more than 1.4 m^3 ha^{-1} a^{-1} and not legally restricted from timber harvesting. Eleven percent of US timberlands are plantations, with two-thirds occurring in the southern states (Smith, Vissage, Darr, & Sheffield, 2001). During 2011, respondents to a survey about herbicide use on industrial forest land reported application of herbicides to 4.4% of the total area under management in the USA. By USA region, respondents applied herbicides to 0.26%, 2.6%, and 5.6% of the total area under management in the North, Pacific Northwest, and South, respectively (Weatherford, Tatum, & Wigley, 2015).

For aerial applications, survey respondents reduced drift by adjusting droplet sizes and boom/rotor ratios, limited application height, buffered treatment areas with untreated strips, observed meteorological limits, and used other practices. The most widely used application method in each region was broadcast via helicopter (78.4% - 97.6% of area treated). Of survey respondents, 90.5% made three or fewer applications during a typical rotation, 55.2% made two or fewer applications. Respondents applied herbicides to, 4.4% of the total area under management, 99.7% of which was planted softwood forest. Within the USA during 2011, imazapyr was the most widely applied herbicide followed by sulfometuron methyl, metsulfuron methyl, glyphosate, triclopyr and hexazinone. Most active ingredients were applied at concentrations well below the per hectare maximum allowed by their labels. Considering applications of atrazine, aminopyralid, and clethodim, for example, only 2% was applied at rates between 70% to almost 100% of the maximum label concentration, on the remaining 98% of the area treated, concentrations per hectare were about 10-65% of label maximums (Weatherford et al., 2015).

2.8 2009 European Union Directive and Derogations

The 2009 EU Directive on the sustainable use of pesticides, effectively banned the application of pesticides with aircraft (manned or unmanned) but the majority of Member States (MS) have exemptions or derogations that allow aerial application. Exemptions are considered where there are clear benefits for human health or the environment and there are no viable alternatives (2009/128/EC). Currently unoccupied aerial spray systems (UASS) with a gross mass of < 150 kg are not covered by the EU regulation meaning the matter is turned over to the MS.

Where an EU country does allow the manned application of pesticides by air the following are required:

- The pilot must have an up to date pilot's license and health certificate.
- Those who apply any type of pesticide with an aircraft are required to be certified and licensed in the category of aerial pest control.
- All aircraft used to apply or dispense any pesticide, fertilizer, or seed product must be registered annually with the relevant Department of Agriculture and to do this the aircraft must have an airworthiness certificate.

- All aircraft must be secured when not in use. This means keeping the aircraft within a locked building, or mechanically disabled from flying, or use of any other reasonable method which prevents or deters theft or unauthorized use.
- All pesticides and fertilizers on the premises owned or controlled by any aerial applicator must be stored and maintained so they are not accessible to unauthorized persons.
- Aerial applicators to keep records of what pesticide was applied, where, by what means, how much and when.

All 28 MS's have prohibited aerial spraying, even if this is not explicitly stated in their National Action Plan's (NAP). Twenty-one MS's allow for the possibility of derogations, and in 2015, at least nine MSs granted derogations covering just over 450 000 ha. France granted derogations, but did not provide data on the treated areas, and the responses of Bulgaria, Czech Republic, Greece, Romania, and the UK to the questionnaire lacked reports of the area sprayed. Spain (339 000 ha) and Hungary (88 000 ha) accounted for almost 95 % of reported aerial spraying in the EU in 2015 (Commission, 2017; EU, 2017).

Underneath the 2009 Directive each member state must produce a NAP containing quantitative objectives, targets, measures, and timetables to reduce risks and impacts of pesticide use. The NAP should also encourage the development and introduction of IPM and of alternative approaches or techniques to reduce dependency on the use of pesticides. Aerial applications are rarely a part of these action plans. The primary focus of NAP's is applicator training, testing of new and used equipment to meet country wide standards and the minimization of Highly Hazardous Pesticides (HHP). It is difficult to compare the NAP's of Member States because each country is very different. For example, the German NAP does not address sprayer testing, as Germany has required testing of field sprayers since 1993.

In all six MS's discussed in the report on the sustainable use pesticides of the European Commission (2017), aerial spraying had been restricted, prior to the Directive. Consequently, the area treated by aerial application of pesticides had fallen dramatically over the last twenty years and continues to decline. Germany has granted derogations for aerial spraying in steep slope vineyards along the Upper Middle Rhine valley to control fungal diseases, and in forestry to control insect pests. Italy also has granted derogations for aerial spraying in steep slope vineyards and forestry, while Poland has granted derogations in forestry. In all three MSs, the derogations are granted only in cases where there are no viable alternatives and are subject to a range of strict conditions. In the case of vineyards, the slopes are so steep that there are significant health and safety issues around the application of pesticides using tractor mounted sprayers.

The German Competent Authorities (CA’s) stated that vine growing on the terraces of the Upper Middle Rhine valley, which is integral to its classification as a World heritage site, is not possible without the use of fungicides. The Polish CAs highlighted that tractor sprayers cannot apply pesticides to treetops, which is necessary to control certain pests, and the CA’s view is that failure to control these pests would result in the death of the trees. The Italian CAs emphasized that all requests for aerial spraying in forestry were supported by a range of technical data and in most cases, non-chemical products containing Bacillus thuringiensis were used to control the pests. In Germany and Poland, in all cases where permits are granted, assurances on the safe use of pesticides are provided from control documents that verify that the conditions of the permits were adhered to (Commission, 2017; EU, 2017).

Although not reported to the EU, within the UK, the Application Plan must be completed by aerial spraying operators, with templates available on the website of the Health and Safety Executive. The national restocking and new planting levels are around 27,000 ha per annum across the UK. For the sites where herbicide use is necessary as a last resort, the main options currently available to forest managers in the UK are propyzamide, glyphosate or cycloxydim. Assuming 5% of sites might be treated, and 50% might fail without treatment, this could lead to 700 ha failing each year, leading to replanting costs of up to £1 million per annum. There would also be loss of increment and an increased period in the establishment phase.

The stakeholders’ opinions on a general ban on aerial spraying in the EU have been strongly divided. Generally, industry, foresters, and farmers, opposed a general ban and favored a more flexible approach (e.g., the introduction of legally binding minimum requirements for the use of aerial spraying). Environmental NGOs, consumer groups, and individuals, such as academics and citizens, were supportive of a general ban, if not a total ban. Over the course of the consultation process the voices of those against a general ban were better represented than those in favor of a restrictive ban. However, despite this widespread opposition, the European Commission still decided to use the terminology of a general “ban” in its proposal for a directive submitted to the European Parliament and the Council in 2006 (Zwetsloot, Nikol, & Jansen, 2018). It is felt by many that the ban in the EU has led to a reduction in the volume of chemicals applied by air but that it also means that appropriate training and equipment inspections may suffer consequently. In the UK a detailed guidance was prepared to record the Forestry Commissions remaining expertise on aerial spraying of forests before it is lost to the organization (Willoughby, Evans, & Jones, 2013).

Part III Summary and Discussion

3.1 Available Reference Best Management Practices (BMPs) and Guidance

The State of Maine requested that recommendations be made as to the safety of aerial forestry herbicide operations considering risk to the public at large. The State also requested that recommendations to lower risk be made in the form of BMPs and/or operational regulation.

The authors of this report find nothing that would contradict the opinions of USEPA and others as expressed on the herbicide labels that aerial application of herbicides can be used safely in this situation without causing undue risk to humans or the environment when applied following label guidelines. The State of Maine has developed additional guidance as given in Maine Board of Pesticide Control's (BPC) 'Guidance for the Application of Pesticides in Forest Settings in Order to Minimize the Risk of Discharges to Surface Waters'. This document references Maine Rule 01-026-22 Code R. 3 'Standards for Aerial Application of Pesticides'. These standards are conservative and show a comprehensive understanding of aerial application as precision agriculture that can be regulated accordingly. The understanding of aerial spray physics as outlined in Part I of this document is demonstrated in the guidance given by the State of Maine.

There are two other standards that can be invoked. The Maine guidance already emphasizes the role of label guidance as law in the application of pesticides. The National Association of Aerial Applicators (NAAA) also has detailed BMPs for the aerial application of pesticides. This group has been very proactive in addressing pressure on the industry brought both by environmental regulators and by the insurance industry. Their handbook 'NAAA Professional Operating Guidelines' (Anon, 2014). is a comprehensive operational guide and could be invoked as a detailed set of operating guidelines that would nest under label guidance and the guidance laid out by the State of Maine in the documents mentioned above. Any proposed deviation from the NAAA Guidance could be filed as part of the required Spray Plan and reviewed by BPC.

There is also an international standard ‘Agricultural and Forestry Machinery- Environmental Requirements for Sprayers Part 5- Aerial Sprayers’ (Anon, 2021). This international standards organization (ISO) standard has been in development for 10 years or so but should be published within the next year. ISO is based in Geneva, Switzerland, has great integrity, credibility and independence and this standard could be used in a similar fashion to the NAAA guidelines allowing BPC to review deviations.

3.1.1 SCS Global Services Report Review

The State of Maine commissioned an independent audit of aerial herbiciding practice in Maine forestry. This audit utilized a checklist that contained upward of 200 individual questions and compiled data. The firm contracted with was specifically selected for their independence and expertise in forestry. The conclusions of this report were that aerial applicators in Maine forestry, along with the contracting organizations, acted with professionalism, were well informed regarding safe practice, risk minimization, and were meeting all legal and regulatory requirements. It was noted that the equipment used was modern and allowed a high level of precision in pesticide application. The only discussion was around the release height which was observed to be around 30’ (this is lower than was stated by the aerial applicator) but the regulation specifically states that the release height will be determined by the pilot to accommodate considerations of safety.

3.1.2 Oregon Forestry Practice

Oregon Forest Practices Act is often cited as the gold standard in forest practice regulation. However, with respect to the questions at hand in this report, Maine’s rules could be viewed as more comprehensive. The Oregon rules are generally focused on protection of waterways and are nested under label restrictions which are relied upon to protect human health considering non-water pathways. Use of pesticides in Oregon is also subjected to the pesticide control laws as administered by the Oregon Department of Agriculture and ODA administers an Oregon Pesticide Exam in the topical area of forestry. The descriptions of forest requirements in ODA documentation references back across to the Forest Practices Act. Though it is difficult to pull specific requirements out of this 139 page act, as all requirements exist in the framework of the whole document, some are very relevant to the discussion here. Aerial application of herbicides is never allowed within 60’ of significant wetlands, aquatic areas of Type F, Type SSBT and Type D streams, the aquatic areas of large lakes, the aquatic areas of other lakes with fish use or any area of open water greater than ¼ acre in extent. In these rules, a Type D stream is a stream with domestic use but no fish use, a Type F stream has both domestic and fish use, and an SSBT stream is a Type F stream that is used by salmon, steelhead or bull trout. As is typical of this type of legal document, there are 6 pages of term definitions, but buffers are used extensively.

This act extends buffers for insecticides and fungicides out to 300’ but eliminates them entirely for most biological pesticides though the regulations are clear that more stringent buffer zones may be imposed in specific cases of any type of chemical application. The act does offer that waivers are possible if any restrictions (including label restrictions) impact the efficacy of a given application.

3.2 More Stringent Regulatory Options

Using the information laid out in Part I of this report, there are a few options to improve targeting and lower off-target movement of herbicides. Generally, as stated previously, aerial herbicide application in Maine is done in an intelligent and careful way using existing knowledge to control spray while achieving efficacy. Since droplet size is the main determinant of droplet movement and control, it is worthwhile to discuss droplet size in the context of additional BMPs. Very large droplets are already being used by all aerial applicators doing prep and release forestry work in Maine. Going to even larger droplets causes logistical spray issues of rate and coverage, may lower efficacy and may cause uneven application (striping) so mandating even larger droplets is not a good option and the spray droplet size is to be used in application is already stated in the pesticide label. In reviewing literature and talking to experts, it is not clear what the relative span of the AccuFlo .02 nozzle is. The manufacturer does not state the relative span (RS) (though claims it is low) and engineers performing these measurements have expressed on-going uncertainty. The manufacturer also states a volume median diameter of 600-800 microns which is lower than the volume median diameter of 834 microns stated in the text. As discussed, the engineers doing the actual measurements of droplet size state that droplet size measurements for these nozzles is difficult, but they have confidence in the droplet sizes and relative span stated in the text. Given the sensitivity of drift to droplet size and relative span, this would be an important question to clarify. It may also be an area where investment of public funds, government pressure or encouragement and/or industry itself could answer this question. The elimination of fines is one of the ultimate goals of spray research and droplet sizing of these large orifice nozzles is difficult, but modeling suggests a small decrease in relative span would be important.

Though release height is an important factor in droplet control and drift, it is impossible to mandate this as it must be left to pilot discretion. Aviation hazards increase at lower flying heights as discussed. The

SCS report referenced in Section 3.1.1 indicates that aerial applicators doing forestry aerial herbicide application in Maine are already flying remarkably low.

Maine guidance does not address the issue of nozzle placement within rotor diameter though it is typically stated on herbicide labels. It is common practice in Maine aerial herbicide application to keep nozzles inside of 75% of the rotor diameter. Maine guidance could be updated to reflect this practice.

Finally, it would be possible to lower maximum wind speeds allowed in aerial herbicide application in Maine. The operational consequence of this would be to reduce the time windows available to land managers to aerially apply herbicides. This could be most consequential in release operations where there is typically a 4-6 week window when the young trees are less susceptible to herbicide injury. Labels will rarely specify a maximum wind speed under 10 mph, and State guidance now sets limits of 2-10 mph in many circumstances. BPC guidance already specifies some buffers as a function of wind speed; it might be possible to institute a moving scale, so that buffer width was dependent on wind speed.

As stated in Part I, long range drift of very small amounts of material is difficult to address. The impact of long-range drift is often stated in terms of biological endpoints. Since the registered herbicides used in Maine have low human and environmental toxicities, the low levels of long-range drift should not be a concern. Any of the measures discussed in the report to lower drift should lower long range drift. However, it needs to be emphasized that some drift, though comprising a tiny fraction of the applied herbicide, can occur. ‘No drift’ is not a guarantee that can be made in any pesticide application.

3.3 Alternatives

Part II of this document reports on alternatives to aerial application of herbicides. Note first that aerial application has two advantages, it minimizes worker exposure and it is lightest on the ground in terms of soil compaction and ground traffic and in terms of potential damage to young trees in release scenarios. As alternatives to aerial application, it is possible to apply herbicide by ground for both site prep and release. Backpack spraying is light on the surface, but very labor intensive and potential for worker exposure is high. The rates used in prep and release herbicide application would require frequent refilling with the inherent spill and exposure hazards and the positioning of refilling points in the field. Utility vehicle spraying is an option, though more likely to damage young trees. Both small vehicle movement and walking may be difficult in thick vegetation and may lead to inconsistent targeting.

Larger spray vehicles are occasionally used in this activity though the potential for damage to the plantation would be high in release treatments. It should be noted that ground spraying scenarios are not ‘no drift’. Thistle et al. (2017) measured drift from backpack and UTV spray scenarios and though minor, drift did occur. From an economic standpoint, available analyses presented in Part II indicate that these activities are substantially more costly than aerial spraying. When considering the fuel expended in transporting equipment and personnel to a site, it is not clear what activity has a lower carbon footprint. All of these activities require material be transported to the site. While no life cycle analyses were found in the literature to address this issue fully, at a simplistic level the math points to lower carbon usage (as gasoline) by helicopters (25 gallons per hour) than by all-terrain vehicle (ATV) applications (15 to 20 gallons per hour). On the ground spray vehicles probably consume more fuel per site than aircraft because of differences in how long the applications take, but this is speculative and will be highly dependent on details of site accessibility. The carbon inputs of hand spraying are beyond the scope of this discussion because they are more involved.

Alternatives to spraying are hand clearing and fire. These techniques are not used extensively in Maine. Fire has been used in site preparation work in Maine but it is not clear whether this is in lieu of or in conjunction with herbicide application. Fire is not used in release work for fear of damaging young trees. The availability of fire as a tool is influenced by local weather conditions and may not be possible or, conversely, prudent depending on moisture and wind conditions. Down sides include air quality issues, potential for loss of control and a complicated carbon footprint. Fire may be a viable alternative to spraying for site preparation.

Manual land clearing, in the absence of herbicide use, is time consuming, extremely labor intensive and physically dangerous. Problems of labor shortages and short time windows accentuate economic issues discussed in Part II which show hand clearing to be many times more expensive than aerial spraying. It should be noted that this is a no-drift activity and that air quality concerns around small engines and crew transport are relatively minor.

The final alternative is no treatment. Part II indicates that the economics of no treatment are poor. Planted tree growth is greatly retarded by competition from unwanted plants and the harvest turnaround time is lengthened.

As expected, land managers have developed methods that are most economical, efficacious and timely (these three factors are interlinked). These considerations have resulted in the use of aerial spraying. If herbicide use is banned or restricted, the equation changes. If aerial application is further restricted, ground spraying alternatives may take its place. If all herbicide use is further restricted, hand clearing, fire and no treatment, or combinations of these are the only other alternatives.

Part IV. Recommendations and Suggested Actions

Recommendations to accommodate concerns regarding aerial herbicide application in Maine forestry:

0) Set a maximum wind speed during application at 10 mph for all cases.
1) Set a maximum extent of nozzles on the boom at 75% of helicopter rotor diameter.
3) Require that all anticipated buffers used in aerial application of herbicides in forestry be shown on all spray plan maps.
4) Require that all ISO standards regarding aerial application and all NAAA best management practices be used except where specifically overridden by regulation or direction from the State of Maine.

Suggested actions:

1) Investigate the use of dynamic buffers around aerial spray operations based on stream watershed size as in the current Timber Harvesting Standards, water body size and/or wind speed. As part of this investigation, evaluate buffer widths based on the AGDISP Stream Assessment algorithm.
2) Consider using a Drift Reduction Technology approach so that aerial applicators utilizing technology such as advanced, real-time meteorological monitoring and/or automated swath off-set technology or in-cockpit real time meteorological displays could be credited with narrower buffer zones. This could be left flexible to credit aerial applicators that invest in new technologies as they arise to reduce drift.
3) Evaluate the approach of a ban on aerial spraying of forest herbicide application with derogation. This could be worded so that derogation required that aerial applicators provide evidence that alternate approaches are necessary.

4) Pursue clarification of the droplet size distribution and relative span generated by the Accu-flo .02 nozzle at the pressures used in Maine forestry aerial herbicide application.

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II B—Evaluation of Potential No-spray Riparian Buffers

Evaluation of Potential No-spray Riparian Buffers in Maine Forestry Aerial Herbicide Application Using the AGDISP Stream Assessment Algorithm

Prepared by Harold Thistle, PhD

11/24/2021

Introduction

There is interest from Maine BPC to evaluate methods that might be used to set riparian buffer widths that would exclude aerial spraying of herbicides. The exercise presented here uses typical inputs from Maine aerial herbicide application practice as input to the AGDISP Aerial Spray model. There is an algorithm contained in the AGDISP Toolbox entitled Stream Assessment and this is used to calculate stream concentrations produced by pesticide droplets moving through riparian forest strips of various widths and description. This algorithm is based on Teske and Ice (2002) and is basically a one-dimensional chemical dispersion model adapted to this problem. The model is based on basic fluid dynamics equations but is driven by inputs that are often empirically determined.

Method and Inputs

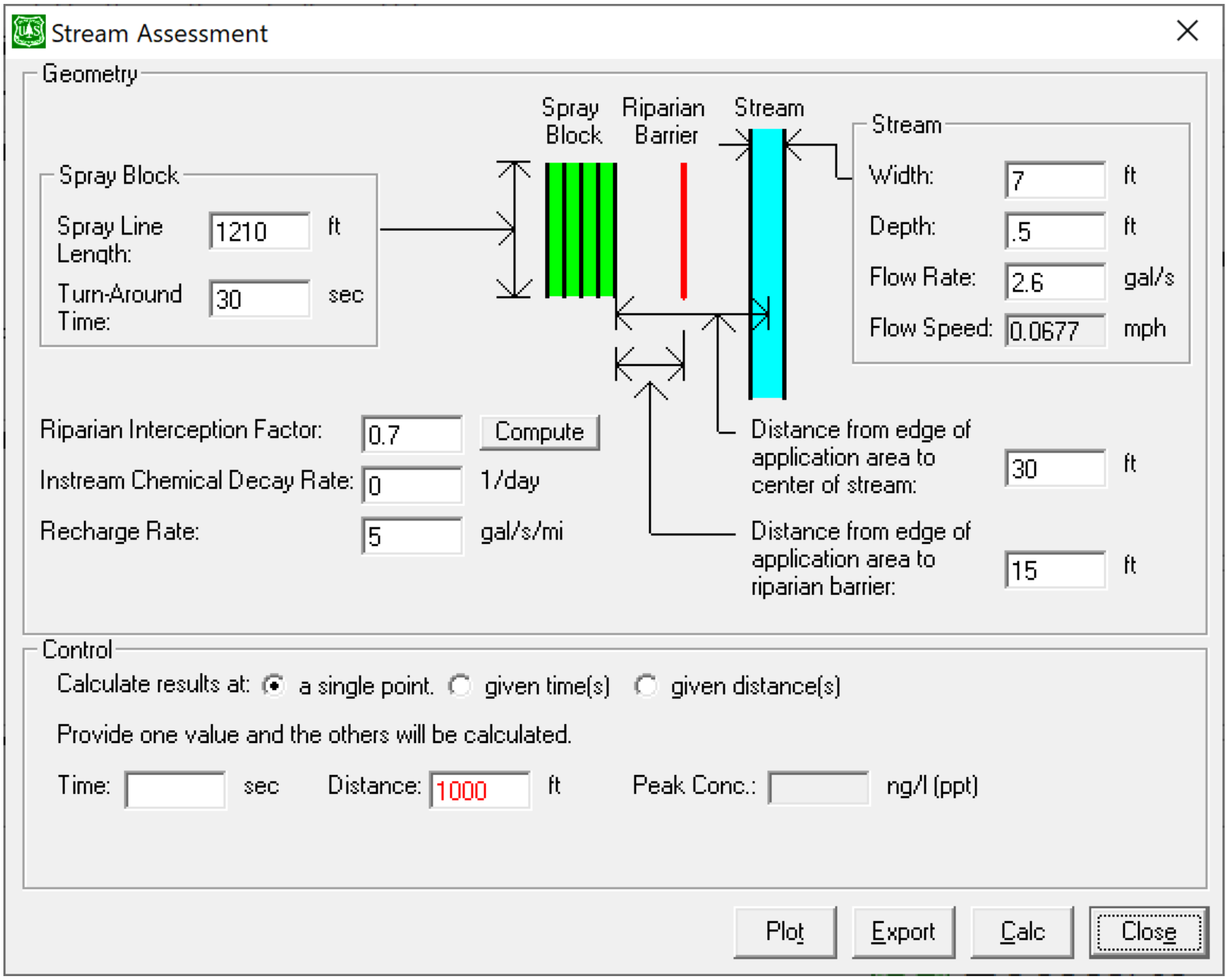
This exercise begins with the Base Case as generated for ‘Herbicide Application in Site Preparation and Release in Plantation Forestry in Maine (Thistle and Bonds, 2021). The output from the modeled Base Case run is then used by the Stream Assessment algorithm as accessed in the Toolbox pull down menu in AGDISP. An example of the Stream Assessment input screen is shown in Figure 1 and the inputs used in this analysis are given in Tables 1-3 along with calculated stream chemical concentrations at 0’ and 1000’ downstream.

The geometry of the algorithm is shown in Figure 1. The basic geometry of the application modeled here assumes 25 flight lines with 45’ swath width of 1210’ length (Table 1). This results in an application area of exactly 25 acres. More upwind flight lines could be added, but these more distant lines add little to the stream deposition. The width of the riparian buffer is calculated as the difference between the distance from the downwind flight line to the buffer edge and the distance from the downwind flight line to the stream centerline. This is the Buffer column shown in Table 3. The downwind edge of the downwind most swath was always kept 20’ away from the upwind buffer edge in these simulations with the exception of a worst case scenario where it was lowered to 15’. The default setting allowing 30 secs for aircraft turn around was used; results are not very sensitive to this input.

One of the controlling inputs in this algorithm is the riparian interception factor (RIF). The determination of this factor was the object of work by Thistle et al., (2009). Generally, the factor appeared to be around 0.9 for the barriers tested. The Stream Assessment algorithm allows calculation of this factor based on canopy height, ‘porosity’, canopy element type (cylinder, flat plate, etc.) and element size. However, this calculation appeared not to be working properly in the model (the same calculation done at different times gave different answers). Therefore, the observed RIF was used but to be conservative and reflect the variability in the measured data, 0.9 was considered the highest RIF and 0.7 was used as the lowest. The lower number allows more material to pass through the barrier as reflected in the calculated concentrations shown in Tables 3 and 4.

Based on discussions with Maine BPC, a target chemical concentration of 46 ppb was targeted as a biological endpoint that should not be exceeded. To build these simulations, it was necessary to determine stream dimensions and flows to use as model inputs. It quickly became apparent (as well as intuitively evident) that slow moving, wide, shallow streams will show the highest concentrations. An important factor is the recharge rate as this acts as a dilution factor. Two streams were input with conservative dimensions based on the above. These are the Medium and Small Streams described in Table 2. These streams are based on those discussed in Teske and Ice (2002) based on stream survey data collected in Oregon. They strike the author as very small, with low flow rates and velocities, so should serve as appropriate conservative cases. The recharge rate is also based on results from Teske and Ice (2002) and is loosely scaled to the flow rate. Note that stream velocity is not an input to the model but is calculated. The Small and Medium Streams input to the model for this exercise have calculated speeds of 0.07 and 0.13 mph respectively.

Finally, chemical decay rate is an input to the Stream Assessment algorithm. For this exercise, this input was set to 0 to be conservative. This input is expressed in fractions per day. Note that if the chemical decays at a rate of 0.5 per day, for a stream flowing at 0.1 mph, about 2 hours has elapsed when the chemical slug passes 1000’ downstream. So, at 50% decay per day, 2 hours is 1/12 or about 8% per day or about 4% of the total chemical over 12 hours. Since the decay rate curve often describes a negative exponential, the decay in the first two hours may be higher than 4% but the point is that the 0 decay assumption is not overly conservative in the near-field calculations presented here.



Stream Assessment

Geometry

Spray Block

Spray Line Length: 1210 ft

Turn-Around Time: 30 sec

Stream

Width: 7 ft

Depth: .5 ft

Flow Rate: 2.6 gal/s

Flow Speed: 0.0677 mph

Riparian Interception Factor: 0.7

Instream Chemical Decay Rate: 0 1/day

Recharge Rate: 5 gal/s/mi

Distance from edge of application area to center of stream: 30 ft

Distance from edge of application area to riparian barrier: 15 ft

Control

Calculate results at: ● a single point. ○ given time(s) ○ given distance(s)

Provide one value and the others will be calculated.

Time: sec Distance: 1000 ft Peak Conc.: ng/l (ppt)

Figure. 1 Example Stream Assessment screen from AGDISP.

Table 1. Fixed Inputs

Spray Line Length (ft)	1210
Turn Around (sec)	30
Chemical Decay Rate (per day)	0

Table 2. Stream Descriptions

Small Stream Width(ft)	7
Small Stream Depth(ft)	0.5
Small Stream Flow Rate (gal/sec)	2.6
Small Stream Recharge Rate (gal/s/mile)	5
Medium Stream Width(ft)	7
Medium Stream Depth(ft)	1.5
Medium Stream Flow Rate (gal/sec)	15
Medium Stream Recharge Rate (gal/s/mile)	20

Results

Using 46 ppb as a threshold number of interest, Table 3 indicates riparian barriers of 50’ or over result in downstream concentrations in Small Streams of less than 4.6 ppb in all cases computed here. 4.6 ppb is 0.1 of the threshold level of interest. For example, assuming a 100’ riparian buffer, the stream concentration at 0’ downstream is 668 ppt assuming RIF of 0.9 and 2002 ppt assuming RIF of 0.7. These numbers are 0.015 and 0.044 of the threshold value of interest, respectively. Corresponding values of stream concentration are all lower for Medium Streams (Table 4). Note the effect of RIF as stream concentration values more than triple as RIF is lowered from 0.9 to 0.7 in Table 3.

However, with the above said, Tables 3 and 4 do point out the importance of buffers in reducing stream concentrations. The algorithm does not allow a no-buffer control case to be run, but it does allow the effect of narrow buffers to be calculated. If buffers are narrowed to 15’ in width, and stand-offs from the barrier edge are lowered, Table 3 shows that stream concentrations then rise to 0.8 of the threshold of interest for a Small Stream with RIF of 0.7.

Table 3. Small Stream Buffers and Calculated Concentrations

Distance from Edge of App Area to Stream Center (ft)	Distance from Edge of App Area to Riparian Barrier (ft)	Buffer (ft)	Riparian Interception Factor	Concentration Peak 0 ft downstream (ppt)	Concentration Peak 1000 ft downstream (ppt)
70	20	50	.9	2139	1699
95	20	75	.9	1085	863
120	20	100	.9	668	531
120	20	100	.8	1335	1062
120	20	100	.7	2002	1592
30	15	15	.7	36787	28869

Table 4. Medium Stream Buffers and Calculated Concentrations

Distance from Edge of App Area to Stream Center (ft)	Distance from Edge of App Area to Riparian Barrier (ft)	Buffer (ft)	Riparian Interception Factor	Concentration Peak 0 ft downstream (ppt)	Concentration Peak 1000 ft downstream (ppt)
70	20	50	.9	709	612
95	20	75	.9	359	311
120	20	100	.9	221	191
120	20	100	.8	442	383
120	20	100	.7	663	574
30	15	15	.7	12228	10435

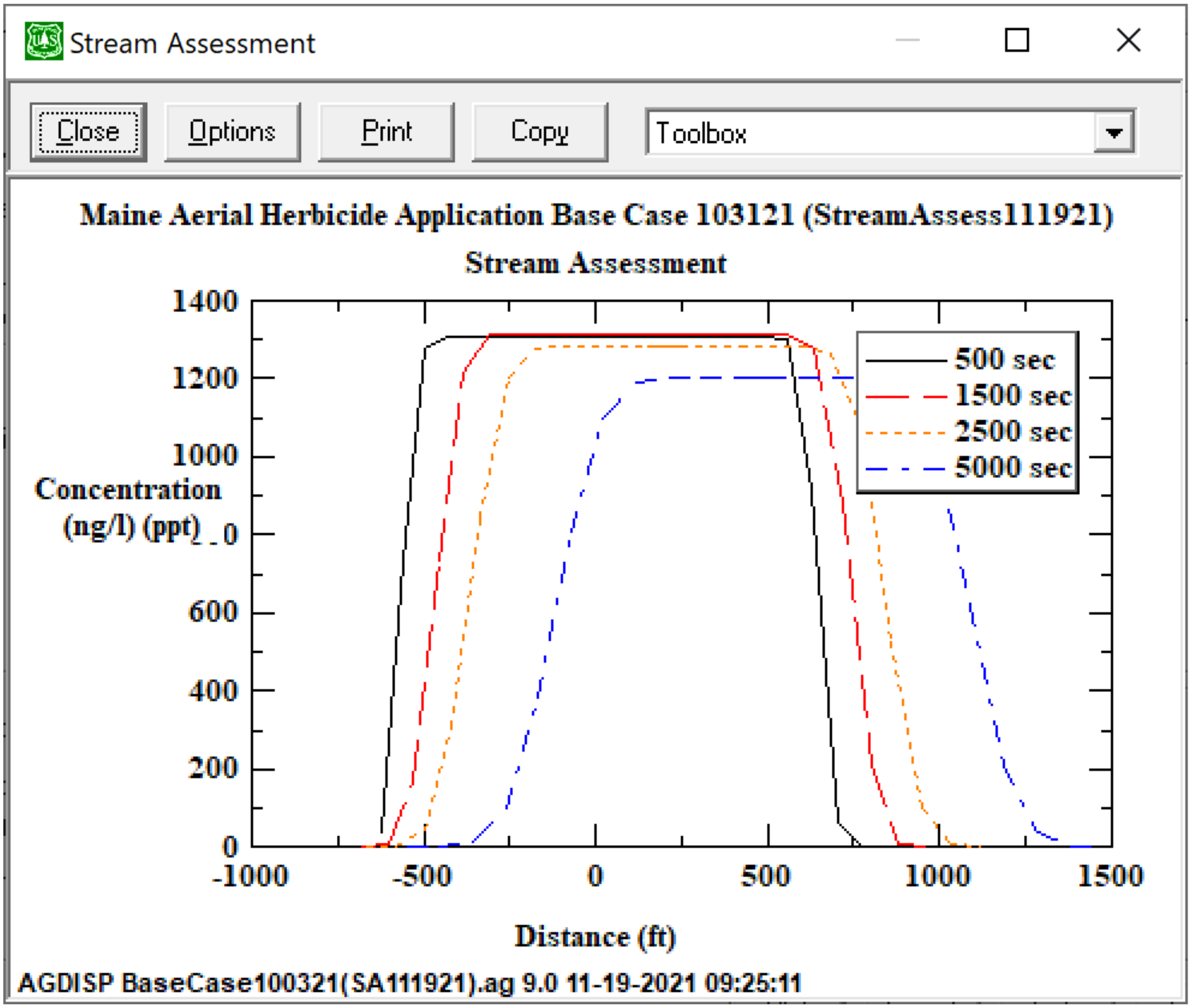


Figure 2 Small stream downstream concentrations with RIF = 0.8 and 100 ft buffer. All else as in Tables 1 and 2.

Figure 2 is an example plot from the Stream Assessment pull down to show other tools available in this algorithm. This plot is interesting as it illustrates the slow dilution calculated by the model when chemical decay is set at 0 and the recharge rate is set near the flow rate. Other loss mechanisms such as binding to organic matter in the stream are not included though they could be incorporated into the decay rate if known.

Conclusions

The Stream Assessment algorithm in AGDISP can be used to calculate pesticide concentrations in streams surrounded by riparian barriers. The algorithm has not been widely used and while results from comparisons to published data are generally promising, the algorithm still needs work and more comparison data would be helpful.

Many of the inputs that the algorithm is sensitive to need to be measured empirically, though it is possible to make conservative estimates of these inputs. The model is very sensitive to the stream description but the physical description of a specific stream is not hard to measure with the only more difficult input being the recharge rate. This rate is less important near the application area. Considering these factors, the algorithm probably represents a reasonable tool for use in the process of designing buffer zones either as categories (small, medium, large streams, etc.) or to be used in specific spray plans.

Finally, the calculations presented here emphasize the role riparian buffers can play in reducing spray deposition to streams. Reductions appear to be dramatic so they over-shadow model inadequacies. Given that other benefits of riparian barriers, involving stream ecology, sediment loading, etc., are recognized and riparian buffers are already used in many cases, requiring riparian buffers of width scaled to stream size seems a reasonable approach in maintaining water quality near aerial herbicide application.

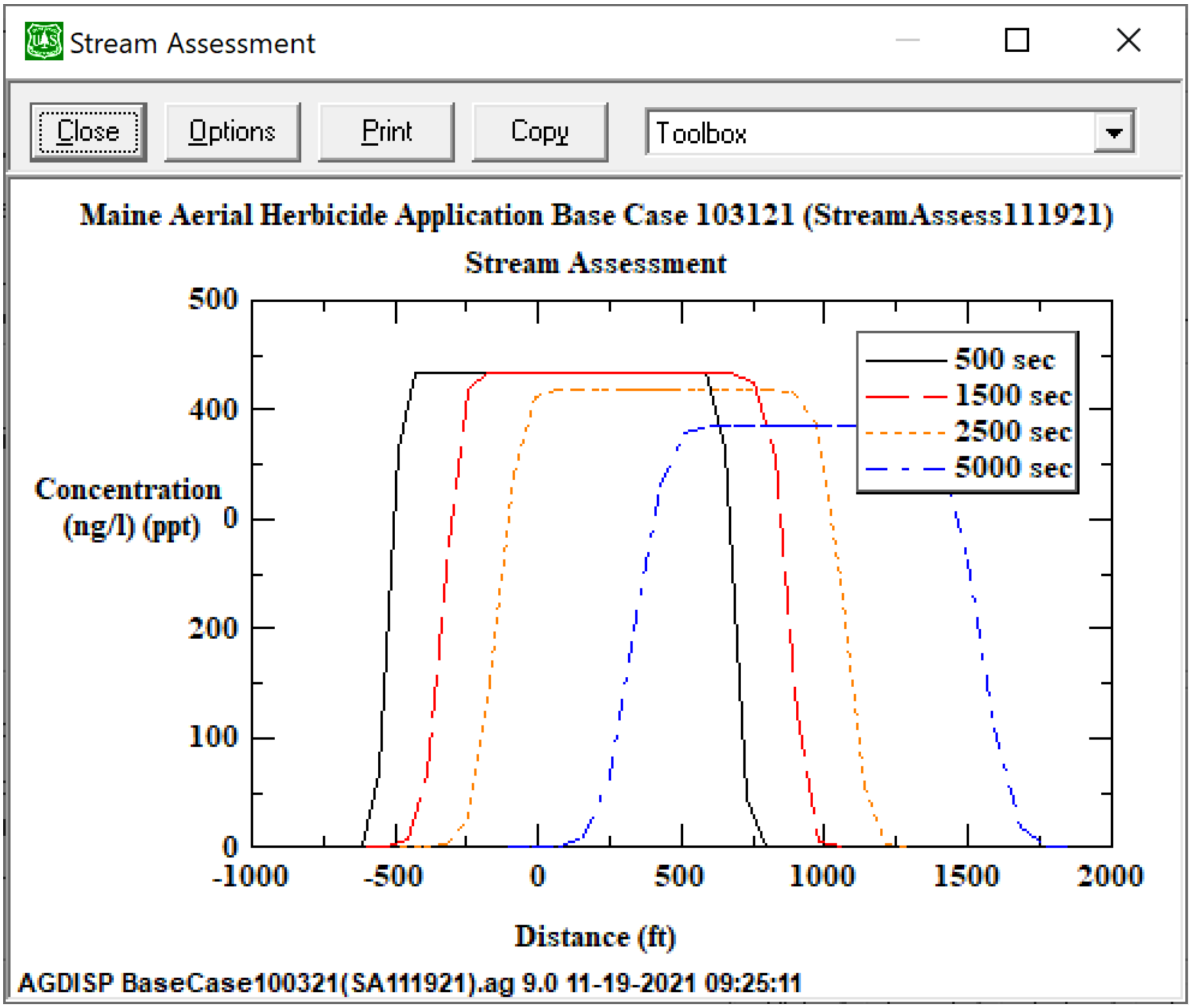


Figure 3 Medium Stream downstream concentrations with RIF = .8 and 100 ft buffer. All else as in Tables 1 and 2.

BPC staff comment on the document by H Thistle entitled:

Evaluation of Potential No-spray Riparian Buffers in Maine Forestry Aerial Herbicide Application Using the AGDISP Stream Assessment Algorithm

During discussions with the forestry consultants, the process of how to best create protective stream buffers arose. One approach is to first determine what stream concentrations are thought to be harmful to stream organisms (fish and aquatic invertebrates) and then build buffers that prevent those concentrations.

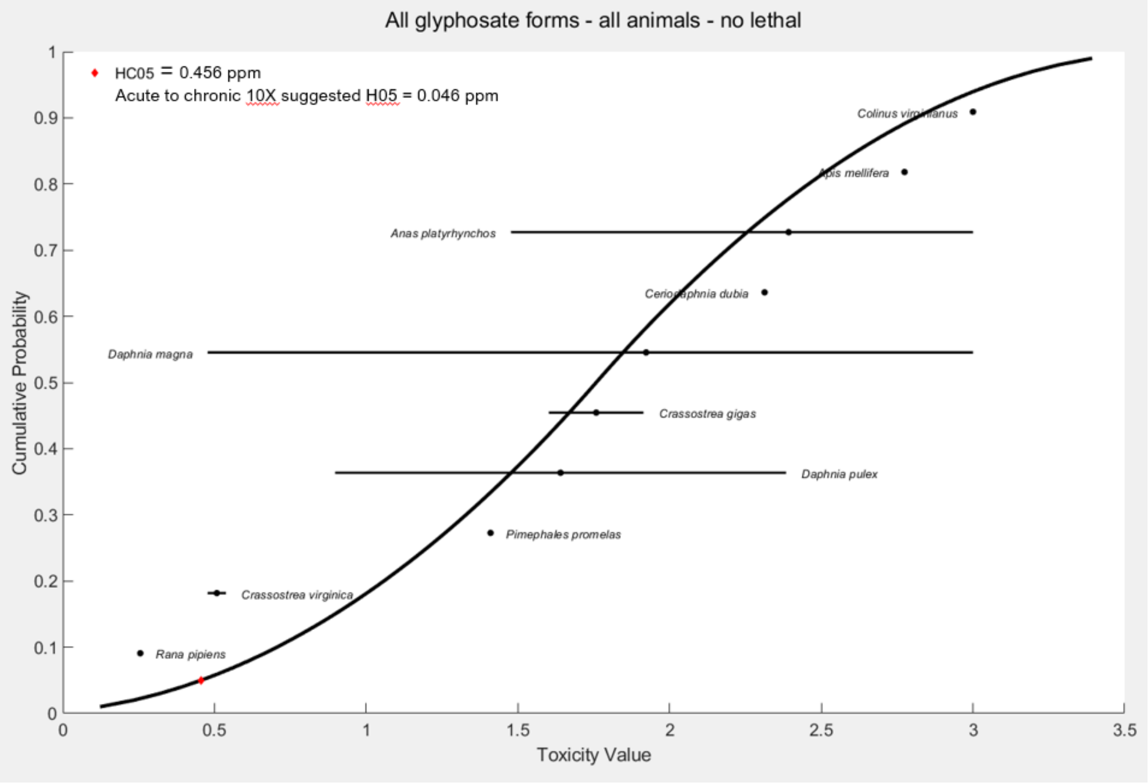
Species sensitivity distributions (SSDs) are a tool used to predict the concentration of a chemical that is likely to affect aquatic organisms. The process involves looking at databases containing chemical test assays and collecting all test data for an individual chemical. It is widely recognized that each species responds to chemical exposures differently. It is also expected that species responses to a given chemical will follow a normal distribution; some will be very sensitive, some very insensitive, and most will be clumped in the middle. This approach combines available assay data into a modeled representation to better describe expected effects in those species that have not been tested.

In order to address specific concerns over glyphosate, glyphosate was chosen as a focal chemical to base the SSD on. Additionally, in order to push the model to maximal protectiveness, only studies looking at non-lethal endpoints were included. Acute lethal studies are more numerous and provide a broader suite of species to be represented. However, acute lethal concentrations are always higher than the concentrations known to cause sublethal effects.

Once constructed, the SSD allows the generation of a HC05, or hazardous concentration for 5% of the species. The HC05 represents the concentration at which it is predicted that 5% of species will be affected; this is intended to be protective of 95% of all species.

The HC05 for glyphosate, based on non-lethal endpoints for all available animal species in the database, is 456 ppt. A rule of thumb conversion for understanding the connection between acute exposure data and chronic data is to reduce the concentration by 10X. The predicted chronic HC05 for all species becomes 46 ppt. This value was submitted to the forestry consultants as a value to form a basis for the size of protective riparian buffers.

This tool was not constructed to be a definitive judgment on the concentration of glyphosate that causes effects; it simply pulls together the standardized chemical assays available to the researcher to generate a ballpark value as a starting point for discussion.



Species sensitivity distribution (SSD) for glyphosate. All sublethal animal data available in EPA’s ECOTOX Database were included. The red point indicates the HC05 value of 0.456 ppm (456 ppt).

III. Proposed Water Quality Monitoring Effort for 2022 in Response to Directive I B of the EO

The goal of this study is to understand the potential effects of aerially applied herbicides following their use in managed blocks of Maine's softwood stands. This is a difficult assessment because of the multitude of inputs and various landscapes that determine the answer. This study will not answer the question of whether or not there are effects. The scope of this study focuses solely on the presence/absence of pesticide active ingredients in the environment. Stream health is best measured by looking at the entire ecosystem and by measuring changes in algae, plants, microorganisms, macroinvertebrates, and larger aquatic organisms, which is a major undertaking when done correctly. Instead of measuring stream health, this study is intended to measure to what degree pesticide active ingredients occur in nearby streams. The detection (and concentration) of pesticides is an indication of the potential of effects from aerial herbicide practices.

This overall study design focuses on determining the amount of pesticide reaching the nearest stream immediately after the spray event to assess drift and assess run-off from the treated area by sampling the nearby stream over a longer period of time. This study is simple in design but challenging logistically due to the remoteness of the locations and the rapidly changing spray plans which are controlled more by weather than the calendar.

This study is to be conducted in cooperation with timber companies during their regularly planned fall site prep and conifer release spray programs. From their proposed treatment blocks, BPC staff will select study sites. Selection criteria focus on isolating treatment plots co-located to streams but separated away from other treated spray blocks. The study sites will need to be accessible by BPC staff for the deployment, sample collection, and maintenance of autosamplers. Remote actuated autosampling devices will allow staff the flexibility to collect samples on the continuously shifting schedule set by the cooperating timber companies. State regulations stipulate a 25-foot minimum distance. However, timber industry representatives indicate we will not be able to locate sprays that close to streams. Timber industry best management practices typically stipulate greater distances. All efforts will be made to identify the streams closest to spray blocks for sampling. In addition to pesticide regulations, forestry best management practices have formulae in relation to shoreline zoning that prescribes how many and how close to a stream trees can be removed. The goal of study site selection will be to choose streams as close to the treated area as possible, with the recognition that there will be a gradient of distances.

Research question:

Are herbicides used in aerial forestry programs reaching forest streams?

Sample size:

- TREATMENT: 20 spray block locations
  - (Includes 20 close site and 20 distant site samples)
- CONTROL: 10 no-spray block locations
  - (Includes 10 close site and 10 distant site samples)

Timing:

Pre-spray sampling: In summer (May-July 2022), sampling locations will be identified, autosamplers emplaced, and a full suite of samples collected. Sampling begins immediately following emplacement, and samplers will collect a sample (as composite) each hour for 24 hours.

Post-spray sampling: In late-summer and fall (September-October 2022) two post-spray samples will be collected in a manner consistent with the sampling frequency set by the pre-spray sampling. Samples will be collected immediately following the spray event to assess spray drift. Samples will also be collected to capture the runoff from the site during the first rain event following the spray.

Post spray sampling schedule:

Close sites:

Day of spray (Drift)- At each location, a section of stream closest to the treatment block will be sampled over a 24 hour period following (sampling begins within 15 minutes following the aerial spraying for the post-spray sampling). Composite autosampling will sample the water every hour for 24 hours, combining each sample into a single container. This sampling approach reduces the cost of the analysis (by reducing the number of analytical samples from 24 to one) yet preserves the ability to identify the average concentration entering the water over the 24 hour period.

First rain event following spray (Runoff)- Using the same location as the day-of-spray sampling location, the stream will be sampled over a 24 hour period following the first rain event (within an hour following the start of the rain). Composite autosampling will sample the water every hour for 24 hours, combining each sample into a single container.

Distant sites:

Day of spray (Drift)- At each location, a section of stream downstream from the treatment block will be sampled over a 24 hour period following (within 15 minutes of the aerial spraying for the post-spray sampling). Composite autosampling will sample the water every hour for 24 hours, combining each sample into a single container. Topographical maps will dictate the location of the autosampler. Maps will be assessed to find the stream location likely to receive all of the runoff from the location.

First rain event following spray (Runoff)- Using the same location as the day-of-spray sampling location, the stream will be sampled over a 24 hour period following the first rain event (within an hour following the start of the rain). Composite autosampling will sample the water every hour for 24 hours, combining each sample into a single container. Topographical maps will dictate the location of the autosampler. Maps will be assessed to find the stream location likely to receive all of the runoff from the location.

Equipment choice:

Remote actuated compositing autosamplers will be rented to complete this study. Composite sampling allows sampling to occur over a range of times which is essential to capture the variation created by topography at each site. Each sample is of equal volume such that at the end of the sample period, the pesticide concentration in the water can be divided by 24, and an hourly average pesticide concentration can be derived. Literature reviews indicate that immediately following application, and during the first rain event, are the two most likely times to detect herbicides following aerial applications. Pesticide concentrations in nearby streams tend to fall below detection levels quickly after the application (within the day) except for rainfall events when they are transiently detected again.

The remote actuating aspect of the samplers is critical to be able to keep up with the helicopter and weather schedules. Flight plans are ever-changing based on weather. This feature additionally comes into play to ensure the first-flush rainfall is captured. In both of these scenarios, BPC staff will set up the autosamplers according to when the anticipated treatments are planned to happen. Should plans change, staff will not have wasted time and effort reaching the location; the autosampler can simply wait in place for the spray event. The spray events happen in a very compressed calendar schedule, so the autosampler is not likely to wait very long. To capture the first rain event, autosamplers will be set up to receive samples as soon as the spray event samples have been collected, and they will remain until rainfall.

Chemical analyses:

Consistent with BPC practice, the collected samples will be transported, on ice, to the office and stored at 4°C until ready to ship. Samples are packed on ice and shipped to the Montana Agricultural Laboratory for analysis. The water samples are processed through a pesticide analysis panel that can identify up to 102 unique analytes (roughly 80 parent compounds plus their degradation products).

IV. Department of Inland Fisheries and Wildlife Report in Response to Directive I C of the EO

Potential Effects of Herbicides on Maine's Better-Known Wildlife: A Review by MDIFW

By way of general introduction, it is important to clarify that this review is not intended to summarize the effects of herbicide toxicity on Maine's wildlife; rather, our focus is specifically on the potential for herbicide effects on the structure and composition of wildlife habitat, mainly those elements of cover and food that support our state's fauna. Furthermore, as statutory context, it is helpful to know that the Legislature has declared it the policy of the State to conserve *all* species of fish or wildlife found in the State, as well as the ecosystems upon which they depend (Title 12, MRSA, Chapter 631, §7751), wherein the term "wildlife" is defined as any species of the animal kingdom (including invertebrates), except fish. However, we include fish in our review to ensure completeness.

One of the foundational underpinnings of wildlife habitat in Maine is the state's diverse flora, comprised of over 1430 native species (Gawler et al., 1996), both because of the essential role that plants serve as structural cover, and as nutrition for herbivorous vertebrates and invertebrates, and their predators. As such, herbicides, by their intended purpose, nearly always have the potential to affect wildlife habitat, depending in part on the extent, timing, and intensity of application. With over 500 species of nonmarine vertebrates and over 15,000 species of terrestrial and freshwater invertebrates (MDIFW 2015), the diversity of wildlife in Maine is staggering, with each species having unique life histories that make any generalizations about the effects of herbicides on wildlife even more challenging. With that said, we have done a preliminary review of the scientific literature with a goal of reporting some significant findings for a small subset of Maine's better-studied wildlife. We also refer readers to Guiseppe et al. (2006) and Sullivan and Sullivan (2012), which provide a thorough overview of this issue and a more detailed summary of much of the research referenced in this document.

Mammals

It is generally accepted that application of herbicide to kill competing trees and shrubs, with the objective of promoting young softwood tree growth, will reduce browse for deer and moose for at least 4 years post-treatment. However, there may be little effect or even an increase in the availability of some types of forage at 7-11 years after treatment (Raymond et al. 1996;Vreeland et al., 2008), and over the long-term, use of treated stands by moose may be higher than in untreated stands due to improvements in softwood cover for bedding and foraging (Escholtz et al. 1996). Research on these effects is often contradictory, with NBDNR

(2009) concluding that aerial application of herbicide results in a long-term reduction in browse for deer on treated stands in New Brunswick. On the other hand, in Maine, aerial application of herbicide can be an effective tool to promote development of winter shelter for deer (MDIFW 2011). Overall, given the relatively small acreage treated each year, we believe there are likely no long-term, landscape-level negative impacts on moose or deer from the application of herbicides for forest management in Maine.

Most small mammals are dependent on high levels of vegetative structure for foraging and refuge from predation. Therefore, application of herbicide reduces cover for small mammals, and reductions in habitat use by some small mammal herbivores and insectivores can be expected to occur for 2–3 years. However, these impacts are likely highly variable across species, and most effects are likely short-term (Guiseppe et al., 2006).

Invertebrates

With approximately 3,000 species in Maine, butterflies and moths (Order: Lepidoptera) are one of the more diverse and better-studied elements of Maine’s invertebrate fauna (MDIFW 2015). They also play important ecological roles, both as pollinators and as prey to larger species, from dragonflies to birds and bats. As is true for many herbivorous insects, most Lepidoptera in Maine are specialized to feed and develop on specific food plants as larvae (Wagner 2005, Cech and Tudor 2005). In some cases, these relationships are quite specialized, with individual species feeding exclusively on certain plant genera or even plant species (e.g., Monarchs and Milkweed). Additionally, most of Maine’s butterflies, and many moths, feed on flowering plant nectar as adults, though this relationship is less specialized.

With this biology as background, herbicides can be expected to have potential negative impacts on habitat quality for some butterflies and moths by reducing or eliminating essential caterpillar food and/or nectar plants, which in turn affects the survivorship and fecundity of larvae and adults, respectively (Boggs and Freeman 2005, Russell and Schultz 2009, Schweitzer et al., 2011). This can be significant where herbicides are used to purposely reduce understory competition and cover, as occurs in some intensive management settings such as silvicultural clearcuts and plantations. Arguably, because Maine’s forest landscape is vast, and the status of most Lepidoptera in the state is thought to be secure, the localized effects of herbicides on habitat for this taxon are not likely to be significant. However, in specific localities where state rare, threatened, or endangered butterflies (22 species) or moths (26 species) are known or predicted to occupy areas targeted by herbicides, there is the potential for populations of at-risk species to be negatively impacted. Indeed, the State’s Wildlife Action Plan (MDIFW 2015) identifies aerial pesticide use as one of several primary threats to butterflies and moths.

Birds

Insects, and most especially Lepidoptera, serve as a principal and highly nutritious food source for a vast majority of breeding birds (via caterpillars) and bats (via adult moths) in North America (Tallamy 2019), and they are arguably a significant component of the habitat (cover, food, water) for much of the state's avifauna. In this regard, and to the extent that herbicide impacts have been shown to reduce the richness and abundance of Lepidopteran biomass in some studies (Hammond and Miller 1998, Summerville and Crist 2002; but see Root et al., 2017), a potential reduction in the *localized* carrying capacity of forest habitat for Maine's passerine bird (and bat) populations might be expected. In addition, reductions in deciduous cover that occur shortly after application of herbicide reduce nesting habitat for some bird species. However, these effects are likely short-term, limited in spatial extent, and species that are associated with mature conifer forests will likely benefit from the long-term changes in forest composition that typically occur on treated sites.

Aquatic Vertebrates

Although there has been significant research investigating the impacts of herbicide on water quality and potential toxicity for aquatic vertebrates (Govindarajula 2008, Relyea 2011, Relyea 2012, Bruhl et al., 2011, Yang et al., 2021), there are few published studies that attempt to determine the impact of aerial application of herbicide on elements of *habitat* structure or quality for fish or amphibians. However, the aforementioned citations (and others) have documented significant dose-dependent toxic effects from herbicides, including glyphosate products, to several amphibian species native to Maine. To the extent that frogs and salamanders serve an important role at the base of our state's forest food web (Hunter et al., 1999), any localized reductions in their abundance due to effects of herbicides would be expected to negatively affect other species in higher trophic levels that rely on them as a food source. We refer readers to Boone and Pauli (2007) for a helpful review of the potential effects of herbicides and other contaminants on vernal pools, a widely distributed and important habitat for amphibians, invertebrates, and other wildlife in the forests of Maine (deMaynadier 2011). Similarly, although there appears to be little published research on the effects of herbicide on habitat structure for fish in the Northeast, there are numerous studies examining the toxicity of herbicides to fish and the aquatic invertebrates that fish rely on as a food source (see reviews by Guiseppe et al., 2006, Sullivan and Sullivan 2012). We caution readers that many of these studies were conducted in a lab setting and may have limited applicability to the conditions in which herbicide is used for forest management in Maine.

In closing, we believe it is important to distinguish the effects of herbicides on wildlife habitat from those effects that are a result of intensive forest management practices (such as clearcutting or plantations) with which use of herbicide is often associated. In many cases, perceptions on long-term changes to wildlife communities in areas that have been treated with herbicide may be more related to other silvicultural techniques used on the site than the use of herbicide itself. Finally, it is important to note that biological or chemical herbicides can be used for purposes of wildlife habitat promotion or conservation. Herbicides can be used to control invasive exotic plant species or to hasten the process of natural forest succession, so that some species that tend to select young or mature softwood stands likely benefit from its use.

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V. Summary of States Regulations Compiled in Response to Directive I D of the EO

Table 1. Survey and research results of regulations pertaining to the aerial application of herbicides in all 50 states. Note: Data compiled from a survey sent out by BPC staff to all states and research results from Thistle and Bonds 2021 report.

State	Aerial Application of Herbicides Allowed	Additional Requirements Beyond the Label	Licensure Requirements	Notification Requirements	Buffers or Sensitive Areas Established	Permits or Approval Process Required	Additional Information/requirements
Alabama	Yes	Yes	Yes		Yes	Yes	
Alaska	Yes	Yes	Yes			Yes	
Arizona					Yes		
Arkansas	Yes						
California	Yes		Yes				
Colorado	Yes	Yes	Yes				
Connecticut	Yes					Yes	Fee-based permit process
Delaware	Yes						
District of Columbia					Yes		Regulations do not cover forestry practices
Florida	Yes	Yes	Yes				
Georgia	Yes						
Hawaii	Yes						
Idaho	Yes						
Indiana	Yes						
Illinois	Yes						
Kansas	Yes	Yes	Yes				
Kentucky							
Louisiana	Yes	Yes	Yes				
Maine	Yes	Yes	Yes	Yes	Yes		Rules establish prima facie evidence for drift enforcement

State	Aerial Application of Herbicides Allowed	Additional Requirements Beyond the Label	Licensure Requirements	Notification Requirements	Buffers or Sensitive Areas Established	Permits or Approval Process Required	Additional Information/requirements
Maryland	Yes	Yes	Yes				
Massachusetts	Yes	Yes	Yes		Yes	Yes	
Michigan	Yes	Yes	Yes			Yes	IPM and BMPs requirements
Minnesota	Yes	Yes	Yes	Yes	Yes		IPM Guidelines/BMPs and additional safety guidelines
Mississippi	Yes						
Missouri	Yes						
Montana	Yes	Yes	Yes				
Nebraska	Yes		Yes				
Nevada	Yes	Yes	Yes				
New Hampshire	Yes	Yes	Yes	Yes	Yes	Yes	
New Jersey	Yes	Yes	Yes	Yes	Yes		
New Mexico	Yes						
New York	Yes						
North Carolina	Yes	Yes	Yes		Yes		Min/Max flight height requirements
North Dakota	Yes						
Ohio	Yes						
Oklahoma	Yes						
Oregon	Yes	Yes	Yes		Yes	Yes	Monitoring requirements
Pennsylvania	Yes						
Rhode Island	Yes	Yes	Yes			Yes	
South Carolina	Yes						
South Dakota	Yes						

State	Aerial Application of Herbicides Allowed	Additional Requirements Beyond the Label	Licensure Requirements	Notification Requirements	Buffers or Sensitive Areas Established	Permits or Approval Process Required	Additional Information/requirements
Tennessee	Yes						
Texas	Yes	Yes	Yes			Yes	
Utah	Yes	Yes	Yes				
Vermont	Yes	Yes	Yes		Yes		
Virginia	Yes	Yes	Yes				Commercial business licenses required
Washington	Yes	Yes	Yes	Yes	Yes		IPM and BMPs requirements
West Virginia	Yes	Yes	Yes				
Wisconsin	Yes	Yes	Yes				
Wyoming	Yes	Yes	Yes				

VI. Summary of Public Comments Received During Meeting(s) Held in Response to Directive I E of the EO

Prior to submission of this report, a draft will be posted on the Maine Forest Service’s publicly accessible website. Instructions for provision of written comment will also be posted. Comments received in response to the posted draft will be summarized and attached to the final report prior to final submission to the Governor by February 18, 2022.

The final report will also be included on the agenda for the January 14, 2022 meeting of the Board of Pesticides Control. This meeting will be open to the public.

VII. Summary of Considerations for Rule/Policy Changes

The body of this report provides detailed discussions and summaries of finding relevant to all provisions of the EO. Relevant to the request for suggestions to amend rules are the recommendations provided in the Thistle/Bonds report. These recommendations were designed to accommodate concerns regarding aerial herbicides application in Maine Forestry and include:

1. Set a maximum wind speed during application at 10 mph for all cases.
2. Set a maximum extent of nozzles on the boom at 75% of helicopter rotor diameter.
3. Require that all anticipated buffers used in aerial application of herbicides in forestry be shown on all spray plan maps.
4. Require that all ISO standards regarding aerial application and all NAAA best management practices be used except where specifically overridden by regulation or direction from the State of Maine.

Addendum A. Summary of current Maine regulations regarding aerial application of pesticides

Regulations for aerial application of pesticides in Maine are contained within Board of Pesticides Control Rules:

> Chapter 22: Standards For Outdoor Application Of Pesticides By Powered Equipment In Order To Minimize Off-Target Deposition (Section 3),
> Chapter 31: Certification And Licensing Provisions/Commercial Applicators (Section 3, XI), and
> Chapter 51: Notice Of Aerial Pesticide Applications.

Licensure Requirements

Currently, Maine requires licensure under the general knowledge core pesticide exam and the "Aerial Pest Control" Category 11, where applicants seeking certification must demonstrate practical knowledge of problems associated with aerial application of pesticides, including:

1. Chemical dispersion equipment;
2. Pump, tank, and plumbing arrangements;
3. Nozzle selection and location;
4. Ultra-low volume systems;
5. Aircraft calibration;
6. Field flight patterns;
7. Droplet size considerations;
8. Flagging method; and
9. Loading procedures.

Applicants must also display competency in the specific category or subcategory in which applications will be made (i.e., Category 2B Forest Pest Management). Required knowledge includes current methodology and technology for the control of pesticide drift to non-target areas, the proper meteorological conditions for the application of pesticides, and the potential adverse effect of pesticides on plants, humans, or animals.

Precautions

Once applicators are licensed, they must follow specific guidelines prior to and following any aerial application. These include:

1. Identifying the target site with Board approved methods (GPS equipment, Visible markings)
2. Creating a site plan which includes a site map that must include:
    a. Delineated boundaries of the target areas and property lines;
    b. Significant landmarks and flight hazards;

    c. Type and location of sensitive areas likely to be occupied within 1,000 ft of the target area; and
    d. Other sensitive areas within 500 feet of the target areas
3. School bus routes, if applicable
4. Site plan records must be retained for a minimum of 2 years

Pre-application Checklist

Applicators are also required to complete a Board-approved pre-application checklist for each distinct field or target site. Checklists must also be retained for a minimum of 2 years with applicator's records. The checklist must include:

1. The date, time, description of the target site and name of the applicator; Confirmation that the notification requirements have been carried out;
2. Confirmation that the target site has been positively identified;
3. The location of where weather conditions are measured and a description of the equipment used to measure the wind speed and direction;
4. Confirmation that conditions are acceptable to treat the proposed target site, considering the location of any Sensitive Area Likely to Be Occupied and current weather conditions;
5. Wind speed and direction;
6. The measures used to protect all Sensitive Areas; and
7. Confirmation that there are no humans visible in or near the target area.

Buffer zones

Aerial applicators also must create site-specific buffer zones adjacent to any sensitive areas likely to be occupied sufficient enough to prevent unlawful pesticide drift. Unless otherwise specified on the pesticide label, an applicator may not apply pesticides within 1,000 ft of sensitive areas likely to be occupied unless the wind speed is between 2 and 10 miles per hour.

Emergency Uses

Although unlikely to be relevant in aerial herbicide operations, regulations exist for emergency application. In the event of an emergency, where severe pest or weather conditions threaten to cause a significant natural resource and/or economic loss, the following may occur:

1. The severe pest and/or weather conditions must necessitate immediate, wide-scale aerial application of pesticides;
2. The immediate need for aerial pesticide application does not provide sufficient time to complete the requirements Chapter 22, Section 3;
3. Prior to any aerial application, the Commissioner shall issue a press release notifying residents of affected regions about the emergency, the likelihood of aerial application in the affected regions and the approximate dates that the emergency may continue;
4. The Commissioner, in consultation with the Board's staff, shall specify the requirements in Chapter 22, Section 3 that will be waived; and
5. Land managers and aerial applicators shall make good faith efforts to comply with the intent of Section 3 and minimize off-target drift to Sensitive Areas.

Notification

Maine also has notification requirements that applicators must follow prior to any aerial application of pesticides. Chapter 51 (Section IV) stipulates the notification requirements specific to forest vegetation management. A newspaper article must be published at least 3 days prior to an application. This publication date may not exceed 60 days prior to application date. All newspaper articles or advertisements must contain the following information:

1. Description of the target area sufficient to inform people who may be in the vicinity;
2. Name of the person who contracts for the application or her/his representative or the applicator and the address and telephone number to contact for more specific information about the intended application;
3. Intended purpose of the pesticide application;
4. Pesticide(s) to be used;
5. Date or reasonable range of dates on which application(s) are proposed to take place;
6. Telephone number of the Maine Board of Pesticides Control;
7. Telephone number of the Maine Poison Control Center; and
8. Public precautions which appear on the pesticide label.

In areas where there is not a regular newspaper circulated, a written notice to all landowners within 500 ft of the target site may be used a substitute. This notice must be provided to all person(s) owning property or using residential rental property within 500 ft of the target spray areas 3 days before the application but not exceeding 60 days prior. This notice must contain the same information as is required for newspaper articles and advertisements. If owners are difficult to contact, certified mail or other similar mailing of the notice to the address listed in the town tax records may be sufficient.

Posters in Target Area

Posting requirements include conspicuously placed notices prior to application that must be left in place until at least 2 days after applications. Areas posted include the major points of entry and exit into the areas to be sprayed, and these areas include federal, state, municipal and private roads open to the public and known to be used by the public that lead into the area to be sprayed; utility crossings of these roads and any place a maintained public trail enters the application site. Posters must include the following information:

1. Name of the person who contracts for the application or her/his representative or the applicator and the address and telephone number to contact for more specific information about the intended application;
2. Intended purpose of the pesticide application;
3. Pesticide(s) to be used;
4. Telephone number of the Maine Board of Pesticides Control;

5. Telephone number of the Maine Poison Control Center; and
6. Public precautions, which appear on the pesticide label.

Written Notices to State Agencies

Person(s) contracting for aerial application of pesticides are also required to send written notices to the Board and the Maine Poison Control Center at least 7 days prior to application but may not exceed 60 days prior. These notices must include the following information when submitted to the Board of Pesticides Control:

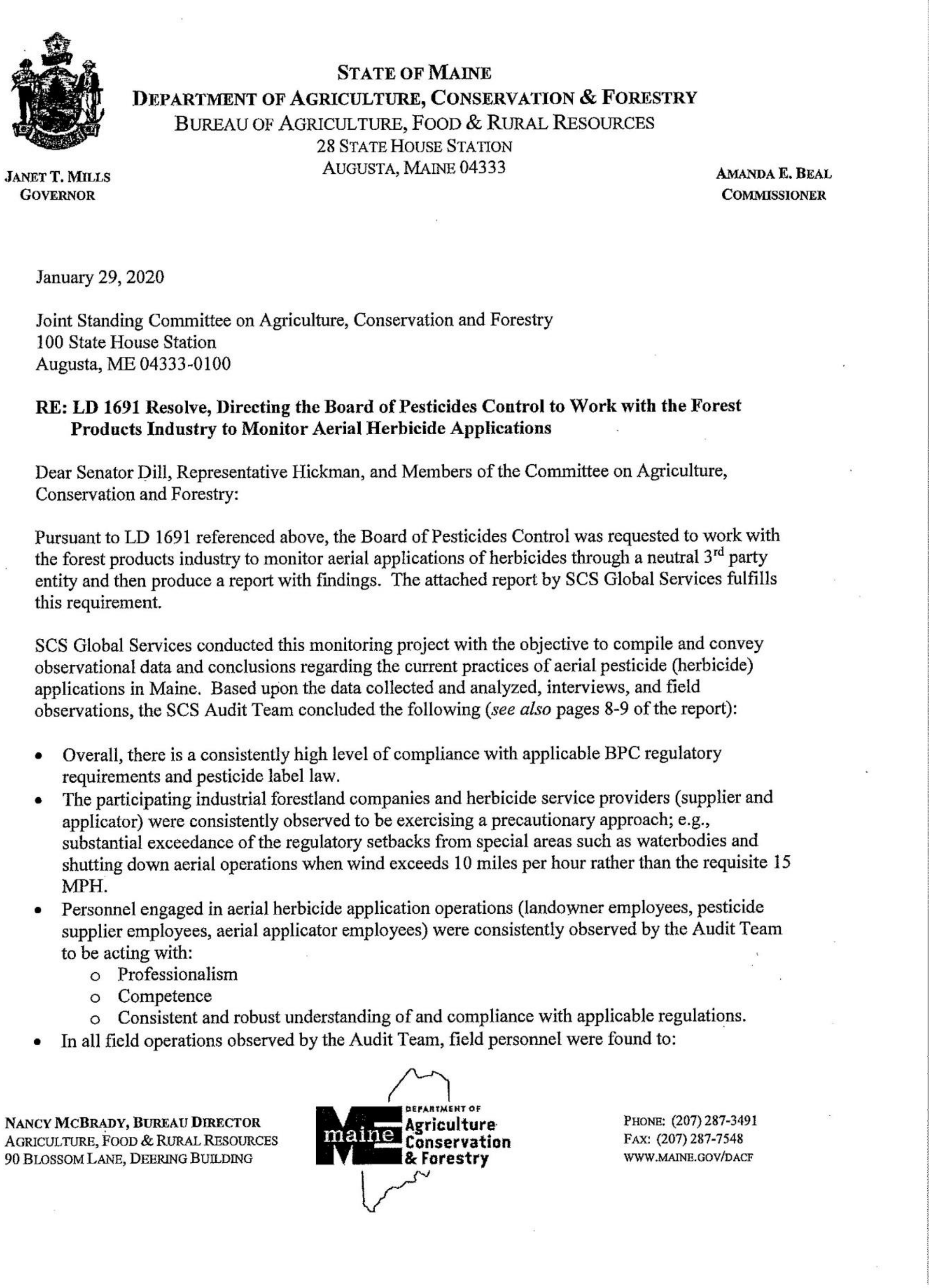
1. A description of the proposed spray activity, including detailed spray application maps showing sensitive areas and major public routes of ingress and egress. Use of The Maine Atlas and Gazetteer, by DeLorme Mapping Company or some other similar atlas, is the suggested format for the base map;
2. The date or dates on which spraying is proposed to take place;
3. A description of the delivery mechanism, which shall include the name, address, telephone number, and license number of the spray contracting firm which will carry out the spray activity;
4. Pesticide(s) to be used, dilution agent(s), ratio(s), and notation of any experimental applications;
5. A listing of precautions taken to ensure notice to the public, including copies of the newspaper notice or the notice given to person(s) owning property or using the residential rental, commercial or institutional buildings within 500 feet of the intended target site; and
6. The name, address, and telephone number of a contact person who will be reasonably accessible by telephone and who will make reasonably current and detailed information about the project available to the Board promptly upon request.

Written notices to the Maine Poison Control Center must include the following information:

1. Description of the general area the proposed application activity will take place;
2. The date or dates on which spraying is proposed to take place;
3. Pesticide(s) to be used, dilution agent(s), ratio(s), and notation of any experimental applications; and
4. The name, address, and telephone number of a contact person who will be reasonably accessible by telephone and who will make reasonably current and detailed information about the project available to the Maine Poison Control Center promptly upon request.

Any changes to the target area intended to be sprayed or pesticides assignments not in the original notice must be sent to the Board as soon as practicable, and reasonable effort should be made to notify the Board of these changes. Notice may be accomplished by telephone with the Board’s staff.

Addendum B—SCS Global Report



STATE OF MAINE
DEPARTMENT OF AGRICULTURE, CONSERVATION & FORESTRY
BUREAU OF AGRICULTURE, FOOD & RURAL RESOURCES
28 STATE HOUSE STATION
AUGUSTA, MAINE 04333

JANET T. MILLS
GOVERNOR

AMANDA E. BEAL
COMMISSIONER

January 29, 2020

Joint Standing Committee on Agriculture, Conservation and Forestry
100 State House Station
Augusta, ME 04333-0100

RE: LD 1691 Resolve, Directing the Board of Pesticides Control to Work with the Forest Products Industry to Monitor Aerial Herbicide Applications

Dear Senator Dill, Representative Hickman, and Members of the Committee on Agriculture, Conservation and Forestry:

Pursuant to LD 1691 referenced above, the Board of Pesticides Control was requested to work with the forest products industry to monitor aerial applications of herbicides through a neutral 3rd party entity and then produce a report with findings. The attached report by SCS Global Services fulfills this requirement.

SCS Global Services conducted this monitoring project with the objective to compile and convey observational data and conclusions regarding the current practices of aerial pesticide (herbicide) applications in Maine. Based upon the data collected and analyzed, interviews, and field observations, the SCS Audit Team concluded the following (*see also* pages 8-9 of the report):

- Overall, there is a consistently high level of compliance with applicable BPC regulatory requirements and pesticide label law.
- The participating industrial forestland companies and herbicide service providers (supplier and applicator) were consistently observed to be exercising a precautionary approach; e.g., substantial exceedance of the regulatory setbacks from special areas such as waterbodies and shutting down aerial operations when wind exceeds 10 miles per hour rather than the requisite 15 MPH.
- Personnel engaged in aerial herbicide application operations (landowner employees, pesticide supplier employees, aerial applicator employees) were consistently observed by the Audit Team to be acting with:
  - Professionalism
  - Competence
  - Consistent and robust understanding of and compliance with applicable regulations.
- In all field operations observed by the Audit Team, field personnel were found to:

NANCY MCBRADY, BUREAU DIRECTOR
AGRICULTURE, FOOD & RURAL RESOURCES
90 BLOSSOM LANE, DEERING BUILDING

maine DEPARTMENT OF Agriculture Conservation & Forestry

PHONE: (207) 287-3491
FAX: (207) 287-7548
WWW.MAINE.GOV/DACF

  - Carefully prepare and accurately measure application volumes
  - Employ safe and precise application procedures.
- All equipment employed in aerial operations (transport, mixing, application) was observed to be well maintained and in good working order.
- The application equipment and spray regulation systems employed by JBI are demonstrably effective at "getting the job done" with precision and minimum necessary deployment of chemicals. The nozzles employed are low pressure, narrow spectrum and designed specifically to minimize drift. The equipment incorporates an integrated flow regulation system that uses GPS inputs to regulate pressures and flow-rates in real time to match aircraft speed variations, resulting in ground-calibrated precision.

SCS also concluded:

> At bottom line, no evidence was gathered during the course of the verification audit to contradict the following overall conclusion: **The State of Maine regulatory framework, within which aerial application of herbicides in forest operations takes place, is functioning as designed.**
>
> Further: within the context of forest landowners' silvicultural decisions and the decision to aerially apply herbicides to control (for a targeted period of time) but not eliminate vegetation that competes with forest stand establishment and early stand development, we observed a consistent and genuine effort on the part of forest managers and pesticide applicators/suppliers to minimize reliance on and use of herbicides, principally through thorough planning and integrated pest management.

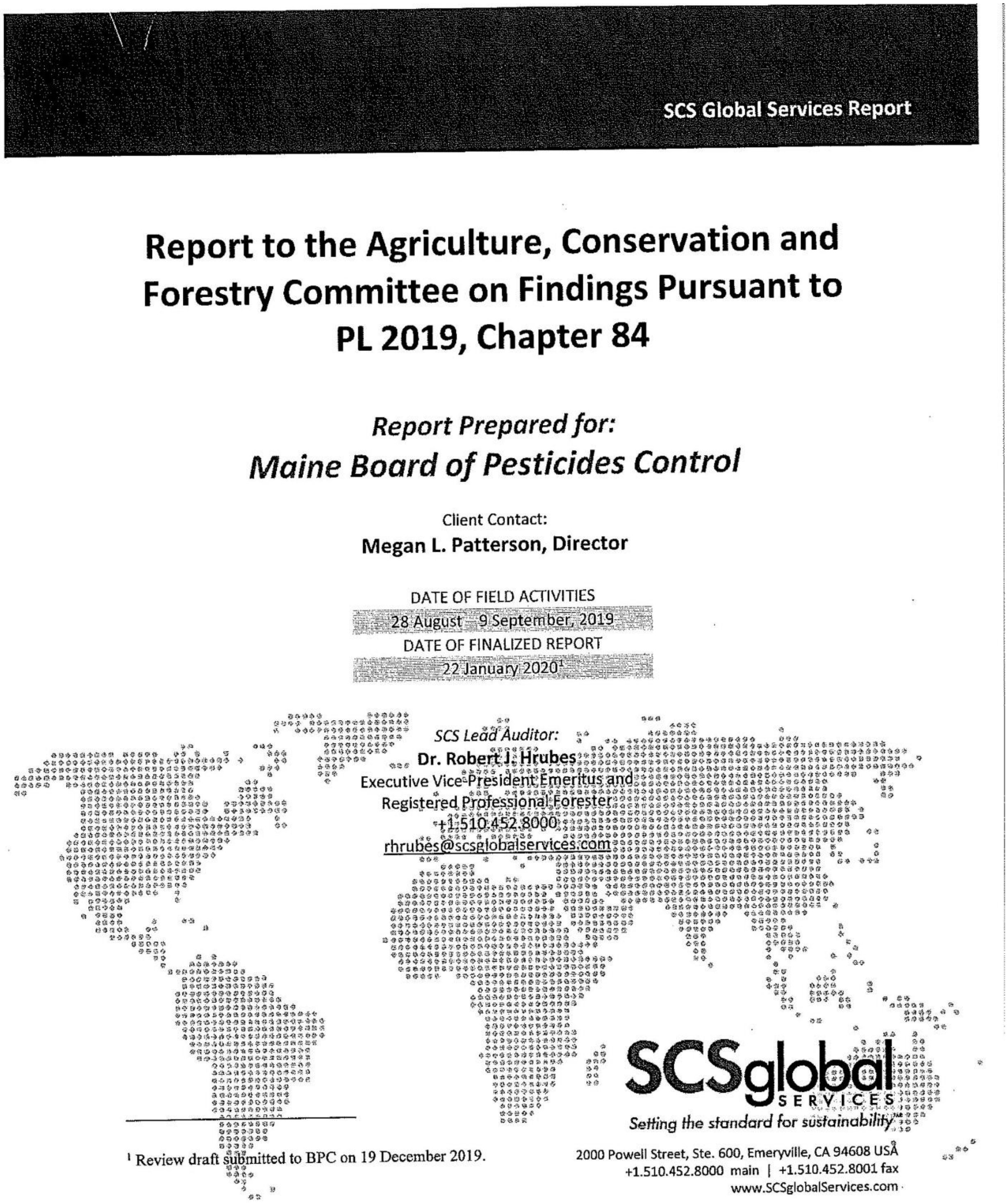
The Department looks forward to the Committee's review of the report and any follow-up questions or recommendations it may have.

Very Truly Yours,

Nancy McBrady, Director
Bureau of Agriculture, Food and Rural Resources

cc: Amanda Beal, Commissioner

Encl.



SCS Global Services Report

Report to the Agriculture, Conservation and Forestry Committee on Findings Pursuant to PL 2019, Chapter 84

Report Prepared for:

Maine Board of Pesticides Control

Client Contact:

Megan L. Patterson, Director

DATE OF FIELD ACTIVITIES
28 August – 9 September, 2019
DATE OF FINALIZED REPORT
22 January 2020[1]

SCS Lead Auditor:
Dr. Robert J. Hrubes
Executive Vice-President Emeritus and
Registered Professional Forester
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[1] Review draft submitted to BPC on 19 December 2019.

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1. General Information

SCS Global Services (formerly, Scientific Certification Systems) was contracted by the Maine Board of Pesticides Control (BPC) to undertake an independent assessment of conformance to State of Maine pesticide use regulations by industrial forest management companies engaged in aerial application of herbicides on forestlands under the jurisdiction of the Maine Board of Pesticides Control. The project results from a Resolve passed by the Maine State Legislature on 18 June 2019 (LD1691) directing the Board of Pesticides Control (BPC) to work with the Maine forest products industry to monitor aerial herbicide applications.

The objective of the contracted project was to gather information to enable the SCS project team to compile and convey observational data and conclusions as to the current practices of aerial pesticide (herbicide) applications in Maine, resulting in a monitoring report. The work was accomplished through personal interviews with forestry staff of Maine industrial forestland owners throughout the State, review of pertinent documents and, most importantly, sample-based field observations of organizations involved in aerial pesticide application (forestland owners, pesticide suppliers, aerial pesticide applicators).

The field work, comprised of monitoring inspections of aerial pesticide operations on three major industrial forestland ownerships[2], took place from August 26 to September 9, 2019. The SCS audit team was comprised of:

Robert J. Hrubes, Ph.D., Lead Auditor: Dr. Hrubes is a California Registered Professional Forester (#2228) with 40+ years of professional experience in both the public and private sectors. He is a founding member of the Forest Stewardship Council and the Forest Stewards Guild and he established and managed SCS' natural resources practice, beginning in the early 1990's until is semi-retirement in 2017. Hrubes holds degrees in forest management (BSF-Iowa State University), resource systems management (MS-University of Michigan), economics (MA-University of California at Berkeley) and wildland resource science (Ph.D.-University of California at Berkeley). Dr. Hrubes has led a large number of FSC forest management certification audits throughout North America as well as other regions ranging from Australia to Brazil to Sweden to Japan. Over the past 25 years, Hrubes has led numerous FSC forest management audits in Maine. Dr. Hrubes retired from his role as Executive Vice President of SCS Global Services in 2017 but remains active with the company on a part-time basis.

Mr. Gordon Moore, Audit Team Member: Gordon Moore is a Maine Professional Forester (#3207). He has worked in the timber industry in Maine for 40 years and, most recently, retired as a District Forester for the Maine Forest Service (MFS). During his time with the State of Maine he worked as the State Water Quality Forester and as a Timber Harvest Management specialist as well as co-author of the Performance Standards for Road Construction and Timber Harvesting on Wetlands Sites for the Land Use Planning Commission & MFS and co-authored along with the

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[2] The pesticides applied on the three participating forestland properties were a mix of the same three commercially available herbicides: Rodeo (active ingredient: glyphosate), Arsenal (active ingredient: imazapyr) and Oust (active ingredient: sulfometuron methyl).

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MFS and US Forest Service in developing Best Management Practices for Water Quality during Timber Harvesting. Gordon is a Maine licensed forester, receiving an AS in Forestry and BA's in Biology and Mathematics from the University of Maine at Fort Kent and completed work towards a MS at the University of Maine at Orono in wetland ecology. Gordon's professional work is conducted under the name: Maple View Forestry. His professional activities include having served on FSC forest management certification audit teams.

Both members of the SCS audit team underwent training and received pesticide handler certificates from BPC prior to commencement of the field auditing activities that are the subject of this report. However, at no time during the verification audit did the SCS auditors handle pesticides.

Any questions or comments regarding this report should be directed to:

Brendan Grady
Director, Forest Management Certification Services
SCS Global Services
Email: bgrady@scsglobalservices.com

Or:

Megan Patterson
Director, Maine Board of Pesticides Control
Email: Megan.L.Patterson@Maine.gov

2. Monitoring Design

The monitoring activities undertaken by the SCS team were focused on assessing conformance to three sets of "Verification Criteria" developed by Daniel J. Simonds[3], principal consultant of MixedWood LLC, who was separately contracted by the Board of Pesticides Control for this purpose. The MixedWood-developed Verification Criteria[4] (duly reviewed and approved by the BPC staff prior to use by SCS) were formatted around three "checklists:"

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[3] Daniel Simonds possesses a suite of experience & expertise — forestry, forestry auditing practices and procedures, and a working knowledge of Maine pesticide law—which made him uniquely qualified to develop the monitoring criteria for this project. Daniel is a Certified Forester, Licensed Maine Forester (ME883), and has 22 years of experience in industrial land management. Daniel is qualified as a Lead Auditor for third-party forest practice certification standards and is a noted expert in the protocols associated with FSC, SFI, and PEFC. Daniel also served 6 years as an appointed member of the Board of Pesticides Control. During his service, which including a year as Board chair, Daniel built expertise in the implementation and development of Maine pesticide regulations.

[4] MixedWood scoped, designed, and vetted the monitoring criteria as well as the associated field verification checklists for use by SCS Global auditors. Initial considerations for criteria included simple adoption of FSC and/or SFI audit criteria. Ultimately, these were determined to be limited in scope and insufficiently Maine-specific for this project. Final criteria were designed using a complex aggregation of the numerous, existing and pertinent, state and federal regulations, as well as pesticide label language. During implementation and use of the monitoring criteria,

- **Document Review Checklist***—intended for office-based use by the audit team when interviewing personnel and reviewing documents generated by industrial forest management companies that agreed to participate in the investigation. The subject areas covered by the Document Review Checklist are:
    - Notifications
    - Licensing (e.g., of applicators)
    - Records (e.g., application projects, annual summary, incident reports, employee training)
    - Sensitive Area (SA) maps
    - Sensitive Area Likely to be Occupied (SALO) checklists
- **Operations Checklist***—intended for field use by the audit team when observing operations and interviewing involved personnel at the helicopter "landing zones" at which pesticides are mixed and loaded onto a helicopter for application on nearby project sites. The subject areas covered by the Operations Checklist are:
    - Mixing and Loading--Label
    - Mixing and Loading—Regulations
    - Herbicide Prescription Specification—By-Product & From Label
    - Application Equipment (Label)
    - Application Equipment (Regulations)
    - Worker Protection
- **Application Checklist***—intended for field use by the audit team when observing operations and interviewing personnel at the project sites (forest stands) where herbicides are aerially applied. The subject areas covered by the Application Checklist are:
    - Site Conditions
    - Early Entry to Site
    - Mixing & Loading
    - Sensitive Areas (SA)
    - Sensitive Areas Likely to be Occupied (SALO)

The auditing/monitoring approach employed by the Audit Team was to gather pertinent information and data, recorded on the appropriate checklist, regarding conformance to the Verification Criteria, through the following means:

- Interviews of personnel employed by participating industrial forestland owners, pesticide suppliers and pesticide applicators; interviews took place both in company offices and in the field
- Review of pertinent documents
- Direct field observations of aerial application sites, landing zones and water drafting sites
- All observational data was recorded on the appropriate Verification Criteria Checklists.

During the course of the monitoring project, at total of 20 Checklists were completed (filled out) by the SCS team: 3 Document Review Checklists, 9 Operations Checklists and 8 Application Checklists. Hard

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* The 3 document checklists are attached at the end of the report.

MixedWood provided training, support, and oversight. This effort ensured effective, efficient and professional implementation of the monitoring project.

and electronic copies of the completed Checklists are maintained in the project file at the SCS Offices. Electronic copies of the completed checklists, along with this report, have been conveyed to BPC.

The findings presented in this Audit Report are based exclusively on the findings of the audit team, as recorded on the Checklists, augmented by notes of face-to-face interviews with participating individuals listed later in this report.

Participating Forestland Owners and Service Providers:

Three industrial forestland owners, each with substantial landholdings in Maine, agreed to participate in the verification audit[5]:

J.D. Irving (personnel based out of their Fort Kent office)
Seven Islands Land Company (personnel based out of their Ashland Office)
Weyerhaeuser (personnel based out of their Greenville and Bingham Offices)

All three forestland owners retain the services of the same pesticide supplier:

Nutrien Ag Solutions

Likewise, all three forestland owners retain the services of the same helicopter application company:

JBI Helicopter Services

Both Nutrien Ag Solutions and JBI Helicopter Services have an extensive and connected track record of work in Maine. It is the SCS audit team's understanding that essentially all aerial application of herbicides in forestry operations in Maine, this year and in recent prior years, involves retaining the services of Nutrien Ag Solutions and JBI Helicopter Services. A clear benefit of this current situation is that there is a very high degree of consistency in aerial application procedures as the same supplier and applicator employees undertook all forestry aerial pesticide applications in Maine in 2019.

Forest landowner field staff play an integral role in the aerial pesticide projects, including:

- Determining which forest stands will be treated during the summer pesticide application "season" which, depending on weather patterns, can be a rather short window of time
- In coordination with other forestland owners requiring the services of Nutrien Ag Solutions and JBI Helicopter Services, and subject to exogenous factors associated with weather, establishing a planned schedule of pesticide treatments for each annual treatment "season"
- Delineating treatment areas as well as Sensitive Areas (SA) and Sensitive Areas Likely to be Occupied (SALO)
- Posting requisite signage and publishing requisite public notices
- "Blocking off" roadways through project sites during active aerial operations
- Undertaking any remedial work that may be required, following operations
- Submitting required documentation to BPC

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[5] SCS had no role in the selection of participating forestland owners, pesticide suppliers and aerial pesticide applicators.

Participating Individuals:

The following individuals participated (i.e., directly interacted with the SCS Audit Team in the field) in the verification audit:

- Ron Lemin, Nutrien
- Rick Dionne, Nutrien
- Bruce Pelletier, Nutrien
- Ray Newcomb, JBI
- Chris Thresher, JBI
- Elvin Alvarez, JBI
- Sean Newcomb, JBI
- Alex Addren, JBI
- Ked Coffin, JDI
- Chris Huston, JDI
- Tim Cyr, JDI
- Nick Baser, 7 Isl.
- Zack Lowry, 7 Isl.
- Jason Desjardin, 7 Isl.
- John Ackley, WYCO
- Ben Dow, WYCO
- Devon Fogarty, WYCO
- Cullen Utermark, WYCO
- Megan Patterson, BPC
- Daniel Simonds, MixedWood LLC and Contractor to BPC

The field component of the verification audit commenced on August 26, 2019. Over the following 14 days, one or both of the SCS auditors engaged in field and office investigations on a total of 8 days. To the extent possible, field work was dependent on helicopter activity which, in turn, was dependent on favorable weather conditions. Weather conditions resulted in the SCS auditors observing active helicopter operations on a total of 5 days; active helicopter operations were observed on JD Irving and Weyerhaeuser forestland. No aerial applications took place on Seven Islands Land Company lands from the commencement date of the project through to the end of the 2019 aerial application "season." During the 5 days of active helicopter operations, a total of approximately 40 "lifts"[6] were observed. On other field days, when weather conditions grounded the helicopter, field work focused on inspection of sites that had received aerial herbicide application earlier in the season, prior to commencement of the verification audit.

Field Observation Locations:

- Aug. 26 – Oxbow Road, JDI
- Aug. 27 – North Maine Woods, JDI

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[6] Helicopter leaving a landing zone with a full load herbicide mix, deploying the load on the target stand, and returning to the landing zone.

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Aug. 28 – T8R7 WELS, 7 Islands (3 sites)
Aug. 29 – Sandwich Academy Grant, Greenville Unit, WYCO
Sept. 1 -- Near Long Pond South of Greenville, Greenville Unit, WYCO
Sept. 5 – Big W Township, Greenville Unit, WYCO
Sept. 6 – Big W, West Middlesex, Brassua, Soldiertown Townships, Greenville Unit, WYCO
Sept. 8 – Mayfield Township, Lexington Township, Bingham Unit, WYCO

3. Monitoring Results

Based upon the data collected and analyzed, interviews completed and field observations made, the SCS Audit Team concludes that:

- Overall, there is a consistently high level of compliance with applicable BPC regulatory requirements and pesticide label law.
- The participating industrial forestland companies and herbicide service providers (supplier and applicator) were consistently observed to be exercising a precautionary approach; e.g., substantial exceedance of the regulatory setbacks from special areas such as waterbodies and shutting down aerial operations when wind exceeds 10 miles per hour rather than the requisite 15 MPH.
- Personnel engaged in aerial herbicide application operations (landowner employees, pesticide supplier employees, aerial applicator employees) were consistently observed by the Audit Team to be acting with:
    - Professionalism
    - Competence
    - Consistent and robust understanding of and compliance with applicable regulations.
- In all field operations observed by the Audit Team, field personnel were found to:
    - Carefully prepare and accurately measure application volumes
    - Employ safe and precise application procedures.
- All equipment employed in aerial operations (transport, mixing, application) was observed to be well maintained and in good working order
- The application equipment and spray regulation systems employed by JBI are demonstrably effective at "getting the job done" with precision and minimum necessary deployment of chemicals. The nozzles employed are low pressure, narrow spectrum and designed specifically to minimize drift. The equipment incorporates an integrated flow regulation system that uses GPS inputs to regulate pressures and flow-rates in real time to match aircraft speed variations, resulting in ground-calibrated precision.

At bottom line, no evidence was gathered during the course of the verification audit to contradict the following overall conclusion:

> **The State of Maine regulatory framework, within which aerial application of herbicides in forest operations takes place, is functioning as designed.**

Further: within the context of forest landowners' silvicultural decisions and the decision to aerially apply herbicides to control (for a targeted period of time) but not eliminate vegetation that competes with forest stand establishment and early stand development, we observed a consistent and genuine effort on the part of forest managers and pesticide applicators/suppliers to minimize reliance on and use of herbicides, principally through thorough planning and integrated pest management.

Additional Observations

Spray Height

Field observations by the Audit Team were that the helicopter's "spray height" (distance above the ground when herbicide is released from the spray boom) was consistently around 30 feet. As the pertinent verification criterion (taken from the regulations) is stated as: "Spray height < 10 ft. except higher for safety", the auditors regularly inquired of the helicopter pilot and ground crew as to the reason for consistently exceeding the 10-foot target. The answer was two-fold:

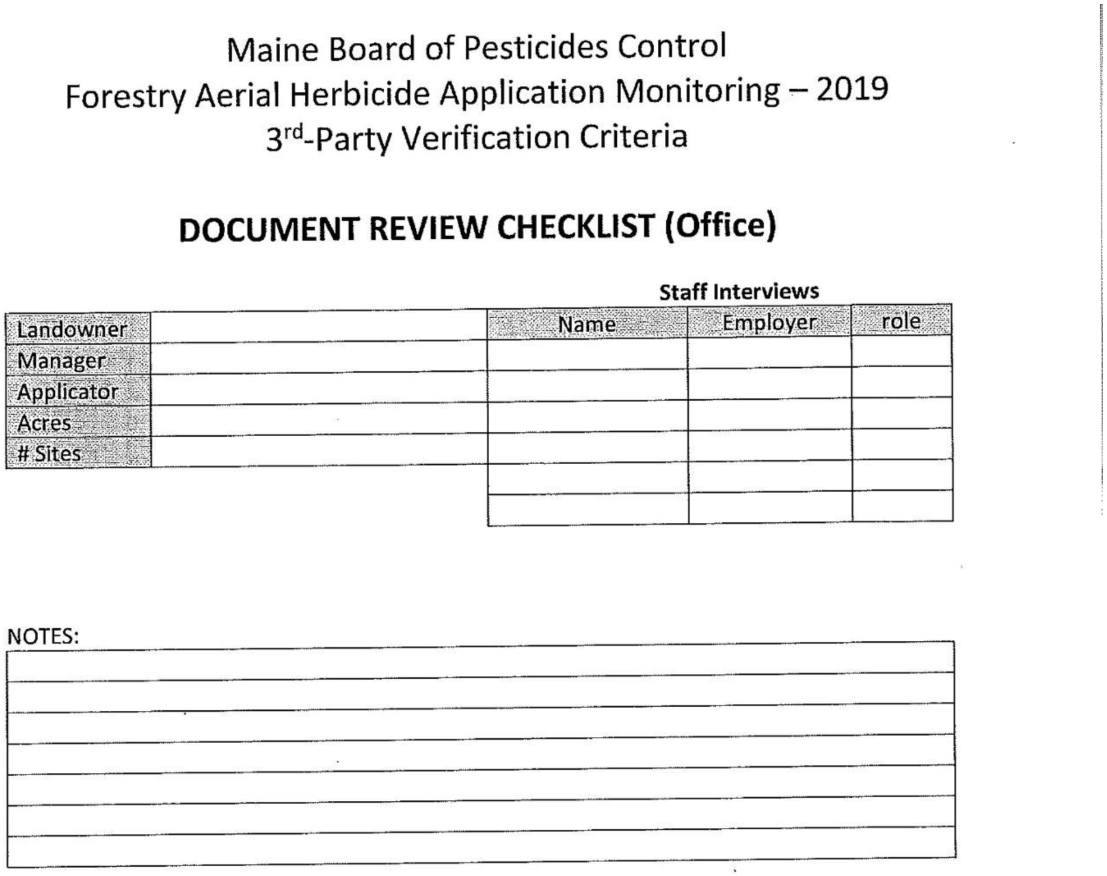
- Due to the fact that most treatment blocks are at least partially bordered by stands of trees of at least 30' height, it is a safety hazard to utilize a spray height of 10'
- Releasing herbicide at 10' would require the pilot to pull up rapidly at the end of the spray run to clear the adjacent tree line, resulting in an increased likelihood of the rotor wash of the banked helicopter pushing herbicide into the adjoining (non-targeted) trees.

That is, field personnel have judged that a 30' spray height is warranted for both safety and environmental considerations. Based upon our observations of the geometry of aerial release of herbicide at the periphery of the treatment block, we concur with the validity of that judgment. Accordingly, we conclude that the operations we observed were in compliance with "spray height < 10 ft. except higher for safety."

Wildlife Disturbance

As young stands of conifer trees can be attractive as a food source for ungulates such as moose and deer, it is not uncommon for moose, or other large mammals such as bear and deer to forage in stands that are scheduled for aerial application of herbicides. Dialogue with field personnel involved in aerial application projects, particularly the pilots, confirmed an awareness of the risk of wildlife "harassment" and that standardized measures are employed for avoiding harassment. Field personnel, employees of the forest landowner companies, regularly conduct "wiggle walks" of a treatment area prior to operations for the purpose of identifying sensitive areas, which are most commonly water bodies. While not the principal purpose of "wiggle walks", some field personnel interviewed during the audit mentioned that their focus also includes evidence of large mammal activity. If evidence of animal presence or activity is detected, the information is, as a matter of practice, conveyed to the helicopter crew. Additionally, the helicopter pilot "scouts" the spray block before treatment. These pass-overs enable the pilot to spot moose or bear and usually the noise of the helicopter results in the animal leaving the treatment block. The pilot can record the presence of large mammals during the scouting passes and can record their locations in the on-board GPS. The pilots informed the auditors that they, as a matter of practice, do not knowingly release herbicides onto large mammals. If necessary, the treatment will be delayed until large mammals vacate the treatment block.

While the audit team members are not qualified to definitively judge the effectiveness of these measures, nor did the audit protocol provide an opportunity to examine the topic in depth, it is our general sense that personnel involved in aerial pesticide application projects are genuinely committed to and effective at avoiding disturbance to wildlife that would qualify as harassment.



Maine Board of Pesticides Control
Forestry Aerial Herbicide Application Monitoring – 2019
3rd-Party Verification Criteria

DOCUMENT REVIEW CHECKLIST (Office)

Landowner	
Manager	
Applicator	
Acres	
# Sites	

Staff Interviews

Name	Employer	role

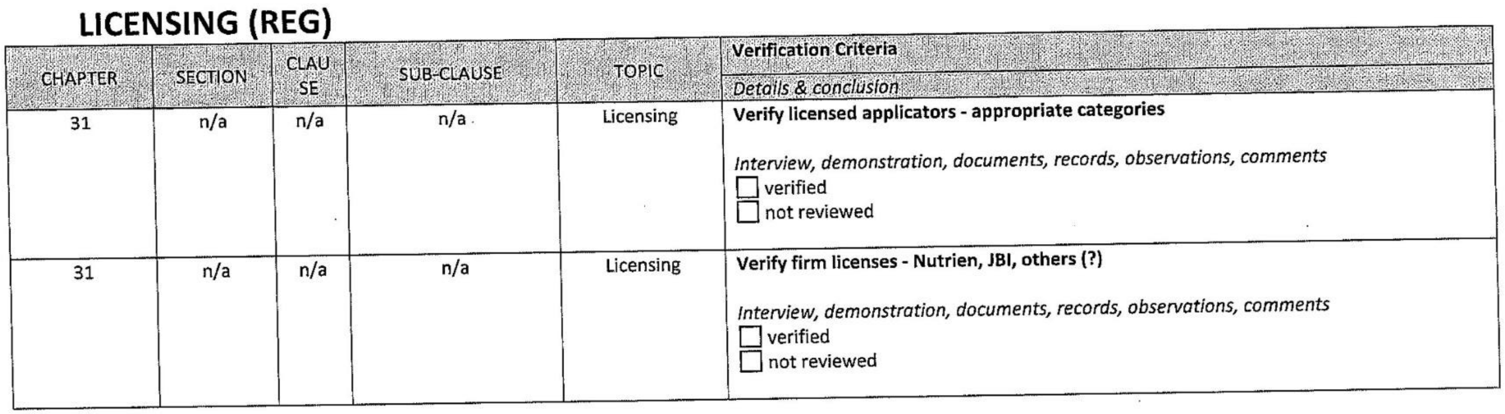
NOTES:

NOTIFICATION (REGS)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria *Details & conclusion*
51	I	A/B	n/a	Newspaper Ads	**Verify** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
51	IV	B	1		
51	I	C	n/a	Posters	**Verify details** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
51	IV	C	1/2		
51	IV	B	2	Indiv. Notice	**Verify notification w/in 500'** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
51	IV	D	n/a	Program Notice	**Verify BPC notification** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
51	IV	D	n/a	Program Notice	**Verify Poison Control Center notification** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
51	VI	A	n/a	Program Notice	**Verify notice 7-30 days prior** *Interview, demonstration, documents, records, observations, comments*

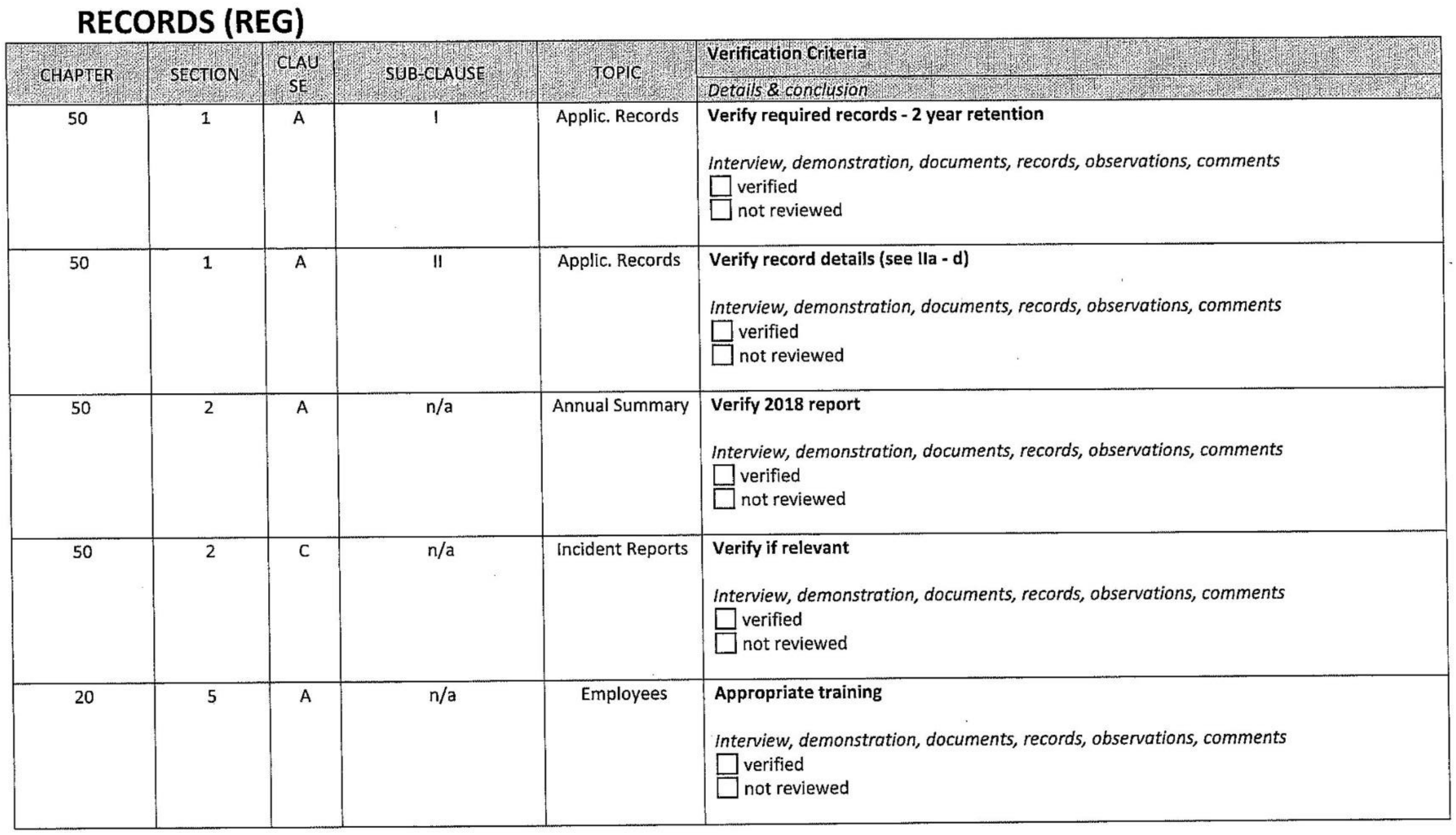
					☐ verified ☐ not reviewed
51	VI	B/C	n/a	Program Notice	**Verify notification details (VI B1-2)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
28	1	A	n/a	Notif. Requests	**Verify relevant notification requests** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
28	1	B	n/a	Notif. Procedure	**Verify relevant notification responses** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
28	2	C	n/a	Registry Consultation	**Verify appropriate consultation of Notification Registry** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
28	2	D	1/2	Registry Notification	**Verify relevant notification responses - w/in 250'** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
28	3	D	3/6/7	Registry Notification	**Verify notification details** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

28	4	D	4	Registry Notification	**Verify add'l information - if requested** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	4	C	I - III	Off-target Application	**Consent recorded for off-target discharge or drift** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	5	A/B	n/a	Variances	**Verify application, receipt , & record** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	6	A/B	n/a	Emergencies	**Verify declaration** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed



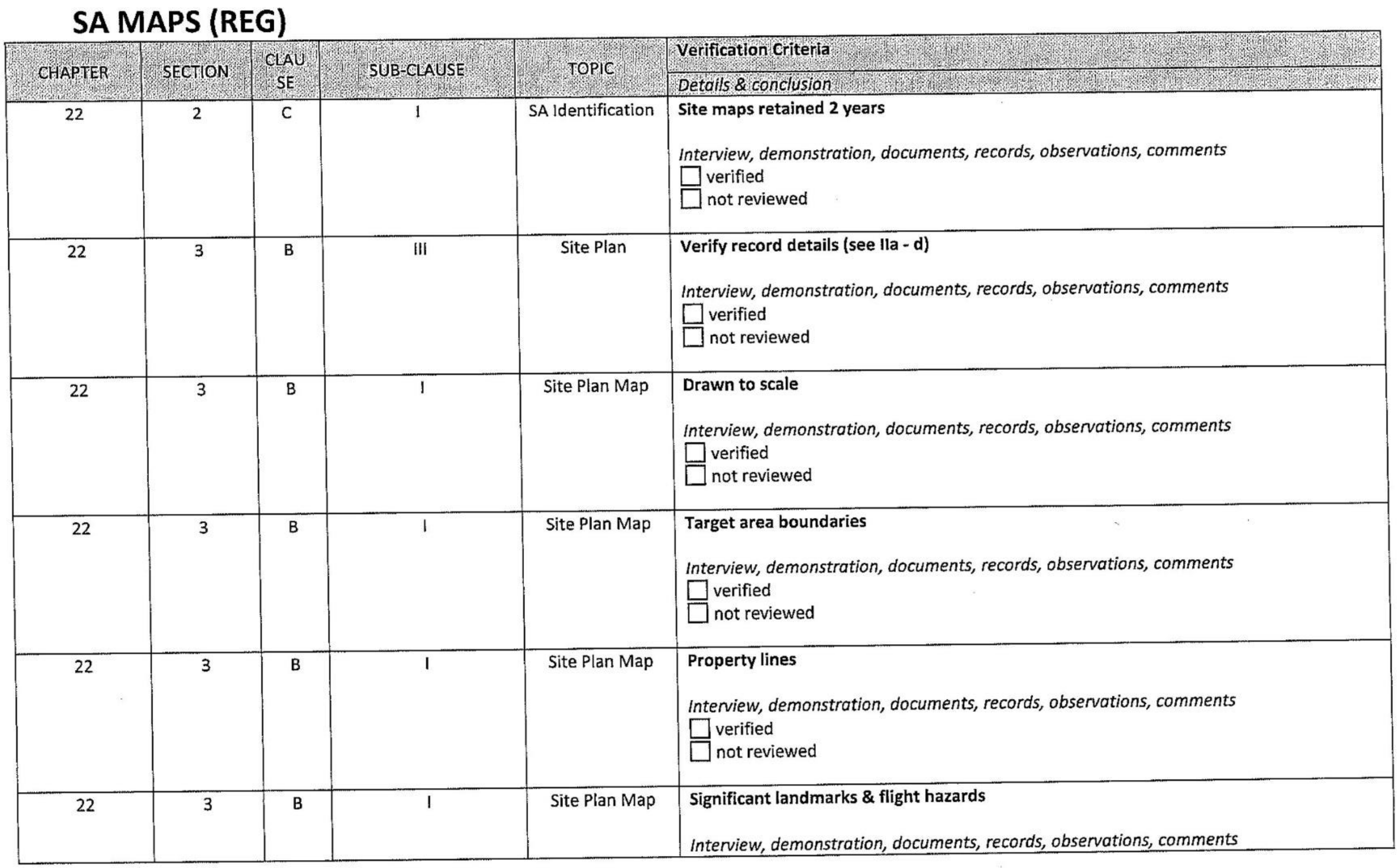
LICENSING (REG)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria
					Details & conclusion
31	n/a	n/a	n/a	Licensing	**Verify licensed applicators - appropriate categories** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
31	n/a	n/a	n/a	Licensing	**Verify firm licenses - Nutrien, JBI, others (?)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed



RECORDS (REG)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria
					Details & conclusion
50	1	A	I	Applic. Records	**Verify required records - 2 year retention** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
50	1	A	II	Applic. Records	**Verify record details (see IIa - d)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
50	2	A	n/a	Annual Summary	**Verify 2018 report** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
50	2	C	n/a	Incident Reports	**Verify if relevant** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
20	5	A	n/a	Employees	**Appropriate training** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed



SA MAPS (REG)

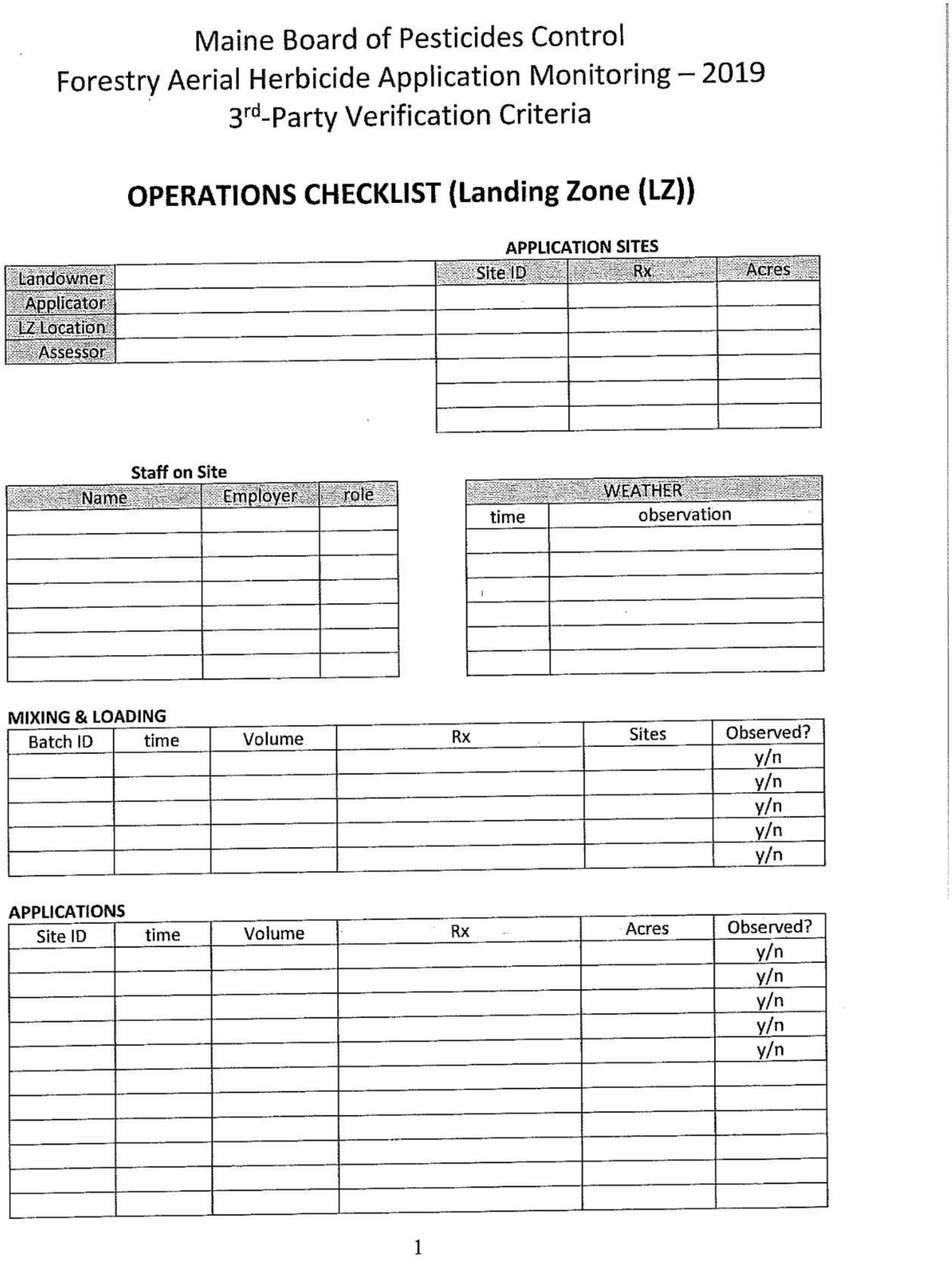
CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria *Details & conclusion*
22	2	C	I	SA Identification	**Site maps retained 2 years** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	B	III	Site Plan	**Verify record details (see IIa - d)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	B	I	Site Plan Map	**Drawn to scale** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	B	I	Site Plan Map	**Target area boundaries** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	B	I	Site Plan Map	**Property lines** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	B	I	Site Plan Map	**Significant landmarks & flight hazards** *Interview, demonstration, documents, records, observations, comments*

					☐ verified ☐ not reviewed
22	3	B	I	Site Plan Map	**SALO w/in 1000'** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	B	I	Site Plan Map	**SA w/in 500'** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	B	II	Site Plan Map	**School bus schedule** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

SALO CHECKLISTS (REG)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria
					Details & conclusion
22	3	C	I	SALO Checklist	**Date, time, target descrip., applic. ID** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I	SALO Checklist	**Confirmation of notifications (Ch28 & 51)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I	SALO Checklist	**Confirmation of site ID (3A)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I	SALO Checklist	**Weather monitoring location** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I	SALO Checklist	**Weather monitoring equipment** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

22	3	C	I	SALO Checklist	**Confirmation of acceptable weather conditions** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I	SALO Checklist	**Current weather observations (wind speed & direction)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I	SALO Checklist	**SA protection measures** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I	SALO Checklist	**Confirmation of no humans visible** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed



Maine Board of Pesticides Control
Forestry Aerial Herbicide Application Monitoring – 2019
3rd-Party Verification Criteria

OPERATIONS CHECKLIST (Landing Zone (LZ))

Landowner	
Applicator	
LZ Location	
Assessor	

APPLICATION SITES

Site ID	Rx	Acres

Staff on Site

Name	Employer	role

WEATHER	
time	observation

MIXING & LOADING

Batch ID	time	Volume	Rx	Sites	Observed?
					y/n
					y/n
					y/n
					y/n
					y/n

APPLICATIONS

Site ID	time	Volume	Rx	Acres	Observed?
					y/n
					y/n
					y/n
					y/n
					y/n

1

MIX & LOAD (LABEL)

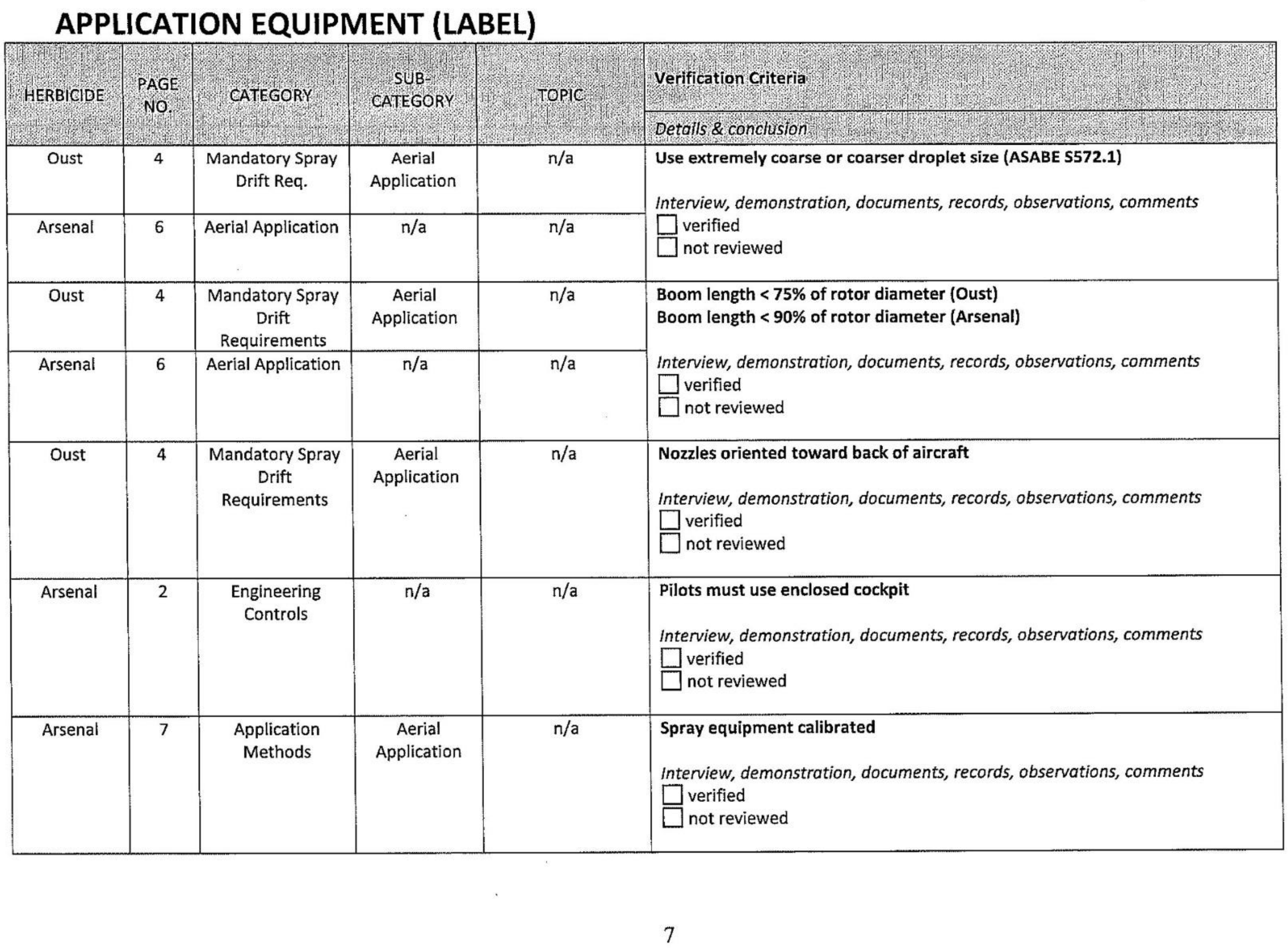
HERBICIDE LABEL	PAGE NO.	CATEGORY	SUB-CATEGORY	TOPIC	Verification Criteria *Details & conclusion*
ACCORD XRT II	1	Haz. to Humans, etc.	n/a	PPE	**Long-sleeved shirt & pants - chem. resistant gloves - shoes/socks** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Rodeo	1	Haz. to Humans, etc.	PPE	PPE	
Oust	2	Haz. to Humans, etc.	Precautionary Statements	PPE	
Arsenal	2	Haz. to Humans, etc.	PPE	PPE	
Accord XRT II	1	Phys. & Chem. Haz.	n/a	n/a	**Do not mix, store, apply in galvanized or unlined steel containers** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Rodeo	1	Phys. & Chem. Haz.	n/a	n/a	
Arsenal	2	Phys. & Chem. Haz.	n/a	n/a	
Accord XRT II	3	Mixing Directions	n/a	n/a	**Eliminate risk of siphoning** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Rodeo	3	Mixing Directions	n/a	n/a	
Accord XRT II	3	Mixing Directions	n/a	n/a	**Avoid water containing soil** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Rodeo	4	Mixing Directions	n/a	n/a	
Accord XRT II	4	Tank Mixing	n/a	n/a	**Maintain agitation at all times** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Rodeo	4	Tank Mixing	n/a	n/a	
Rodeo	1	Directions for Use	n/a	n/a	**Do not apply in a way that will contact persons** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

MIX & LOAD (REGS)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria *Details & conclusion*
20	3	A	n/a	Storage	**Secure enclosure - prevent unauthorized use, mishandling, etc.** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
20	5	A	n/a	Employees	**Appropriate training** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
20	5	B	n/a	Employees	**Appropriate PPE** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

	8	Forestry Conifer & HW Release	Broadcast Applic.	ME & NH	**May be tank mixed 1-2.5 oz Arsenal App Conc** ☐ verified ☐ not reviewed
	9	Forestry Conifer & HW Release	Broadcast Applic.	ME & NH	**May be tank mixed 1-3 oz Oust XP** ☐ verified ☐ not reviewed
Oust	13	Agric. Use Requirements	Conifers Site Prep	NE & Lake States	**Application = 2-4 oz/ac - black spruce** ☐ verified ☐ not reviewed
	14	Agric. Use Requirements	Conifer Release	NE & Lake States	**Application = 1.5-3 oz/acre white spruce** ☐ verified ☐ not reviewed
	17	Agric. Use Requirements	Use Restrict. Forestry	n/a	**Apply < 8 oz/acre/year** ☐ verified ☐ not reviewed
	17	Agric. Use Requirements	Use Restrict. Forestry	n/a	**Do not apply more than 2 applications/year** ☐ verified ☐ not reviewed
	22	Non-Agric. Uses	Tank Mix Combos	n/a	**Add 2-6 oz/ac to Glyphosate** ☐ verified ☐ not reviewed
	26	Additional Instructions	n/a	n/a	**Apply < 4.25 oz/ac/single application** ☐ verified ☐ not reviewed

Arsenal	5	Site Specific Restrictions	Nonagr. Land/Forest	n/a	**Do not apply more than 48 fl.oz/year** ☐ verified ☐ not reviewed
	7	Application Methods	Aerial Application	n/a	**Application rate = 2-30 gal/ac** ☐ verified ☐ not reviewed
	9	Forestry Use	Site Prep Treatment	n/a	**Application rate = 5-30 gal/ac** ☐ verified ☐ not reviewed
	9	Forestry Use	Site Prep Treatment	Broadcast Applic.	**Application rate = 12-16 oz/ac** ☐ verified ☐ not reviewed
	10	Forestry Use	Conifer Release	Broadcast Applic.	**Application rate = 6-12 oz/ac** ☐ verified ☐ not reviewed



APPLICATION EQUIPMENT (LABEL)

HERBICIDE	PAGE NO.	CATEGORY	SUB-CATEGORY	TOPIC	Verification Criteria
					Details & conclusion
Oust	4	Mandatory Spray Drift Req.	Aerial Application	n/a	**Use extremely coarse or coarser droplet size (ASABE S572.1)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	6	Aerial Application	n/a	n/a	
Oust	4	Mandatory Spray Drift Requirements	Aerial Application	n/a	**Boom length < 75% of rotor diameter (Oust)** **Boom length < 90% of rotor diameter (Arsenal)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	6	Aerial Application	n/a	n/a	
Oust	4	Mandatory Spray Drift Requirements	Aerial Application	n/a	**Nozzles oriented toward back of aircraft** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	2	Engineering Controls	n/a	n/a	**Pilots must use enclosed cockpit** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	7	Application Methods	Aerial Application	n/a	**Spray equipment calibrated** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

APPLICATION EQUIPMENT (REG)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria
					Details & conclusion
22	2	A	I	Spray Equipment	**Used in accordance with mfg. recommendations & instructions** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	A	I	Spray Equipment	**Sound mechanical condition** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	A	I	Spray Equipment	**free of leaks, defects, malfunctions - which may cause off-target** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	A	II	Spray Equipment	**Calibrated according to relevant guidance** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	A	II	Spray Equipment	**Calibration records sufficient** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	A	III	Spray Equipment	**Functioning shut-off valves** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

22	2	A	III	Spray Equipment	**Anti-siphoning device** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	B	I	Weather	**Does not favor drift onto SA** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	B	I	Weather	**Does not prevent proper target deposition** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	B	II	Weather	**Application ceased when off-site deposition observed** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	B	III	Weather	**Wind speed does not exceed 15 mph** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

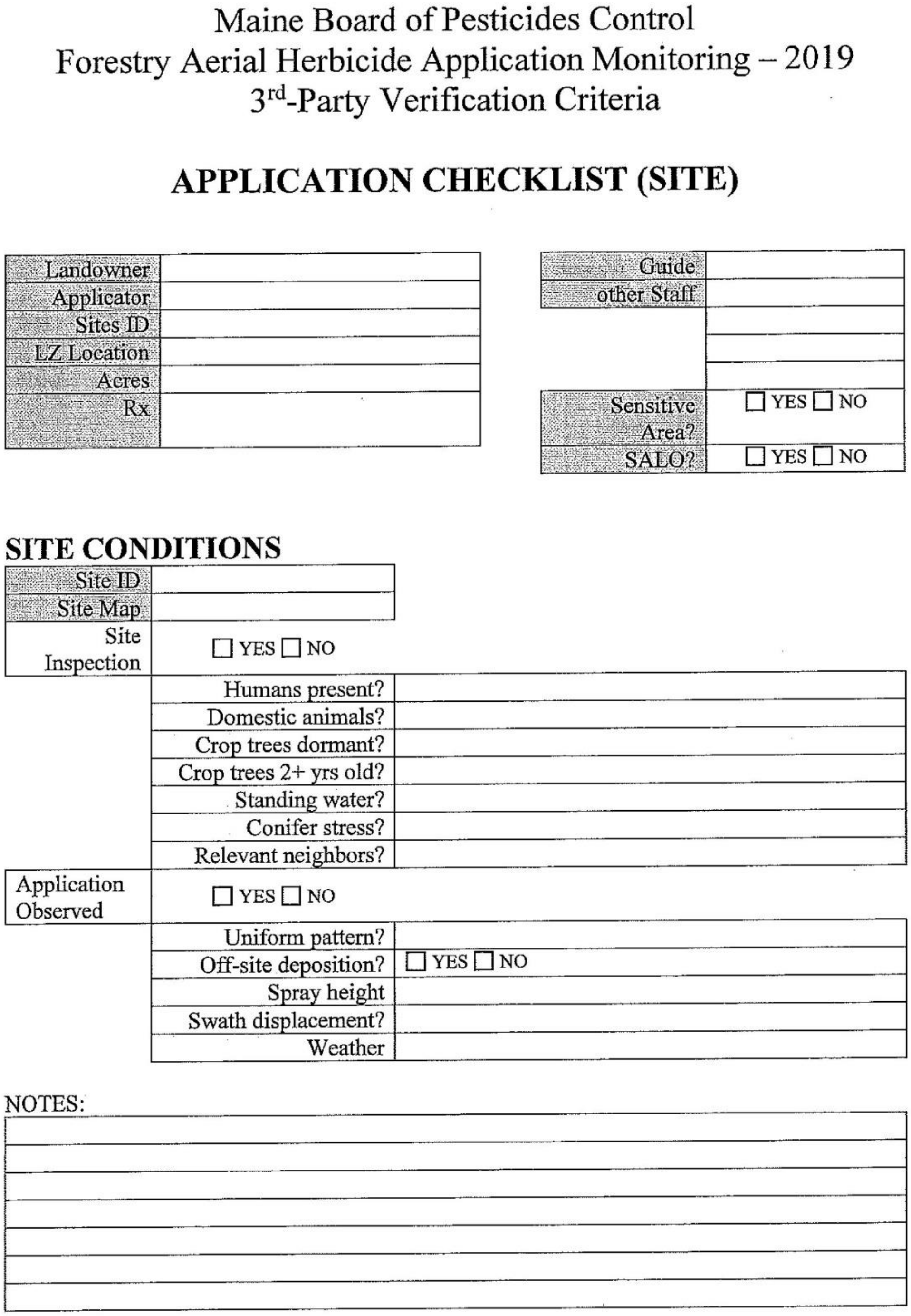
WATER QUALITY PROTECTION (REG)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria
					Details & conclusion
29	1	A	n/a	Mix/Load	**Mixing & Loading >50' from water body** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
29	1	B	n/a	Pumps	**Water pumping equipment clean of pesticides** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
29	1	C	n/a	Anti-syphon	**Verify anti-syphon for water pumping equipment** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
29	2	n/a	n/a	Tanks & Containers	**Verify secure transport** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
29	3	n/a	n/a	Spill Cleanup	**Verify spills w/in 50' of water cleaned promptly** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
29	6	A	n/a	Water Buffer	**Verify minimum 25' buffer on water bodies** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

WORKER PROTECTION STANDARD (WPS) - (BPS Inspection Forms)

FORM	TOPIC	Verification Criteria *Details & conclusion*
General	Posted Information	**Visible, central location** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
General	Posted Information	**SDS - all products** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
General	Posted Information	**Names of pesticides in use** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
General	Posted Information	**REI's and expiration** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
General	Posted Information	**Time/date of application** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
General	Posted Information	**Pesticide safety information** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

General	Posted Information	**Medical facility information** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
General	Posted Information	**Label information (EPA reg., Active ingredients)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
General	Training	**Verify training for interviewed staff** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Workers	Site Entry	**Verify no entry prior to REI expiration** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Handlers	PPE	**Appropriate PPE** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Handlers	Equipment Operation	**Verify training for all equipment** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Handlers	Label Access	**Verify handlers access to label** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed



Maine Board of Pesticides Control
Forestry Aerial Herbicide Application Monitoring – 2019
3rd-Party Verification Criteria

APPLICATION CHECKLIST (SITE)

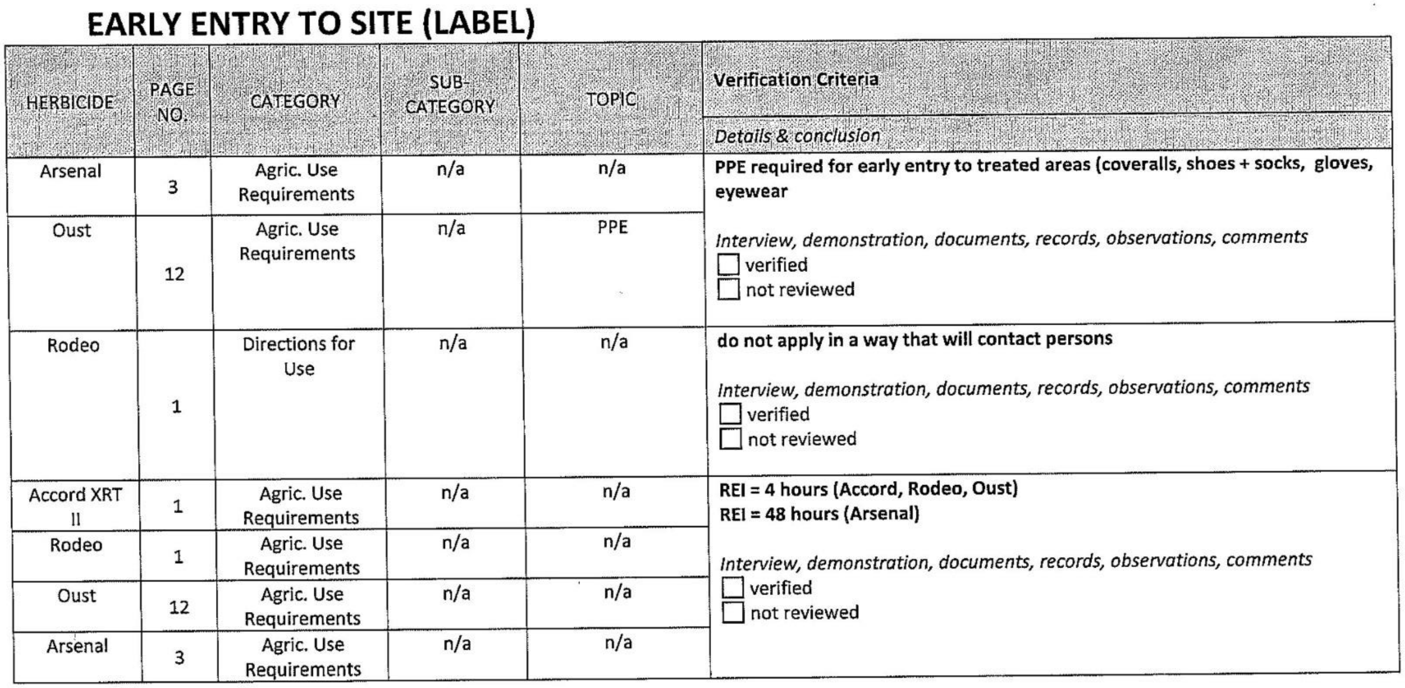
Landowner	
Applicator	
Sites ID	
LZ Location	
Acres	
Rx	

Guide	
other Staff	
Sensitive Area?	☐ YES ☐ NO
SALO?	☐ YES ☐ NO

SITE CONDITIONS

Site ID		
Site Map		
Site Inspection	☐ YES ☐ NO	
	Humans present?	
	Domestic animals?	
	Crop trees dormant?	
	Crop trees 2+ yrs old?	
	Standing water?	
	Conifer stress?	
	Relevant neighbors?	
Application Observed	☐ YES ☐ NO	
	Uniform pattern?	
	Off-site deposition?	☐ YES ☐ NO
	Spray height	
	Swath displacement?	
	Weather	

NOTES:

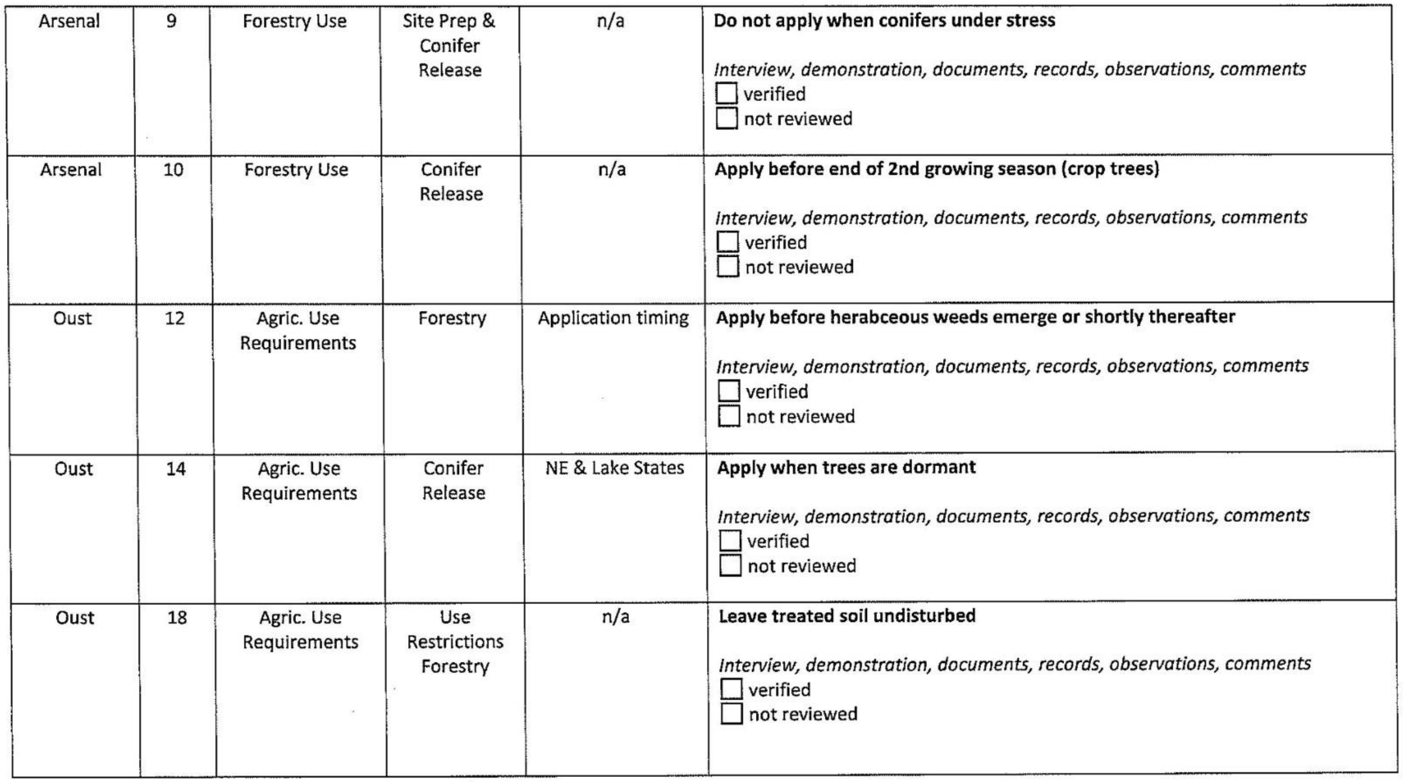


EARLY ENTRY TO SITE (LABEL)

HERBICIDE	PAGE NO.	CATEGORY	SUB-CATEGORY	TOPIC	Verification Criteria *Details & conclusion*
Arsenal	3	Agric. Use Requirements	n/a	n/a	**PPE required for early entry to treated areas (coveralls, shoes + socks, gloves, eyewear** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	12	Agric. Use Requirements	n/a	PPE	
Rodeo	1	Directions for Use	n/a	n/a	**do not apply in a way that will contact persons** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Accord XRT II	1	Agric. Use Requirements	n/a	n/a	**REI = 4 hours (Accord, Rodeo, Oust)** **REI = 48 hours (Arsenal)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Rodeo	1	Agric. Use Requirements	n/a	n/a	
Oust	12	Agric. Use Requirements	n/a	n/a	
Arsenal	3	Agric. Use Requirements	n/a	n/a	

SITE CONDITIONS (LABEL)

HERBICIDE	PAGE NO.	CATEGORY	SUB-CATEGORY	TOPIC	Verification Criteria *Details & conclusion*
Oust	3	Environmental Hazards	n/a	n/a	**Do not apply directly to surface of water** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	8	Product Information	n/a	n/a	**Do not apply to bodies of water** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	27	Additional Instructions	n/a	n/a	**Do not treat frozen or snow covered soil** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	2	Environmental Hazards	n/a	n/a	**Do not apply to water except as specified in label** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	5	Site Specific Restrictions	Potable Water Intakes	n/a	**Do not apply 1/2 mile upstream of active potable water intake** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed



Arsenal	9	Forestry Use	Site Prep & Conifer Release	n/a	**Do not apply when conifers under stress** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	10	Forestry Use	Conifer Release	n/a	**Apply before end of 2nd growing season (crop trees)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	12	Agric. Use Requirements	Forestry	Application timing	**Apply before herabceous weeds emerge or shortly thereafter** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	14	Agric. Use Requirements	Conifer Release	NE & Lake States	**Apply when trees are dormant** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	18	Agric. Use Requirements	Use Restrictions Forestry	n/a	**Leave treated soil undisturbed** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

EARLY ENTRY TO SITE (LABEL)

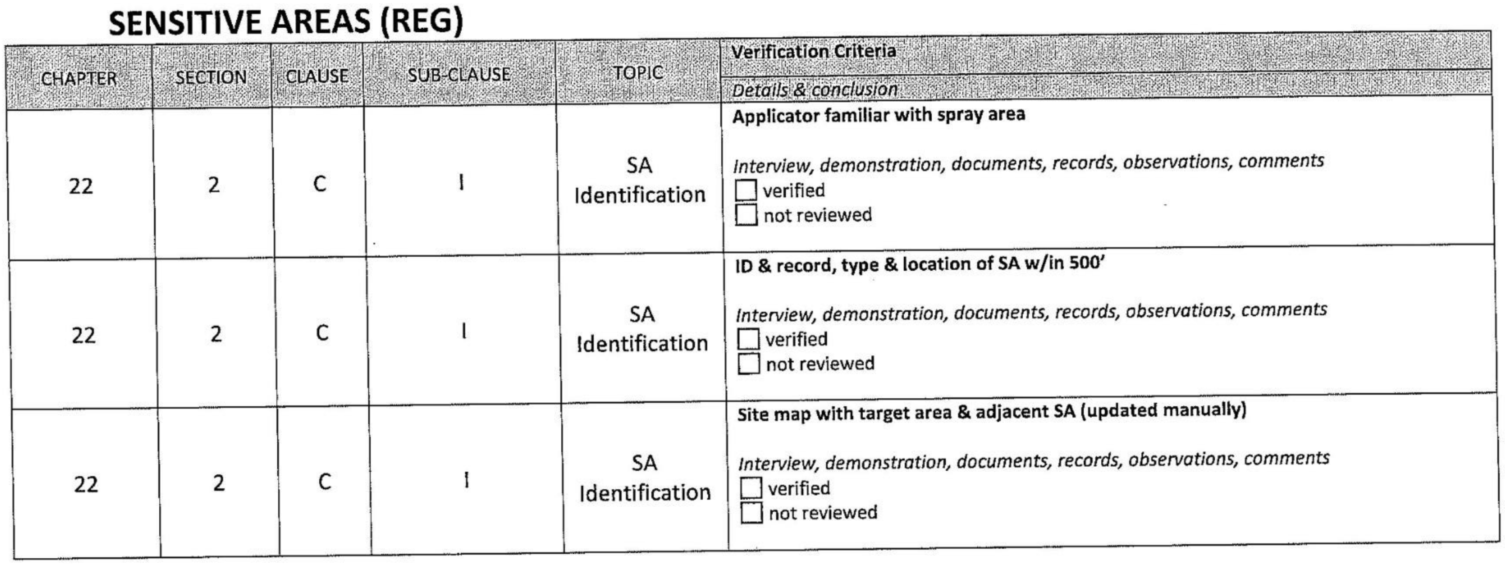
HERBICIDE	PAGE NO.	CATEGORY	SUB-CATEGORY	TOPIC	Verification Criteria *Details & conclusion*
Oust	3	Agric. Use Requirements	n/a	n/a	**Use ½ upwind swath displacement** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	12	Agric. Use Requirements	n/a	PPE	
Oust	28	Additional Precautions	Application	n/a	**Vol. & delivery for uniform pattern, minimize drift** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	7	Application Methods	Aerial Application	n/a	
Arsenal	6	Aerial Application	n/a	n/a	**Wind speeds 3-10 mph** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	6	Aerial Application	n/a	n/a	**Required to use upwind swath displacement** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	4	Mandatory Spray Drift Requrements	Aerial Application	n/a	**Spray height < 10 ft. except higher for safety** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

Oust	3	Environmental Hazards	n/a	n/a	**Surface water buffer strip is applied** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	7	Application Methods	Aerial Application	n/a	**Appropriate buffers except on open tracts of land** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	4	Mandatory Spray Drift Requrements	Aerial Application	n/a	**Do not apply during temperature inversions** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Oust	11	Site Specific Considerations	n/a	n/a	**Careful evaluation prior to use** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
Arsenal	6	Aerial Application	n/a	n/a	**Required to use upwind swath displacement** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

MIX & LOAD (REGS)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria
					Details & conclusion
51	I	C	n/a	Posters	**Verify details** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
51	IV	C	1/2		
51	IV	B	2	Indiv. Notice	**Verify notification w/in 500'** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	D	n/a	Humans & Animals	**Application minimizes exposure to humans, animals, livestock** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	E	n/a	Other Factors	**Special precautions to avoid adverse impacts** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	A	n/a	Postive ID	**Geo-referenced, electronic mapping (e.g. GPS)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	A	n/a	Postive ID	**Effective, visible site marking** *Interview, demonstration, documents, records, observations, comments*

					☐ verified ☐ not reviewed
22	3	A	n/a	Postive ID	**Other approved method** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	4	A/B	n/a	Off-target Application	**Evidence of Off-Target Direct Discharge of Pesticides** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	4	C	I - III	Off-target Application	**Consent recorded for off-target discharge or drift** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	5	A/B	n/a	Variances	**Verify application, receipt , & record** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	6	A/B	n/a	Emergencies	**Verify declaration** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed



SENSITIVE AREAS (REG)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	Verification Criteria
					Details & conclusion
22	2	C	I	SA Identification	**Applicator familiar with spray area** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	C	I	SA Identification	**ID & record, type & location of SA w/in 500'** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	2	C	I	SA Identification	**Site map with target area & adjacent SA (updated manually)** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

SALOS (REG)

CHAPTER	SECTION	CLAUSE	SUB-CLAUSE	TOPIC	**Verification Criteria** *Details & conclusion*
22	3	B	I	Site Plan Map	**Confirmation re: record review** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	C	I-VIII	SALO Checklist	**Confirm checklist use on-site** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	D	n/a	SALO Buffers	**Confirm on-site** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed
22	3	E	n/a	SALO Wind	**Verify wind speed 2-10 mph** *Interview, demonstration, documents, records, observations, comments* ☐ verified ☐ not reviewed

Addendum C—Maine Board of Pesticides Control Guidance for the Application of Pesticides in Forest Settings in Order to Minimize the Risk of Discharges to Surface Waters

Maine Board of Pesticides Control

Guidance for the Application of Pesticides in Forest Settings in Order to Minimize the Risk of Discharges to Surface Waters

Selected List of Legal Requirements

There are numerous state and federal laws pertaining to the use of pesticides in Maine, including forestry settings. The following is a partial list of pesticide laws that are often applicable to forest pesticide applications. This is not intended as an exhaustive compilation of every legal requirement. It is the responsibility of the landowner and the pesticide applicator to identify and comply with all applicable laws.

All Applications

1. **The Pesticide label.** The pesticide label is the law. Abide by all pesticide label requirements, including use rates, handling, storage, and disposal.
    - Triple rinse empty pesticide containers or use equivalent procedures such as a pressure rinser.

2. **Chapter 22.** Maine Board of Pesticides Control ("BPC") rule CMR 01-026, Chapter 22, "Standards for Outdoor Application of Pesticides by Powered Equipment in Order to Minimize Off-Target Deposition" (commonly called "the drift rule"), establishes procedures and standards for the outdoor application of pesticides by powered equipment in order to minimize spray drift and other unconsented exposure to pesticides. This chapter contains numerous standards that are important to minimizing the risks of discharges to surface waters. Forestry applicators are advised to pay particular attention to this chapter.
3. **Chapter 29.** BPC rule CMR 01-026, Chapter 29, "Standards for Water Quality Protection," establishes standards for protecting surface water. Of particular note, this chapter:
    - Prohibits broadcast application of pesticides within 25 feet of surface water.
    - Establishes a 50 foot setback from surface water for mixing and loading of pesticides.
    - Sets requirements for the use of anti-siphoning devices and segregation of hoses used for pesticides and mix water.
    - Sets forth requirements for securing containers on vehicles and sprayers and cleaning up spills occurring within the setback zone. Establishes restrictions on pesticide applications to control browntail moths near marine waters.

4. **Chapter 50**. BPC rule CMR 01-026, Chapter 50 requires applicators to report all significant spills to the BPC. The Maine Department of Environmental Protection and also has spill reporting requirements.
5. In most cases, applications must only be conducted by BPC licensed applicators or USEPA Worker Protection Standard Pesticide Handlers. See BPC Rules for specifics.

Aerial Applications

6. For aerial applications, follow the terms of the Department of Environmental Protection (DEP) Pesticides General Permit.
7. BPC **Chapter 22** contains specific standards for aerial application of pesticides, including:
    - Positive identification of target site.
    - Site plan requirements.
    - Site specific checklist. Buffer zones.
8. BPC **Chapter 22** specifies that aerial applications may not be conducted within 1,000 feet of a sensitive area likely to be occupied unless wind speed is between 2 and 10 miles per hour.
9. **Chapter 51.** BPC rule CMR 01-026, Chapter 51, "Notice of Aerial Pesticide Applications." describes the notification requirements for persons contracting aerial pesticide applications to control forest, ornamental plant, right-of-way, biting fly and public health pests.

Pesticide Application Guidelines

The following guidelines are intended to complement laws pertaining to pesticide use and assist applicators in preventing drift and discharges to surface waters. These guidelines are not intended to be construed as mandatory requirements, since not all of the practices will be feasible or appropriate in every circumstance. Applicators must consider site specific conditions to determine which recommendations are applicable and adjust practices to minimize the likelihood of discharges of pesticides to surface waters of the state.

General Guidelines

1. Use a pesticide screening tool such as the USDA-NRCS, WIN-PST program and choose effective products that exhibit the lowest combination of leaching potential, pesticide solution runoff potential, and pesticide adsorbed runoff potential.

2. Conduct all pesticide handling—mixing, loading, equipment cleaning, and storage—on upland sites, away from water bodies, outside filter areas, and away from road drainage systems.

3. Maintain a spill containment and cleanup kit appropriate for the materials being applied.

4. Store pesticides in a secure enclosure and maintain them at application sites only as long as necessary.

5. When practical, use product delivery technology that offers features such as a closed system and product tracking and allows for accurate premixed solutions. These technology options eliminate the need for open containers and triple rinsing and provide proper prescriptions without the need to use open pesticide containers.

6. Recycle containers when possible or dispose of them through a solid waste facility when required.

Equipment

7. When rinsing spray equipment, apply rinse water only in areas that are part of the application site.

Sensitive Areas/Application

8. Use spot, injection or stump treatments methods when applying chemicals not labeled for aquatic use in streamside management zones. Broadcast pesticide applications are prohibited within 25 feet of a stream.

9. Direct spray applications away from surface waters when feasible.

10. Avoid drift to areas with standing water connected to surface water.

11. Avoid applications to saturated soils.

12. Avoid applying herbicides in areas where the chemicals can injure stabilizing vegetation on slopes, gullies, and other fragile areas subject to erosion that drain into surface water.

13. Avoid applications close to steep slopes or drainage swales and other features that lead to surface waters which may potentially result in a discharge.

14. Avoid application to impervious surfaces, exposed bedrock, or frozen soils.

Weather

15. Apply pesticides only during favorable weather conditions:
    - Avoid applications prior to an expected heavy rainfall.
    - Avoid applications during periods of atmospheric inversion or fog.
    - Avoid application in high temp, low humidity conditions.
    - Whenever possible, only apply pesticides when wind conditions are between 2-10 mph.

Drift Management

16. In addition to following the requirements in BPC Chapter 22:
    - Maintain buffers between spray operations and water bodies.
    - Increase the buffer size when there is no vegetation in the buffer.
    - Use low-volatility pesticides when possible.
    - Spray when winds blow away from surface waters or have a spotter in full PPE to warn the applicator if drift becomes an issue.

- Select spray nozzles and pump pressures that produce the largest, effective droplet.
- Consider adjuvants to reduce spray drift when the pesticide label allows, unless not recommended by the University of Maine Cooperative Extension.

Guidelines Specific to Aerial Applications

17. Use the best available weather information sources to provide the most accurate, locally relevant, real-time weather information in order to target suitable application conditions for proper deposition. Use available combinations of on-site portable weather stations, remote sensing stations and stationary sites.

18. Make applications in neutral air conditions when small droplets are required to effectively control targeted pests:
    - Neutral atmospheric conditions represent the most suitable conditions for proper spray deposition. Droplets spread out evenly and fall close to the release point rather than carried upward by unstable conditions or concentrated and carried laterally from the release point by stable conditions. Neutral atmospheric conditions are most likely to occur in the morning and evening.
    - Stable atmospheric conditions—when there is little to no air movement—indicate the likelihood of inversions under which diffusion is the primary physical property influencing fine droplet movement. Stable air causes droplets to be carried laterally, for short distances, resulting in higher off target deposition in proximity to the application site.
    - Unstable atmospheric conditions—when there is both vertical and horizontal air movement—indicate the likely existence of thermal updrafts which decrease the target site deposition and can lead to long range transport of fine droplets, but reduce the probability of high off-target residues in proximity to the application site.

19. Use on-board GPS navigation systems coupled with digital site maps to ensure that the correct sites are being treated, appropriate buffers are observed, and booms are turned on and off at the appropriate times.

20. Depict all sensitive areas and the appropriate buffers on application maps to ensure adequate protection.

21. Supply pilots with individual site treatment maps for each treatment block prior to application.

22. Discuss each site with the pilot prior to application to ensure all sensitive areas are protected.

23. Pre-fly application sites to:
    - Ensure the digitized maps reflect the true nature of the treatment site.
    - Scout for surface water that might not be present on the paper site map provided to the pilot.

24. Use AUTOCAL or a similar system to maintain proper application rate based on the speed of the aircraft.

25. Use the best available nozzles that minimize formation of fine droplets for herbicide applications in order to produce the largest effective droplets with the narrowest size spectrum to minimize drift.

26. Configure application equipment to minimize wind shear of spray droplets when appropriate.

27. Turn booms on and off at the appropriate time when entering or leaving a treatment block.

28. Avoid spraying directly on the downwind edge of a treatment block. Move the spray swath upwind from this this edge, i.e., offset by 1/2 to 1 swath width.

29. Identify and avoid streamside management zones and surface water to prevent pesticides from drifting over open water or from accidentally being applied directly on the water. Avoid flying directly over surface waters while making applications.

30. Apply parallel to surface waters when feasible.

31. Employ all depicted buffers around all surface waters.

32. Fly treatment block edges that are next to surface waters when the wind is away from the surface waters.

33. Download post-application log files from the on-board GPS system showing the flight of the helicopter/aircraft with booms on and off. Create maps and overlay on the treatment site maps; save for two years and file with the required application reports. For aerial forest insect applications, submit site/spray maps to the BPC with the annual summary reports (requested by the Joint Standing Committee on Agriculture, Conservation and Forestry).

For more information, contact the Maine Board of Pesticides Control at 287-2731.

References

Barry, Don and Gary Fish (eds). 2012. *Pesticide Education Manual*. The University of Maine Cooperative Extension. Orono.

Maine Forest Service. 2004. *Best Management Practices for Forestry: Protecting Maine’s Water Quality*. Augusta.

Addendum D—Preliminary Water Quality Work

Date: November 9, 2021

SURFACE WATER MONITORING REPORT

I. Study Overview:

- **Study Title:** Preliminary Report to the Board on the 2021 Water Quality Scoping Study of Aerially Applied Herbicides in Forestry
- **Project Lead: Mary Tomlinson, Water Quality Specialist**

II. Objective:

Conduct a baseline assessment of the occurrence of herbicides known to be applied via aerial application in forest management.

III. Study Area:

County: Aroostook, Franklin, Piscataquis, Somerset

Waterbody/Watershed: Daigle Brook, Fourmile Brook, Kibby Stream, Moose Brook, Moose River, Reed Brook, South Branch Machias River, Tomhegan Stream, two unnamed brooks (Table 1 and Figure 1)

Based on aerial application plans submitted to the BPC by timber companies, ten sites likely to receive drainage from site preparation or conifer release preparation were selected.

Table 1. Sites sampled in July 2021 for aerially applied herbicides used in managed Maine timberlands during 2020. Surface water grab samples and composite sediment samples were collected from each site.

Map Key	Town of Sample	Water Body	Coordinates	
			Latitude (N)	Longitude (W)
1	T17 R5 WELS	Daigle Brook	47.150140°	68.381590°
2	T17 R4 WELS	Unnamed Brook	47.11900	68.24754
3	Westmanland	Unnamed Brook	47.01361	68.26597
4	Kibby Twp	Kibby Stream	45.37000	70.55780
5	Skinner Twp	Moose River	45.44800	70.57280
6	Soldiertown	Tomhegan Stream	45.770554	69.884443
7	Big W	Moose Brook	45.816843	69.767564
8	T9 R7 WELS	Fourmile Brook	46.41883	68.58545
9	T8 R10 WELS	Reed Brook	46.35997	69.0104
10	T10 R7 WELS	S. Branch Machias River	46.526568	68.679185

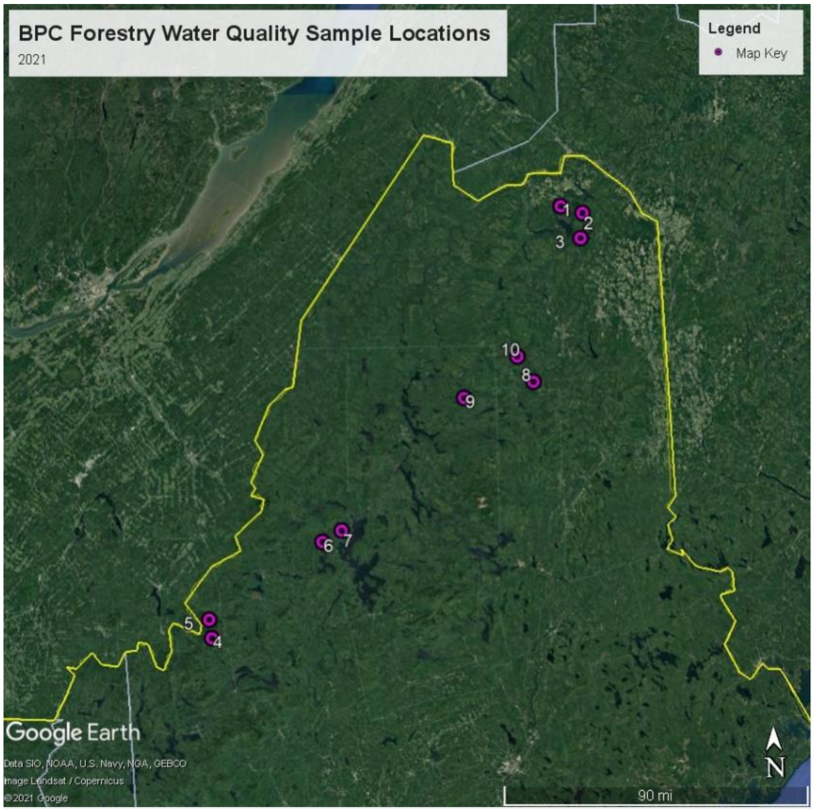


Figure 1. Location of sampling sites. Specific location information is displayed in Table 1.

IV. Land use type: ☐ Ag ☐ Urban ☒Forest ☐ Mixed ☐ Other___________________

V. Waterbody type:

☒ Brook ☒River ☐Pond ☐ Lake ☐Drainage Ditch/Culvert ☐Storm drain outfall ☐Other ____________________

VI. Sampling period: July 12, 2021 – July 13, 2021

VII. Target pesticides monitored: glyphosate, AMPA, imazapyr, metsulfuron methyl, sulfometuron methyl, and triclopyr (Table 2). A list of additional pesticides analyzed is located in Section XIII.

Table 2. Aerially applied pesticides used by Irving Inc., Seven Islands Land Company, and Weyerhaeuser Timberlands in 2020 for site preparation and/or conifer release preparation.

Product Brand Name	EPA Reg. No.	Active Ingredient	Percent AI	Maximum Labled Site Prep Rate/Acre	Maximum Labeled Release Rate/Acre
Accord XRT II	62719-556	glyphosate	50.20%	8 qts unless specified by species, 3-3.75 qts by species	Not labeled
Arsenal AC	241-299	imazapyr	53.1	12 oz	16 oz
Escort XP	432-1549	metsulfuron methyl	60	2 oz	Not labeled
Forestry Garlon XRT	62719-553	triclopyr	83.9	2.5-4.0 qts	1-2 qts
Oust XP	432-1552	sulfometuron methyl	75	3 oz (white spruce)	4 oz
Rodeo	62719-324	glyphosate	53.08	1.0-7.5 qts aerially	2.25 qts

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VIII. Definitions:

- Analyte: Chemical compound that is the subject of chemical analysis
- Detection limit: The lowest concentration at which the presence of an analyte can confidently be identified by the laboratory
- Metabolite: An intermediate substance or end product formed when a chemical breaks down
- Nondetect (ND): Chemical is not detected; concentration is below the laboratory detection limit
- Q: Positive detection of the chemical, but concentration is below the reporting limit (RL)
- QA/QC: Quality assurance/quality control; performed to provide greater confidence in the data
- Quantifiable: Measurable
- Reporting limit (RL): Lowest concentration of a compound that can be measured and confirmed by the laboratory method
- US EPA Aquatic Life Benchmarks (ALB): Used as a screening tool to estimate risk of pesticides and their metabolites (degradates) to aquatic life in surface water. Concentrations below the ALB are not expected to represent a risk to aquatic life.

IX. Major findings:

Target pesticides not detected

Glyphosate, metsulfuron methyl, or triclopyr were not detected in any water or sediment samples collected. AMPA (a glyphosate metabolite) also was not detected. Analysis of samples from two of the ten study sites indicated no detections of any pesticides or their metabolite in water or sediment.

Detections in water

Table 3 displays all pesticidal compounds detected in surface water grab samples by site; target pesticides of the study are shaded. Of the six compounds detected, imazapyr and sulfometuron methyl were the only two target compounds detected. There were 11 detections from six sites, three of which were above the RLs.

Four pesticidal compounds unrelated to aerial application in forest management were detected in water samples from six sites: 2,4-D, atrazine, deethyl atrazine (a metabolite of atrazine), and MCPP. There were 12 detections, two of which were above the RLs. Deethyl atrazine was the most frequently detected compound, present in water from six sites, but all detections were below the RL.

Table 3. Pesticide and metabolite detections in surface water samples collected July 2021 in managed northern Maine timberlands. The metabolite is indicated by an asterisk. Target analytes are shaded. Reporting limits are provided in Section XIII.

Town	**Analyte [µg/L (ppb)]**					
	Imazapyr (RL=0.0035)	Sulfometuron methyl (RL=0.0025)	2,4-D (RL=0.0090)	Atrazine (RL=0.0022)	*Deethyl atrazine (RL=0.0017)	MCPP (RL=0.0044)
T17 R5 WELS	Q	Q	ND	ND	ND	ND
T17 R4 WELS	0.033	Q	ND	Q	Q	ND
Westmanland	Q	Q	ND	ND	ND	ND
Kibby Twp	ND	ND	ND	ND	Q	ND
Skinner Twp	Q	Q	0.014	ND	Q	Q
Soldiertown	Q	ND	0.0091	Q	Q	Q
Big W	ND	ND	ND	ND	ND	ND
T9 R7 WELS	ND	ND	ND	ND	ND	ND
T8 R10 WELS	0.016	0.0035	ND	ND	Q	ND
T10 R7 WELS	ND	ND	ND	ND	Q	ND

Table 4 compares the detections in water samples with the associated US EPA Aquatic and Ecological Risk Assessments for Registered Pesticides (2021). There were no pesticides detected above their associated Aquatic Life Benchmark.

Table 4. Pesticide and metabolite detections in surface water, collected July 2021 from ten sites in northern Maine timberlands, compared with US EPA Aquatic and Ecological Risk Assessments for Registered Pesticides (2021). The lowest Aquatic Life Benchmark (ALB) for each pesticide detected is presented with its benchmark type. Target pesticide are shaded.

Pesticide	Number of Detections	Reporting Limit ug/L (ppb)	Lowest US EPA Benchmark (ALB)[1] ug/L	ALB Type[1]	Number of ALB Exceedances
Imazapyr	6	0.0035	24	VA	0
Sulfometuron methyl	5	0.0025	0.45	VA	0
2,4-D	2	0.0090	299.2	VA	0
Atrazine	2	0.0022	<1	NA	0
Deethyl atrazine	6	0.0017	See atrazine		0
MCPP	2	0.0044	14	VA	0

[1] Aquatic Life Benchmark Type: NA - non-vascular plants acute; VA - vascular plants acute

Detections in sediment

Sediments were analyzed for glyphosate, imazapyr, metsulfuron methyl, sulfometuron methyl, triclopyr, and AMPA (Table 4). There was a single detection each of imazapyr and sulfometuron.

Table 5. Analysis results for five pesticides and AMPA (glyphosate metabolite) in sediment, collected July 2021 in managed northern Maine timberlands. Results were reported as µg/L (ppb) on a dry weight basis**.** Reporting limit for glyphosate and AMPA in T17 R4 WELS was raised from 0.05 ppm to 0.25 ppm due to high moisture content.

Town	Analyte [µg/L (ppb)]					
	AMPA (RL=0.050)	Glyphosate (RL=0.050)	Imazapyr (RL=0.50)	Metsulfuron methyl (RL=0.50)	Sulfometuron methyl (R=0.050)	Triclopyr (RL=10.00)
T17 R5 WELS	*ND	ND	ND	ND	ND	ND
T17 R4 WELS	ND	ND	0.71	ND	ND	ND
Westmanland	ND	ND	ND	ND	0.14	ND
Kibby Twp	no sample	no sample	ND	ND	ND	ND
Skinner Twp	no sample	no sample	ND	ND	ND	ND
Soldiertown	no sample	no sample	ND	ND	ND	ND
Big W	no sample	no sample	ND	ND	ND	ND
T9 R7 WELS	ND	ND	ND	ND	ND	ND
T8 R10 WELS	ND	ND	ND	ND	ND	ND
T10 R7 WELS	ND	ND	ND	ND	ND	ND

X. Conclusions:

1. Of the 104 pesticides analyzed for, six compounds (pesticides and metabolites) were detected either in water or sediment. Three were above the RLs and three below the RLs.

2. There were 23 detections (active ingredients and metabolites combined) in water and two in sediment out of 1,032 and 46 possible detections for water and sediment respectively. Seven detections were above the RLs and 18 below the reporting limits.

3. There were no exceedances of the US EPA Aquatic Life Benchmarks.

XI. QA/QC: The relative percent difference analysis indicates duplicates and split samples were within the acceptable range as established for this study. No pesticides were detected in blank samples.

XII. Data: water quality, analytical chemistry results

Water quality and monitoring results are available upon request. Please contact the Maine Board of Pesticides Control for the complete data set.

XIII. Tables

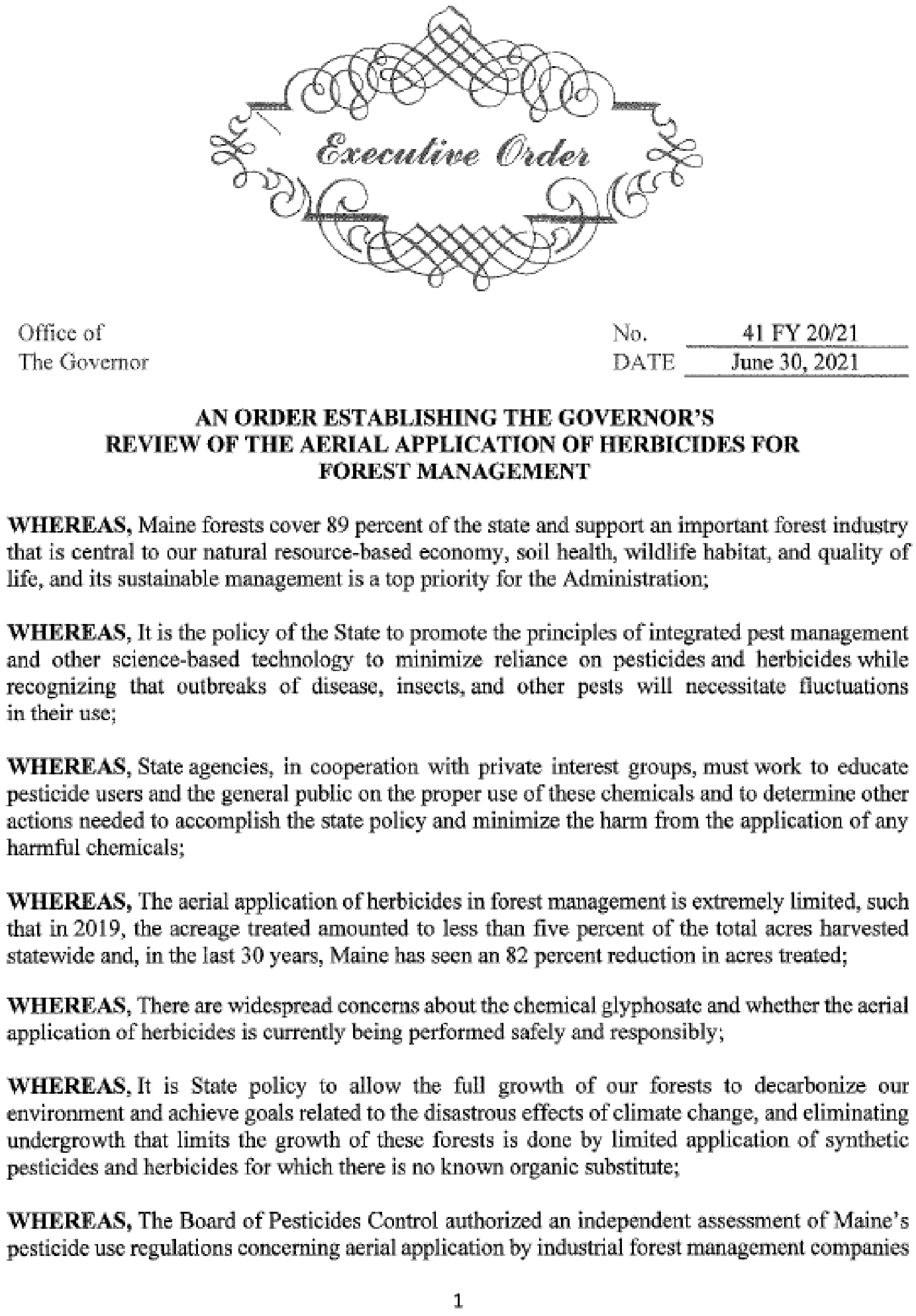
List of 102 pesticides analyzed by Montana Department of Agriculture Analytical Laboratory. Method: Montana Department of Agriculture, MTUNIV_W1, Revision 11: March 2021, "Universal Method for the Determination of Polar Pesticides in Water Using Solid Phase Extraction and Liquid Chromatography/Mass Spectrometry/Mass Spectrometry."

Analyte	Reporting Limit ug/L (ppb)
2,4-D	0.009
Acetochlor	0.14
Acetochlor ESA	0.02
Acetochlor OA	0.0084
Alachlor	0.11
Alachlor ESA	0.044
Alachlor OA	0.0068
AMBA	0.021
Aminocyclopyrachlor	0.025
Aminopyralid	0.03
Atrazine	0.0022
Azoxystrobin	0.0052
Bentazon	0.0022
Bromacil	0.0041
Bromoxynil	0.012
Carbaryl	0.014
Chlorpyrifos	0.06
Chlorsulfuron	0.0056
Clodinafop acid	0.013
Clopyralid	0.088
Clothianidin	0.016
Deethyl atrazine	0.0017
DEDIA	0.1
Deisopropyl atrazine	0.04
Dicamba	0.88
Difenoconazole	0.011
Dimethenamid	0.006
Dimethenamid OA	0.0072
Dimethoate	0.0022
Disulfoton sulfone	0.0066
Diuron	0.0053
FDAT (indaziflam met)	0.0051
Fipronil	0.0024
Fipronil desulfinyl	0.14
Fipronil sulfide	0.08
Fipronil sulfone	0.04
Flucarbazone	0.0024
Flucarbazone sulfonamide	0.0039
Flumetsulam	0.029
Flupyradifurone	0.045
Fluroxypyr	0.035
Glutaric acid	0.03
Hydroxy atrazine	0.004
Halosulfuron methyl	0.01
Hexazinone	0.0015
Imazamethabenz acid	0.0025
Imazamethabenz ester	0.001
Imazamox	0.0057
Imazapic	0.003
Imazapyr	0.0035
Imazethapyr	0.004
Imidacloprid	0.0018
Indaziflam	0.002
Isoxaben	0.003
Isoxaflutole	0.13
Malathion	0.028
Malathion oxon	0.0024
MCPA	0.0046
MCPP	0.0044
Metalaxyl	0.0035
Methomyl	0.012
Methoxyfenozide	0.01
Metolachlor	0.024
Metolachlor ESA	0.005

List of 102 pesticides analyzed by Montana Department of Agriculture Analytical Laboratory. Method: Montana Department of Agriculture, MTUNIV_W1, Revision 11: March 2021, "Universal Method for the Determination of Polar Pesticides in Water Using Solid Phase Extraction and Liquid Chromatography/Mass Spectrometry/Mass Spectrometry."

Analyte	Reporting Limit ug/L (ppb)
Metolachlor OA	0.042
Metsulfuron methyl	0.01
Nicosulfuron	0.011
NOA 407854	0.0052
NOA 447204	0.02
Norflurazon	0.02
Norflurazon desmethyl	0.02
Oxamyl	0.01
Parathion methyl oxon	0.012
Phorate sulfone	0.024
Phorate sulfoxide	0.003
Picloram	0.28
Picoxystrobin	0.0075
Prometon	0.001
Propiconazole	0.01
Prosulfuron	0.005
Pyrasulfotole	0.02
Pyroxsulam	0.013
Saflufenacil	0.01
Simazine	0.0026
Sulfentrazone	0.035
Sulfometuron methyl	0.0025
Sulfosulfuron	0.0054
Tebuconazole	0.014
Tebuthiuron	0.0011
Tembotrione	0.073
Terbacil	0.0048
Terbufos sulfone	0.011
Tetraconazole	0.0039
Thiamethoxam	0.02
Thiencarbazone methyl	0.04
Thifensulfuron methyl	0.022
Tralkoxydim	0.0051
Tralkoxydim acid	0.005
Triallate	0.3
Triasulfuron	0.0055
Triclopyr	0.022
Trifloxystrobin	0.02

<u>**Addendum E—Original Executive Order Text**</u>



Executive Order

Office of
The Governor

No. 41 FY 20/21
DATE June 30, 2021

AN ORDER ESTABLISHING THE GOVERNOR'S REVIEW OF THE AERIAL APPLICATION OF HERBICIDES FOR FOREST MANAGEMENT

WHEREAS, Maine forests cover 89 percent of the state and support an important forest industry that is central to our natural resource-based economy, soil health, wildlife habitat, and quality of life, and its sustainable management is a top priority for the Administration;

WHEREAS, It is the policy of the State to promote the principles of integrated pest management and other science-based technology to minimize reliance on pesticides and herbicides while recognizing that outbreaks of disease, insects, and other pests will necessitate fluctuations in their use;

WHEREAS, State agencies, in cooperation with private interest groups, must work to educate pesticide users and the general public on the proper use of these chemicals and to determine other actions needed to accomplish the state policy and minimize the harm from the application of any harmful chemicals;

WHEREAS, The aerial application of herbicides in forest management is extremely limited, such that in 2019, the acreage treated amounted to less than five percent of the total acres harvested statewide and, in the last 30 years, Maine has seen an 82 percent reduction in acres treated;

WHEREAS, There are widespread concerns about the chemical glyphosate and whether the aerial application of herbicides is currently being performed safely and responsibly;

WHEREAS, It is State policy to allow the full growth of our forests to decarbonize our environment and achieve goals related to the disastrous effects of climate change, and eliminating undergrowth that limits the growth of these forests is done by limited application of synthetic pesticides and herbicides for which there is no known organic substitute;

WHEREAS, The Board of Pesticides Control authorized an independent assessment of Maine's pesticide use regulations concerning aerial application by industrial forest management companies

1

in 2020, and the independent auditor, SCS Global Services, concluded, "The State of Maine regulatory framework, within which aerial application of herbicides in forest operations takes place, is functioning as designed."

NOW, THEREFORE, I, Janet T. Mills, Governor of the State of Maine, pursuant to *Me. Const. Art V, Pt 1, §1 and §12*, do hereby Order as follows:

I. ESTABLISHMENT AND PURPOSE

The Board of Pesticides Control shall, in consultation with the Maine Forest Service and other stakeholders and interested parties, review and amend rules related to the aerial application of glyphosate and other synthetic herbicides for the purpose of silviculture, including reforestation, forest regeneration, or vegetation control in forestry operations.

The process shall include:

A. A review of the existing BMPs for aerial application of herbicides including:

- a. A review of the findings and recommendations of the independent assessment on aerial applications conducted in 2020.
- b. A review of the current international scientific literature regarding the aerial application of herbicides for forestry purposes, taking into account the species addressed in other states and countries.
- c. A review of Integrated Pest Management guidelines as they apply to aerial application of herbicides for forestry purposes to assess the relative effectiveness and costs of other treatment methods.

B. Development of a surface water quality monitoring effort to focus on aerial application of herbicides in forestry to be conducted in 2022.

C. A review undertaken by the Department of Inland Fisheries and Wildlife to assess wildlife habitat impacts related to sites treated by aerial application of herbicides.

D. A review of the existing regulatory framework for aerial application of herbicides in forest operations, to include:

- a. A proposal to amend rules to expand the buffers and setbacks to further protect rivers, lakes, streams, ponds, brooks, wetlands, wildlife and human habitats and other natural resources.
- b. A proposal to amend rules to expand the buffers for areas next to Sensitive Areas Likely to be Occupied (SALO) and other sensitive areas to include farming operations.

E. A series of public meetings to share and obtain public input on the results of the review before finalizing.

II. PROCEEDINGS

The Board of Pesticides Control and the Maine Forest Service shall solicit feedback from, and consult with, the University of Maine School of Forest Resources, Department of Inland Fisheries and Wildlife, forest landowners, foresters, licensed applicators, conservation groups, and others as necessary to complete their tasks.

The effort shall be led jointly by the Board of Pesticides Control and the Maine Forest Service and co-chaired by the respective directors. The meetings shall be held in locations determined by the chairs or will be held virtually but the proceedings of the group are not otherwise "public proceedings" within the meaning of 1 M.R.S. section 402.

III. RECOMMENDATIONS

The Board of Pesticides Control and the Maine Forest Service shall submit a summary of the review process and findings and any corresponding recommendations to the Governor on or before January 2, 2022, after which the authority of this Executive Order will dissolve.

IV. EFFECTIVE DATE

The effective date of this Order is June 30, 2021.

Janet T. Mills, Governor

Addendum E—Contributors to this report

BPC Staff-

Megan Patterson, Director
Karla Boyd, Regulations and Policy Specialist
Mary Tomlinson, Water Quality Specialist
Pamela Bryer, Ph.D., Pesticides Toxicologist

BPC Contractors-

Harold Thistle, Ph.D. Bio: Dr. Thistle received his PhD from the University of Connecticut in Plant Science specializing in Forest Meteorology in 1988. He worked as an air pollution modeler for TRC, Inc. for three years and received his certification as a Certified Consulting Meteorologist. He joined the USDA Forest Service in 1992 and worked in the area of Forest Health specializing in the area of pesticide transport and fate in the atmosphere. He ran the technical development program that designed and managed the development of the AGDISP model used by USEPA as part of their toolkit in developing pesticide risk assessments for use in pesticide registration. He resigned from the FS in 2018 and is now a private consultant specializing in the technical areas of pesticide drift and dispersion of forest pests and diseases. He is an author of over 80 peer review articles and book chapters in the areas of pesticide drift, forest pest management and micrometeorology.

Jane Bonds, Ph.D. Bio: Dr Bonds received her PhD from Cranfield University in England specializing in crop protection in 2001. She spent a decade in research in academia including time as an associate professor at Florida A&M University. Currently she is a consultant in Bonds Consulting Group LLC. Her CV states, **“**With over 20 years of experience in the control of pests and diseases, my mission is to promote the development, advancement and application of scientific research related to public health and crop protection.” Dr. Bonds has worked extensively with local, state, federal, and international agencies in addition to participation in various stakeholder working groups.

IFW Staff-

Philip deMaynadier, Ph.D., Biologist
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Nate Webb, Wildlife Division Director