A2 GOOD PRACTICE FOR WILDING CONIFER CONTROL

NATIONAL WILDING CONIFER CONTROL PROGRAMME

AERIAL FOLIAR SPRAY APPLICATION (AFSA)

VERSION 5: MAY 2023

Aerial spraying by helicopter boom can be a cost-effective way to control large areas of dense wilding conifer infestations.

CONTENTS

Front cover: AFSA boom spraying method in action. (Photograph: Pete Willemse, DOC)

ABOUT THIS DOCUMENT

Overall disclaimer:	The information in this publication represents the collective view of the National Wilding Conifer Control Programme (the 'National Programme'). We have made every effort to ensure the information is accurate. However, the National Programme does not accept any responsibility or liability for error of fact, omission, interpretation or opinion, nor for the consequences of any decisions based on this information. Good practice use by any reader is done so at their own risk, and the National Programme rejects all liability for any risk or loss as a result of applying this good practice information. This guide is not designed to provide exhaustive compliance information and is not a substitute for professional advice. It remains the full responsibility of the user to obtain the specific guidance, authorisations, consents and permits as required to meet regulatory requirements and complete the work.
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Principal author:	Biosecurity New Zealand (Ministry for Primary Industries)
Document Owner:	Programme Manager, National Wilding Conifer Control Programme
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VERSION CONTROL

DATE PUBLISHED	DETAILS	VERSION NO.
February 2019	Original document	Version 1
1 July 2020	Herbicide Mix updated	Version 2
December 2021	Added guidance on managing water contamination risk and water sampling. Delta T safe aerial spray window added. Signage required.	Version 3
March 2022	Edits to mixing order of herbicide mixes and recommended dicamba product.	Version 4
May 2023	- Additional information about stock withholding periods in pre-start briefing - Metsulfuron buffer increased to 50m and nozzle update - When to sample updated to "after spraying finishes" for water sampling collection - Updated reference to Hazardous Substances Amendment Regulations 2021	Version 5

This document should be read in conjunction with:

WorkSafe - *Working safely with chemicals and fuels on farms*

WorkSafe - *HSNO codes of practice for hazardous substances*

NZ Standard for Management of Agrichemicals NZS 8409:2021

Approved Code of Practice for Safety and Health in Forest Operations

Health and Safety at Work (Hazardous Substances) Amendment Regulations 2021

Civil Aviation Authority rules and regulations

1. AFSA PRE-CONTROL WORK

1.1 PRE-START BRIEFING

Before the operation begins you must hold a pre-start briefing with key operators. This should be in a timely enough manner to allow for potentially affected parties to be notified of changes.

Pre-start briefing may include, but not be limited to:

- Ensure consent from the landowner or nominated occupier.
- Any stock in the control area shall be discussed with the owner or managers.
- If relevant, check the Safety Data Sheet for your operation's herbicide for any stock withholding period guidelines that need to be adhered to. In the absence of guidelines in the Safety Data Sheet, introduction of stock after spray operations should be cautionary.
- It should be noted that some herbicides can potentially make toxic plants more palatable to livestock. Where this is the case restocking should not occur until toxic plants within the treated area have died off completely.
- All applicable contractual matters must be completed.
- All cost sharing must be agreed upon and confirmed so that everyone knows how the operation is funded and any conditions that need to be met. Any separate agreements and understandings regarding control of other plant pests encountered must be finalised before the operation begins.
- Brief the helicopter pilot and crew and any other contractor/team members, all adjacent neighbours, and the landowner(s) or occupier(s) on whose land the operation is being carried out. The briefing must explain where the operational area is. Show the area visually using a map and describe the outermost boundary of the operation. Each party needs to be provided with a map.
- Seek information from occupiers and neighbours on all potential hazards that might be encountered (e.g. main grid power lines or hot wires that go from ridge to ridge on farmland). These hazards need to be entered as appropriate into the site safety hazard register, which needs to be available for inspection by everyone involved for the duration of the work.
- Ensure the flight path when spraying is not over any active waterbodies (see Appendix 1 for a definition); check any regional rules surrounding this.
- Identify all sensitive areas and plan mitigation actions accordingly to reduce risk of water contamination and off-target damage. Work with occupiers and neighbours to identify all water takes and arrange alternative water supplies as needed
- Check weather conditions at time of programmed operation (see Section 4.3 for details). Note, current herbicide mixes are generally 'rain-fast' after an hour – that is, after an hour there is no effect of rain on the efficacy of the herbicide. However, a period of at least 24 hours without rain after application is ideal. Affected parties must also be notified in the event of a weather postponement.

2. AFSA MATERIALS

This guidance is for boom spraying from a helicopter; if using a drone, discuss with the National Programme.

2.1 HERBICIDE FORMULATION

The most critical step in all spraying operations is to select the most appropriate formulation of herbicide, adjuvants and carriers and apply them at the right time. Changes to any formulation (and/or helicopter setup) can affect control efficacy, non-target impacts, drift risk, or ground deposition of herbicide[1].

The recommended herbicide formulations are the results of published and unpublished trials (Gous et al., 2010; Gous et al., 2012; Gous et al., 2014; Howell, 2014). These formulations also have a recommended droplet size class application (refer to Table 4).

The application rate can be varied based on the stature of vegetation. In general, larger trees require greater application volume of the carrier (i.e. the same amount of herbicide is applied but in a greater volume of carrier liquid to get good foliar coverage on larger trees).

If a National Programme operational controller/fund manager wishes to depart from the recommended formulations for wilding conifer species outlined below, they should discuss their situation with the programme manager, who may refer the matter to the Technical Advisory Group (which may decide that trials should be carried out first).

There are three recommended herbicide formulations, depending on the species of conifer to control.

Herbicide formulation 1: Douglas fir, Pinus radiata and Pinus muricata

Recommended boom spraying formulation for infestations of Pseudotsuga menziesii (Douglas fir), Pinus radiata (radiata pine) and Pinus muricata (Bishop's pine), with a greater than 80% canopy cover[2], during the active growing period (December to February) is detailed in Table 1 below.

Table 1. Recommended herbicide formulation for boom spraying *Douglas fir, Pinus radiata* and *Pinus muricata*

PRODUCT	ACTIVE INGREDIENT TOTALS
1000 g Associate (or equivalent – requires further research)	600 g metsulfuron methyl*
10 L Punch Penetrant	10,000 mL oil
2 L Slikka (wetter/penetrant)	1,600 g heptamethyltrisiloxane
4 kg ammonium sulphate fertiliser	2,300 g ammonium sulphate*
200 ml Jab	200 ml polyether-modified polysiloxane

*Because only generic metsulfuron methyl products are available to be used, operators will need to check that the pH of the resultant formulation is between 6.5 and 7.5, or buffer accordingly.

1 Choice of product manufacturer is also very important. Not all products are 'equal', even if they contain the same active ingredient

2 Decisions around boom spraying and canopy cover may vary. The lower the canopy cover (i.e. under 80%), the higher the discharge of herbicide to non-target species and bare soil (and increased risk of run off). Farmers wanting pasture as a result of boom spraying might choose to spray at a lower canopy cover where other values are not put at risk. When land is managed for biodiversity reasons, consider which non-target species are present and their susceptibility to the herbicides being used when deciding whether to spray at a lower canopy cover. If wilding conifers are clumped together, it may be possible to design a flight path that targets these and avoids non-wilding areas. For these smaller areas it may be better to spot spray wildings – however, the efficacy of this approach is yet to be fully proven.

Herbicide formulation 2: larch species

Recommended boom spraying formulation for infestations of Larix decidua (larch), with a greater than 80% canopy cover, during the active growing period (December to February) is detailed in Table 2.

Table 2. Recommended herbicide formulation for boom spraying larch

PRODUCT	ACTIVE INGREDIENT TOTALS
500 g Associate (or equivalent – requires further research)	300 g metsulfuron methyl*
10 L Punch Penetrant	10,000 mL oil
2 L Slikka (wetter/penetrant)	1,600 g heptamethyltrisiloxane
4 kg ammonium sulphate fertiliser	2,300 g ammonium sulphate
200 ml Jab	200 ml polyether-modified polysiloxane

*Because only generic metsulfuron methyl products are available to be used, operators will need to check that the pH of the resultant formulation is between 6.5 and 7.5, or buffer accordingly.

Mixing order for herbicide formulation 1 and 2:

1. Put in about 200 litres of water.
2. Add ammonium sulphate fertiliser.
3. Add the Associate (or equivalent).
4. Add Punch Penetrant.
5. Add Slikka.
6. Add Jab.
7. Add water up to a total volume of either 400 (or 600) litres (see 'Helicopter specifications' below).

Herbicide formulation 3: Pinus species excluding radiata and muricata pines *(although this formulation will also control these pine species)*

Recommended boom spraying formulation for dense infestations of P. contorta (lodgepole pine), P. mugo (mountain pine), P. nigra (Corsican pine), P. pinaster (maritime pine), P. ponderosa (ponderosa pine) or P. sylvestris (Scots pine), with a greater than 80% canopy cover, during the active growing period (December to February) is detailed in Table 3.

Table 3. Recommended herbicide formulation for boom spraying *Pinus* species (excluding *radiata* and *muricata*)

PRODUCT	ACTIVE INGREDIENT TOTALS
20 L Grazon or equivalent	18,000 g triclopyr ester
10 L Cutlass 500 or equivalent **OR** 6.67 L Kamba 750	5,000 g dicamba
20 L Tordon Brushkiller XT	2,000 g picloram
3.3 L T-Max	259 g aminopyralid
20 L Punch Penetrant	20,000 mL oil
0.5 L Li-700	500 mL propionic acid buffer
4 kg ammonium sulphate fertiliser	2,300 g ammonium sulphate
200 ml Jab	200 ml polyether-modified polysiloxane

Herbicide formulation 3 is commonly referred to as 'TDPA', based on the four active ingredients (triclopyr ester, dicamba, picloram, and aminopyralid). It is best to pre-mix the TDPA before putting the formulation into the spray tank, but if there is a good agitator in the machine, putting products directly into the helicopter tanks also works.

Mixing order for herbicide formulation 3:

1. Put in about 200 litres of water.
2. Add the ammonium sulphate fertiliser.
3. Add the Grazon or equivalent.
4. Add the Tordon Brushkiller XT.
5. Add the Li-700 (because it buffers the water for the dicamba).
6. Add the dicamba.
7. Add T-Max.
8. Add the Punch Penetrant oil.
9. Add Jab.
10. Add water up to a total volume of 400 (or 600) litres (see 'Helicopter specifications' below).

2.2 DELIVERY EQUIPMENT AND SETUP

Global Positioning System

A Global Positioning System (GPS) must be used for all boom spraying operations. Geographic information system (GIS) generated shape files showing the areas to be boom sprayed must be loaded into the GPS before starting the operation. This information is used by the pilot to plan the flight strategy to be used for the target area.

During the operation, the GPS must record flight lines, helicopter speed, altitude, and spray pump (flow rate) operation (on–off). This data can then be used in post control success monitoring and record keeping when transferred to the Wilding Conifer Information System (WCIS).

Signage

Signage must be put up at access points along the boundaries of spray areas warning people that spraying will be taking place and that they must not enter the area until the signage has been taken down. MPI can provide signage to partners of the National Programme if required.

Spray tanks

Spray tanks must be sufficient to hold enough herbicide mixture to treat a minimum of half a hectare per load, but preferably 1 hectare or more. Spray tanks should be free-draining, easy to clean and provide easy access for loading herbicide. The tank must have a removable 50-micron mesh filter (generally at the outlet point) to strain out debris, which may clog some nozzles and affect spraying performance. Filters should be cleaned regularly.

To ensure that the herbicide remains properly mixed, the spray tank must have an efficient agitation system. A mechanical agitation system is satisfactory. It is best to pre-mix the herbicides before putting the formulation into the spray tank, but if there is a good agitator in the machine, putting products directly into the helicopter tanks also works.

The Civil Aviation Authority (CAA) requires that where tanks have a 'dumping system' fitted (to be able to jettison any unwanted liquids), it must be fully operational. Note: emergency "dumping" may trigger an environmental incident.

Booms and boom spray pumps

Boom spray pumps must have the capacity to deliver the required spraying volumes without excessive heat production. Most systems have the pump lower than the tank. However, for systems where the pump is level with the tank, the pump must have a bleed line from the top of the pump chamber leading back into the tank to purge (clear) the pump of airlocks. The hose system must have a three-way valve and by-pass system, which enables the complete pump output to be redirected back to the tank. This ensures adequate tank agitation and reduces pump wear.

Some operators may choose to install a variable rate controller (VRC), which controls both the pressure within, and the flow rate to, the boom. The VRC ensures an accurate flow rate of herbicide at all times despite changes in aircraft speed during an operation. A pressure gauge measuring the pressure in the spray boom (not the pressure in the plumbing lines) should be installed. This gauge is generally fitted halfway along the boom and needs to be easily visible to the pilot. The boom diameter (its thickness or depth, not the width) should be large enough to enable the largest liquid volume required to flow with minimum friction. If a VRC is fitted, there is no benefit in having any other type of flow meter.

Nozzle selection, spacing and orientation

Different nozzles

Scion has tested a wide range of nozzles with the TDPA formulation. A summary of the results is included in Appendix 2. The key is that the nozzles produce droplets in the appropriate volume median diameter (VMD) (categorised in Table 4). Different nozzle types should never be mixed on the same spray boom because this can produce an uneven spray distribution. The relative span (RS) of droplet sizes around the median is an important consideration for operations (Gous & Richardson, 2008). Where there is a choice, operators should select nozzles that have the smallest RS value (that is, very little variation in droplet size). This should be checked/confirmed when the helicopter setup is calibrated.

Mounting of booms and nozzles

On helicopters, the boom should be mounted as far forward on the skids as possible to minimise wake effects. Nozzles should be restricted to 80% of the rotor width to reduce risk of droplets being influenced by rotor tip vortices. Rotor tip vortices have long been included in spray drift models (Hewitt et al., 2001), and risks are minimised by reducing boom lengths to less than the rotor diameter (Donaldson et al., 1975). An 80% limit (i.e. boom width should be less than 80% of the rotor diameter) has been adopted in New Zealand (Richardson & Thistle, 2006). This should be checked/confirmed when the helicopter setup is calibrated.

Nozzles should be evenly spaced along the boom. The spacing distance can vary with nozzle types but should not exceed 75 cm because the spray becomes less uniform with wider spacing (Klein et al., 2007). Nozzles should always be orientated straight-back (180 degrees) to the rear, in the horizontal position. Due to wind-shear, nozzles orientated into the air flow will produce smaller droplets than those orientated straight back. However, correct droplet sizes should be achieved by selecting the correct nozzle size, not by changing nozzle orientation. This should be checked/confirmed when the helicopter setup is calibrated. In reality the 'correct' droplet size is a function of nozzle, formulation, orientation and airspeed.

Droplet categories

Operators in New Zealand should follow the internationally accepted standard for droplet size classification known as ASAE S572, which was developed by the American Society of Agricultural and Biological Engineers (ASABE, formerly ASAE) (Fritz et al., 2012). ASAE S572 droplet categories are shown in Table 4 below.

Which droplet size is best?

The best spray droplet size is determined by a trade-off between using larger droplets to minimise the risk of spray drift and smaller droplets to maximise coverage on the target plant, which usually increases effectiveness. For most National Programme operations, operators should specify nozzles that produce 'medium' or 'coarse' droplets (although see Section 3.3. for guidance on minimising water contamination risk). When specifying nozzles, use the ASAE S572 droplet category (see Table 4 above) and not the micron (micrometres or μm) size.[3] No discretion should be allowed here. The droplet size is specified – therefore, it should be checked and confirmed that the nozzles being used are fit for purpose when the helicopter setup is calibrated.

Where and when spray drift is a major concern, nozzles that produce 'very coarse' droplets could be considered. Note, however, that nozzles that produce 'extremely coarse' droplets are not recommended because coverage is reduced and ground deposition is increased (Richardson & Thistle, 2006). Even very coarse droplets could compromise efficacy and kill rates, with flow-on implications for post-control monitoring evaluations. Nozzles that produce 'fine' or 'very fine' droplets are not recommended because the small droplets are prone to drift (Akesson & Yates, 1984).

Table 4. ASAE S572 droplet categories

DROPLET CATEGORY	SYMBOL	TYPE OF DROPLET	COLOUR CODE	APPROXIMATE VMD* RANGE (MICRONS)
Extremely coarse	XC	Heavy rain	1 blue droplet	› 450μm
Very coarse	VC	Light to heavy rain	2 green droplets	375 – 450μm
Coarse	C	Light to fine rain	3 teal droplets	250 – 375μm
Medium	M	Fine drizzle	4 yellow droplets	175 - 250μm
Fine	F	Very fine drizzle	5 orange droplets	100 – 175μm
Very fine	VF	Wet fog	6 red droplets	‹100μm

2.3. MINIMISING WATER CONTAMINATION RISK

In areas where active waterbodies are present, it is important to minimize the risk of boom spray herbicides entering waterways. Here, an 'active waterbody' means: Fresh water or geothermal water in a river, lake, stream, pond, wetland, or aquifer, or any part thereof, including ephemeral streams or rivers if they are flowing at the time of spraying.

It is a regulatory requirement not to exceed Maximum Acceptable Values (MAVs) for drinking water or Ecological Exposure Limits (EELs) where EELs are set for an active ingredient in a particular product. Where an EEL has been set for a particular active ingredient, it is good practice to adhere to this EEL across related approvals and products containing that active ingredient. The guidance below is based on the adherence to MAVs and EELs that have been set for the active components of TDPA and metsulfuron methyl in water (Table 5).

Note, this guidance does not supersede any regulatory rules around buffers. In particular, check district or regional plans (Air Plans, Land and Water Plans) for rules about spraying around waterways and apply the more precautionary approach where the rules differ from the guidance presented here.

3 Note that changes in nozzle orientation and flight speed can significantly change the droplet size classification.

Table 5. Maximum Acceptable Values for drinking water and Ecological Exposure Limits for water for the active ingredients within TDPA and metsulfuron methyl. A dash indicates there is no threshold value.

THRESHOLD	TRICLOPYR	DICAMBA	PICLORAM	AMINOPYRALID	METSULFURON METHYL
Maximum Acceptable Value for Drinking Water in NZ (mg/L)	0.1	0.1 (recommended by Ministry of Health)	0.2	-	-
Ecological Exposure Limits – freshwater mg/L)	0.059	-	0.029	0.060	0.0000084

TDPA – spray drift

To minimize the risk of water contamination from spray drift, guidance has been developed by Scion and the National Programme to support nozzle selection and the use of no-spray buffers when spraying with TDPA in areas with active waterbodies (Figure 1). This guidance is based on the results of modelling herbicide concentrations in waterways from spray deposition using the AGDISP model.

The guidance includes recommendations about two nozzle classes that were included in the modelling: nozzles producing very coarse (VC) and extremely coarse (XC) droplets.

Very coarse (VC): The model was based on the CP-09 0.078, 30° nozzle with a 0° angle (pointing straight back) producing a 450 µm VMD. This nozzle produces a more desirable droplet size from an efficacy perspective but requires larger no-spray buffers around waterways. The guidance in Figure 1 for VC nozzles could be applied to other nozzle types that produce a similar droplet VMD to the CP-09 0.078 nozzle.

Extremely coarse (XC): The model was based on the Accuflo .16, angled straight back, producing a 787 µm VMD. This nozzle has a low spray drift risk but efficacy may be reduced due to the larger droplets. The guidance in Figure 1 for XC nozzles could be applied to a number of low spray drift nozzles, including:

- Accuflo .16, .20, .28. The .16 is a good choice because it combines low driftable fraction with a VMD that is large but not excessive. This nozzle performs well when oriented straight back or at 45°, 2 bars pressure. If flying faster than 30-35 knots, it is recommended that the nozzles are pointed straight back.
- TVB (Thru-valve boom). Has been used to good effect in forestry.
- D6 or D8 straight back is sometimes used in forestry and gives good drift control when pointed straight back, but has very large droplets.
- CP-09, 0.125, 30 or 5°. With 2 bars pressure, 30 knots airspeed, and nozzles straight back, the driftable fraction is generally low. At 45° nozzle orientation, research shows there are variable results and there seems to be a degree of sensitivity with these nozzles (in terms of driftable fraction), so use with caution.

See Appendix 2 for other nozzle spectra characteristics.

The key model assumptions and their impacts are shown in Table 6. These assumptions should be considered when interpreting the guidance in Figure 1 as they include a number of 'worst case' scenarios. The full model specifications and assumptions are shown in Appendix 3.

Note that even with these mitigations in place, water contamination may occur following a large rainfall event. See below for advice on managing this risk.

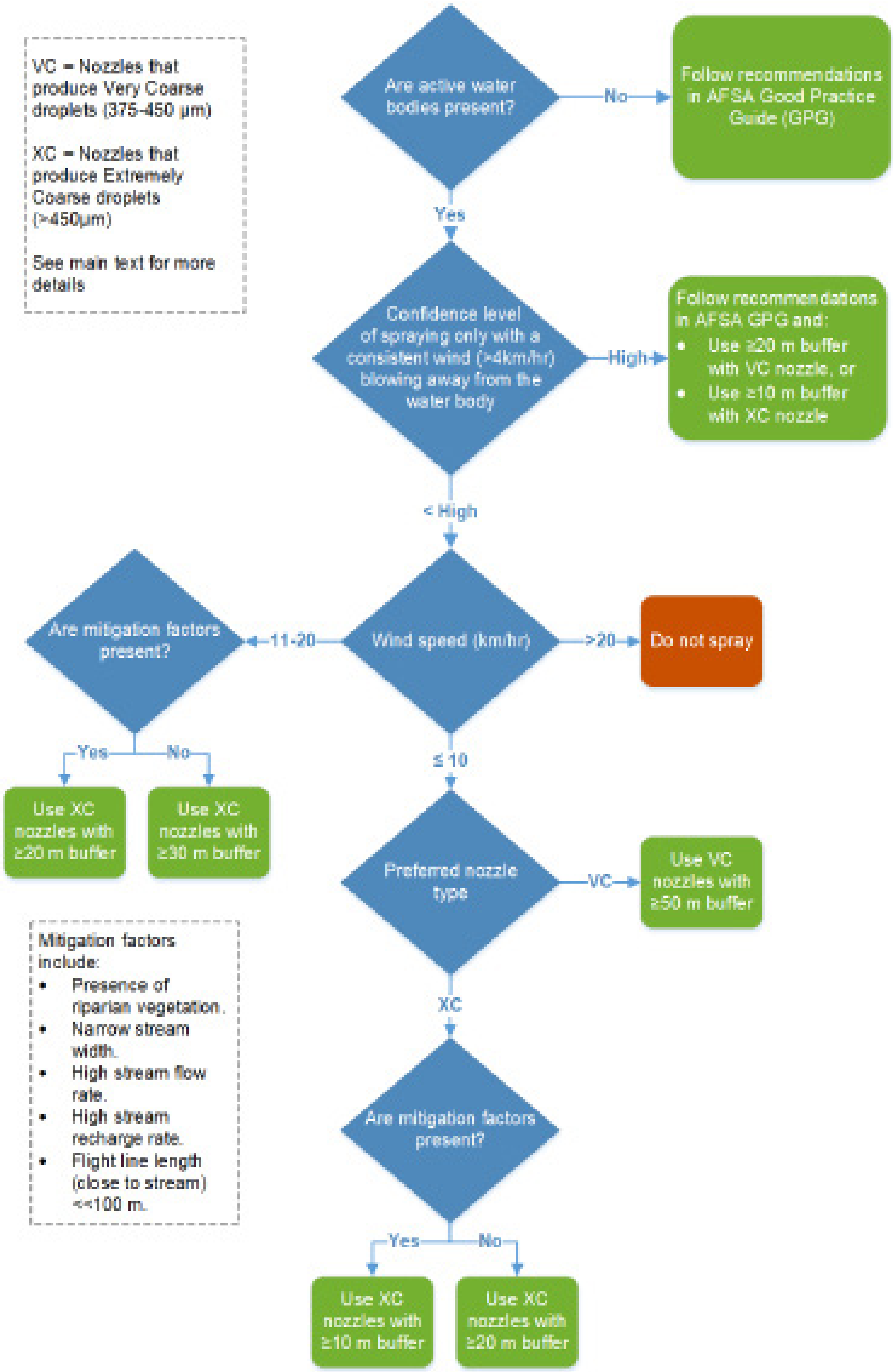

Figure 1. Decision tree to support nozzle selection and no-spray buffer widths under different wind speeds when boom spraying with TDPA. Mitigation factors should be considered relative to the modelled scenarios (Appendix 3).

Table 6. Assumptions included in the AGDISP models and their impacts on interpretation of the guidance.

SPECIFICATION	MODELLED SCENARIO	REALITY	IMPACTS ON INTERPRETATION OF GUIDANCE
Wind direction	A consistent wind speed blowing directly from the sprayed area towards the stream ('worst-case' scenario)	Wind speed and direction fluctuate around a mean with mean changing over time.	Spraying should only occur when the wind is blowing away from sensitive areas; this would reduce the risk of spray drift entering waterbodies or other sensitive areas. Most drift incidents occur with marginal conditions; not consistently bad. We took a precautionary approach and based the models on the 'worst-case' scenario.
Spray release height	8 metres, no canopy	Height 3 – 10 m above trees i.e. 10 to 20 m (or more) above ground. Variable scenarios in terms of downwind vegetation cover.	Selected release height underestimates drift at greater heights. But the lack of a modelled canopy overestimates drift (the canopy would intercept drift to some extent). Downwind vegetation (in addition to riparian barrier) would decrease drift.
Flight line length and width	100 m long (running parallel to waterbody) and 20 flight lines wide (200 m)	Flight line lengths and widths are likely to vary and not always run parallel to waterbodies	We modelled the 'worst-case' scenario when in reality only fractions of the spray line may have the risk of downwind spray reaching a stream. Shorter flight lengths beside waterbodies will reduce contamination risk.
Topography	Flat	Topography influences release height and meteorology. Some areas may have significant slopes.	Drift will generally increase downslope unless there is an upslope wind. Steep slopes increase the risk of run off to downhill waterbodies.

Metsulfuron methyl – spray drift

Metsulfuron has a very low EEL but is applied at substantially lower rates per ha than TDPA and has a much lower driftable fraction. When spraying near active waterbodies apply a minimum 50m no-spray buffer, use Accuflo or a similar low spray drift nozzle configuration, and only spray in low wind speeds (<10km/hr).

There may be some sites where the minimum 50m no-spray buffer is not practical or would compromise wilding control in the area. In this instance, it is recommended that the operator discuss a site specific spray plan with the Programme, to minimize the risk of spray drift.

Mitigating the risk of water contamination from run-off – TDPA and Metsulfuron

Water sampling to assess levels of herbicide residues in waterbodies is being carried out at some sites, to assess run-off after rainfall. To minimize the risk of concentrations exceeding MAVs or EELs after rainfall, consider any spray areas where a large proportion of the local catchment of a particular waterbody will be sprayed (the REC2 Watersheds layer can help with this), particularly small waterbodies or those with downstream water takes. Factors that increase the risk of run-off are:

- spraying on steep slopes above waterbodies (there is no exact threshold for steepness in terms of run-off risk, as research shows that even a slope of 10 degrees can experience significant run-off under certain conditions. But spatial datasets such as the NZLRI Slope layer can help to assess the degree of steepness in relation to other risk factors present)
- the spray site has shallow and permeable sediment (e.g. gravel). There are many GIS based classifications that can help with this (most have a soil drainage classification; e.g. New Zealand Soils Portal)
- there is little vegetation between the spray area and the waterbodies.

If the spray site meets some of these high-risk criteria for run-off, discuss this with the National Programme

2.4 EQUIPMENT CALIBRATION

Before any helicopter boom spray operation starts, the aircraft applying the herbicides must be calibrated for the spray formulation that will be applied. This is the pilot's responsibility in the first instance but must be verified with the operational controller to ensure the helicopter setup is fit for operation. Note that alteration of the formulation may affect the droplet size. Calibration should be done under a range of suitable conditions that are comparable to the conditions that will be experienced for the operation.

So that the helicopter and spray boom can be calibrated correctly, within the National programme, every contract for aerial foliar spraying boom spray application must specify:

- the application rate per hectare,
- the droplet size class,
- and the herbicide formulation to be used.

The person responsible for calibrating the helicopter will calculate the effective swath width of the spray boom for a particular flying speed and release using the selected nozzles, and advise the bout width (flight line separation) required to ensure even coverage. The operational controller can verify the expected output of each nozzle on site by doing a nozzle flow test.

Scion (NZ Forest Research Institute Ltd) has developed a publicly available web-based application called the Scion Swath Calibration Tool[4], which is designed to help helicopter spray applicators improve their boom spraying operations. Scion can also provide calibration advice for those who require technical support. Several tools have been developed that can be used by helicopter pilots and their customers to determine spray drift potential under different meteorological conditions to lessen the possibility of off-target deposition and lead to a more efficient and effective operation.

One such model is AGDISP, the most commonly used aerial application simulation model worldwide (Teske et al., 2003), and was used to generate the above guidance around buffers and nozzles. AGDISP predicts spray deposition on the ground and in a plant canopy as well as spray drift. If helicopter companies make improvements that result in more efficient droplet control, the National Programme would be interested in incorporating these into this guideline.[5]

4 http://webapps.scionresearch.com/SwathCalibration

5 It is relatively easy to achieve droplet control by using bigger droplets – however, the herbicides will probably not be as effective.

3. AFSA METHODS

3.1 SPRAY CONDITIONS

All aerial spray operations have the potential to be adversely affected by weather conditions. Large droplets are influenced less by weather conditions such as wind, temperature, and humidity than small droplets. Monitoring the weather conditions before and during a spray operation is essential to ensure operators are aware of changes as they occur. Use handheld weather equipment unless an established weather station is available at the site. Record the weather conditions during the operation and include in all operation reports.

Ideal weather conditions to operate in

It is best to boom spray in the mornings when the relative humidity is generally higher (> 70%) and the temperature is below 20°C. Hot, dry conditions cause more rapid evaporation of spray droplets and a higher potential for spray drift. Even with 'extremely coarse' droplets (refer Table 4) it can be difficult to get droplets from the smaller size classes to settle under hot, dry conditions. The Delta T safe aerial spray window (Figure 2) shows safe temperature and humidity combinations for aerial spraying.

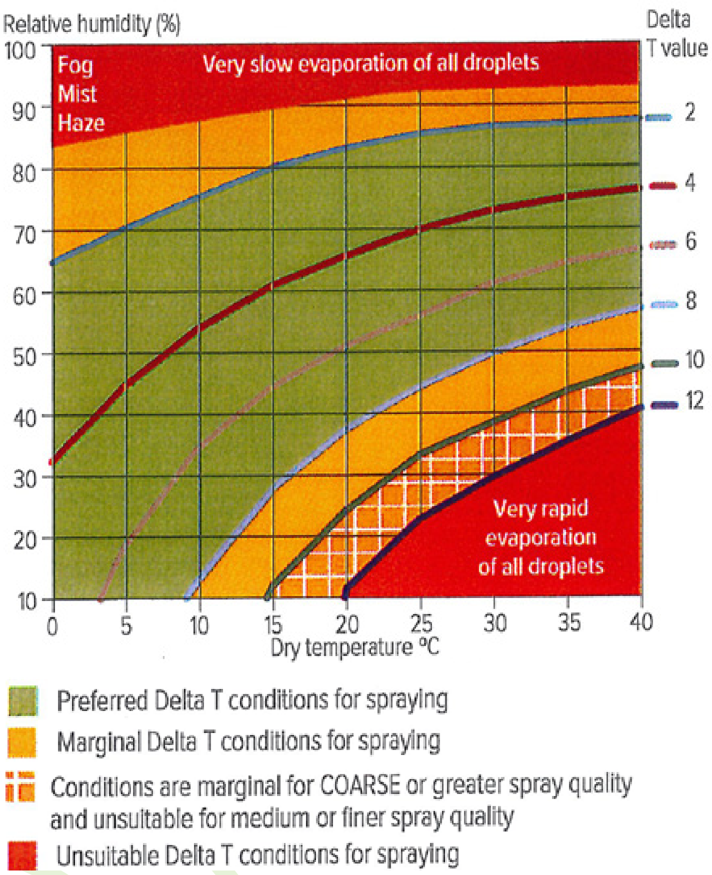

Figure 2. Delta T safe aerial spray window. A common spray guideline is to spray when Delta T is between 2 and 10; with caution below 2 and above 12.

Wind speed between 4 km/h and 20 km/h is the ideal range for boom spraying. Spraying under very calm, high or variable wind conditions is not recommended. Herbicides should not be applied when the wind is blowing towards a sensitive area. It is important to be aware of localised airflow conditions (e.g. related to topography, anabatic or katabatic winds, and land or sea breezes). Cold air drainage (down-slope or katabatic winds) occurs when the air cools and drains to the lowest point and is most common in the late afternoon and evening.

It is important to be aware of atmospheric stability (the vertical temperature profile of the atmosphere). Stable conditions occur when the temperature increases with height above the ground, typical of calm, still mornings after a clear sky at night. Under these very stable conditions it is difficult to predict the direction of air movement and any fine spray particles remain in a concentrated cloud, thereby increasing risks from spray drift. Fog and dew formation is an indication of these stable conditions with a temperature inversion. Unstable conditions occur when temperatures rise and thermals develop. Warm air rises and, because it is warmer (and less dense) than surrounding air, it continues to rise. Under these conditions spray deposition may be reduced.

Do not spray if there is any rain predicted or forecast within 24 hours. Herbicide formulations are usually rain-fast after a few hours, but rainfall within 6 hours can reduce herbicide efficacy. Ground surface run-off (see also section 5.1) can occur well outside the rain-fast period. For example, the greatest concentration of triclopyr recorded in an adjacent stream after gorse control was recorded when about 200 mm of rain fell 41–46 days after application (Wilcock et al., 1991).

In general, aerial spraying should not occur when:

- the air temperature reaches 25°C or more; or
- humidity drops to 50% or less; or
- wind speed increases to 15–20 km/h or more.
- There is evidence of temperature inversion; or
- thermal uplift; or
- cold air drainage.

3.2 FLIGHT PATH

AFSA boom spray operations must all use the 'half overlap–opposite pass' technique – that is, the distance between flight lines (bout width) is set at half the effective swath width and each successive pass is flown in opposite directions.[6] The first and last swaths covering an area should be applied with the outer half of the boom turned off.

Operational controllers should specify the area to be treated to the helicopter pilot by providing a shapefile in WGS84 co-ordinates.[7] The National Programme's Wilding Conifer Information System (WCIS) uses NZTM projection, but shapefiles can easily be converted to WGS84 by someone with GIS experience or by using the LINZ online co-ordinate converter[8].

3.3 HELICOPTER SPEED AND RELEASE HEIGHT OF HERBICIDE

The best speed for aerial boom spraying is determined by a trade-off between accuracy of release at slow speeds (and less spray drift) and greater efficiency at higher speeds. Speed is a matter that the pilot needs to determine based on the characteristics of the block. The optimum air speed is usually between 20 to 30 knots (37–55 km/h). Flying at very slow speeds of less than 14 knots (25 km/h) can produce unpredictable turbulent

6 Effectively flying one way and then ensuring that half the swath width is overlapped on the way back to ensure that both sides of the treated trees receive herbicide.

7 A geodetic datum or geodetic system is a co-ordinate system, and a set of reference points, used to locate places on the Earth. The World Geodetic System 1984 (WGS84) is a global datum. Co-ordinates change over time for objects which are fixed in the ground. This is because the tectonic plates on which New Zealand sits are constantly moving, albeit slowly. In New Zealand, this movement is usually about 5 cm per year. Therefore, it is important that co-ordinates in terms of WGS84 have a time associated with them, especially where the best levels of accuracy are required.

8 http://apps.linz.govt.nz/coordinate-conversion/

wakes. Therefore it is recommended, to reduce spray drift, to spray at a speed of 20 knots (37 km/h) to 30 knots (55 km/h) (Gous & Richardson, 2008).

Flying at high speeds (above 32 knots or 60 km/h) is likely to result in loose and inaccurate application. High speed application should only be considered for very large operations over flat terrain, and with the helicopter/equipment calibrated properly (e.g. Pinus radiata sprayed at 45 knots or 83 km/h; Richardson & Thistle, 2006). Flying at very high speeds (up to 130 knots or 240 km/h) is used in some agricultural situations with fixed-wing aircraft but is not appropriate for most environmental weed control in New Zealand.

The best spray distribution is obtained by flying with a release height of 2–6 m above the target. Generally, lower release heights are preferred (3–4 m) because it reduces evaporation and the chance of wind affecting the spray (Akesson & Yates, 1984). However, very low heights can be dangerous and there may be inadequate overlap between swaths resulting in 'striping' and poor efficacy. Ultimately, the spray height determined for each operation/block is at the pilot's discretion, taking safety into consideration at all times.

No additional allowance needs to be made for any uneven tree heights encountered. Good coverage of all foliage will be achieved provided that the herbicide is delivered at the correct water rate of 400 litres per hectare (or 600 for larger trees) and using the right droplet size. These parameters form an integral part of the helicopter calibration process (see section 2.2).

4. AFSA POST – CONTROL

4.1 HERBICIDE RUN-OFF AND RESIDUES

Run-off is most likely to occur after heavy rain (Wilcock et al., 1991) and can occur a considerable time after application (e.g. up 170 days; Norris et al., 1987). However, the risk of run-off varies with herbicides, soil types and slopes. Limited work in New Zealand to date suggests that even after very high rates of herbicide use, residues can be below sensitive levels within 12 months (Howell, 2014).

Water testing

Testing water for spray drift and herbicide run-off or soil for herbicide residues is not a requirement of the National Programme. However, it may be carried out at the discretion of the operational controller, in conjunction with the appropriate fund manager, and should be discussed with the National Programme team. Water testing may be recommended in high-risk areas for run-off and/or in areas with:

- downstream domestic or stock water takes
- high value aquatic sites
- slow moving waterbodies
- waterbodies beside steep slopes
- exposed waterbodies (i.e. little riparian vegetation)
- static waterbodies

Testing may also be requested following an environmental incident near or involving a water body.

See Appendix 4 for a water sampling protocol.

4.2 POST-CONTROL OPERATIONAL MONITORING

The success of the control operation will take time to reveal, with full effects not apparent for up to 2 years or more after application. To ensure the objective of full herbicide coverage of the infestation, GPS flight paths should be checked immediately after each operation to determine if any gaps in application have occurred, so that any gaps found can be immediately sprayed to achieve the intended control coverage.

Other post-control monitoring may be considered – for example, by visual site inspection, using aerial or ground-based transects randomly generated for the operational area. The results of this post-control monitoring can be cross-checked against the GPS flight paths submitted from the control operation. Operators' spray diaries can also be requested to verify exact dates and times when work was done. It is essential that all recording of information is valid and kept up-to-date (usually within 24 hours while matters remain fresh to mind).

Note, post-control monitoring techniques are currently being investigated with the intention of developing good practice guidance for use across the programme.

4.3 PROGRAMME QUALITY CONTROL

Operators should conduct internal self-audits and assessments themselves regarding area coverage using GPS recordings of flight lines and areas and locations of trees treated, ideally at each refuelling. Pilots need to be recording the GPS calibration for every load. This ensures they are monitoring the calibration so that any discrepancies can be immediately identified and rectified. As well as load-by-load monitoring, there is much to be gained by reviewing the day's operation, in preparing for the next.

External quality control checks should be conducted to ensure operations are being carried out in accordance with agreed plans and good practice methods. These are also helpful in post control success monitoring and to enable adaptive management and more efficacy in the programme.

External inspections may cover a wide variety of aspects, such as:

- checking daily briefing forms;
- sighting evidence of daily equipment checks and annual checks;
- air operational observations (from a ground position);
- observation of ground operation procedures (refuelling, chemical handling, helicopter landing/take off procedures);
- checking the boom and nozzle setup to make sure they are functioning correctly;
- checking tanks on helicopters to make sure they are mounted safely and are in good working condition (carried out by a qualified Licensed Aircraft Maintenance Engineer);
- inspecting the treated area to confirm that herbicide has been applied correctly (e.g. an assessment to confirm there are some symptoms visible from the treatment, and potentially two years later if required);
- checking GPS track logs (flight lines), spray diaries and flow rate data to show which stands of trees have been treated; and
- checking actual volume of herbicide used compared with the area (i.e. hectares) stated as being treated.

A boom spray run completed, Molesworth Station (Photo: T Michelle)

5. ADDITIONAL INFORMATION

Selected websites relevant for the National Programme

EPA. (2017). *Hazardous Substances (Hazardous Property Controls) Notice 2017.* https://www.epa.govt.nz/assets/Uploads/Documents/Hazardous-Substances/EPA-Notices/Hazardous-Substances-Hazardous-Property-Controls-Notice-2017.pdf

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Standards New Zealand. (2021). *NZS 8409:2021 Management of Agrichemicals.* https://www.standards.govt.nz/shop/nzs-84092021/

New Zealand Wilding Pine Network

Information for communities: http://wildingpinenetwork.org.nz/home/

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Klein, R.N., Schulze, L.D., Ogg, C. (2007). G07-1773 *Spray drift of pesticides*. https://www.researchgate.net/publication/237520355_G07-1773_Spray_Drift_of_Pesticides

Norris, L. A., Montgomery, M. L., & Warren, L. E. (1987). Triclopyr persistence in western Oregon hill pastures. *Bulletin of Environmental Contamination and Toxicology*, 39, 134–141.

Richardson, B., & Thistle, H. (2006). Measured and predicted aerial spray interception by a young *Pinus radiata* canopy. *Transactions of the ASABE*, 49, 15–23.

Teske, M., Thistle, H., & Ice, G. (2003). Technical advances in modeling aerially applied sprays. *Transactions of the ASAE*, 46(4), 985–993.

Wilcock, R. J., Costley, K. J., Cowles, R. J., Wilson, B., & Southgate, P. (1991). Stream run-off losses and soil and grass residues of triclopyr applied to hillside gorse. *New Zealand Journal of Agricultural Research*, 34, 351–357.

APPENDIX 1: TERMS AND DEFINITIONS

TERM	DEFINITION
Active waterbody	Fresh water or geothermal water in a river, lake, stream, pond, wetland, or aquifer, or any part thereof, including ephemeral streams or rivers if they are flowing at the time of spraying.
Adjuvant	A substance that helps or enhances the effect of the herbicide. Some adjuvants are already in the herbicide formulation. Others are added at mixing. These can include surfactants, compatibility agents, buffering agents, antifoam agents, drift retardants, and others that widen the range of conditions for herbicide use.
AFSA	Aerial Foliar Spray Application (includes both boom and spot spraying)
Bout width	The distance between successive passes of the aircraft is the bout width, which will always be less than the swath width (see below). The required bout width is determined according to the evenness of application required. The coefficient of variation percentage (CV%) (= standard deviation divided by the mean deposition ×100) is a measure of the uniformity of spray deposits and depends on the shape of the swath pattern and bout width. The higher the CV% value, the poorer the overall distribution – i.e. the more uneven it is. For systemic herbicides, a 30% CV is usually the maximum acceptable to ensure even spray deposit distribution.
Calibration	The process of determining, checking or rectifying the graduation of any instrument that gives quantitative measurements. In this case, checking that the equipment, when operated to the specifications, delivers the required amount of spray mixture per unit area over the bout (or effective swath) width.
Carrier	The substance that carries the herbicide formulation and any adjuvants. The formulation will specify the carrier, often water or a plant-based oil.
Droplet or diameter variance (DV)	A DV 0.1 value indicates that 10% of the volume of the spray is contained in droplets with diameters smaller than this value. A DV 0.9 value indicates that 90% of the spray is in droplets with diameters smaller than the value. See also relative span (RS) and volume median diameter (VMD) definitions below.
Effective swath width	Aerial booms distribute spray in a band or swath greater than the boom's width. The swath width is the total width of the spray (herbicide mixture) deposit pattern for one pass of the aircraft. The deposit pattern is influenced by herbicide formulation, selected nozzles and their orientation, flying speed, release height, wind speed and wind direction. To ensure full coverage of the target vegetation, the distance between successive passes of the aircraft (bout width, which will always be less than the swath width) must overlap. The effective swath or bout width is determined by calculating the amount of overlap needed to ensure all target vegetation receives the required quantity of spray. Scion (NZ Forest Research Institute Ltd) has developed a publicly available web-based application called the Scion Swath Calibration Tool[10], with an associated Scion Swath Calibration Manual[11]. Scion also can provide advice on aircraft calibration methods.

10 http://webapps.scionresearch.com/SwathCalibration

11 http://webapps.scionresearch.com/SwathCalibration/Swath%20Calibration%20Tool.pdf

TERM	DEFINITION
GROWSAFE	The brand name used by the industry training organisation known as New Zealand Agrichemical Education Trust (NZAET). The role of NZAET is to ensure independent trainers train to national industry standards. NZAET appraises, accredits and reviews specialist trainers to ensure quality. It also publishes the GROWSAFE manual, a training aid for teaching NZS 8409:2004 *Management of Agrichemicals* (Standards New Zealand, 2004).
GROWSAFE Pilot Chemical Rating certificate	GROWSAFE certification for pilots applying agrichemicals. The Hazardous Substances (Hazardous Property Controls) Notice 2017 requires pilots to have a current Pilot Chemical Rating under Part 61 of the Civil Aviation Rules.
New Zealand Standard for Management of Agrichemicals (NZS 8409:2021)	The New Zealand Code of Practice approved by the Environmental Protection Authority (EPA) under the Hazardous Substances and New Organisms Act 1996. It sets out how to manage agrichemicals to comply with the relevant hazardous substance regulations. Knowledge of this industry Code of Practice is an essential part of GROWSAFE certification and Qualified Person certification.
NZTM projection	New Zealand Transverse Mercator (NZTM2000) is the projection used for New Zealand's Topo50 1:50,000 and other small-scale mapping. Spatial data users should use NZTM2000 where a projection is required within mainland New Zealand. You can convert co-ordinates between NZTM and WGS84 using the Land Information New Zealand (LINZ) online co-ordinate converter.[12]
Operational Controller	Where the operation is being carried out under the National Wilding Conifer Control Programme, there will be an Operational Controller – who acts on behalf of the Programme Manager to ensure the operation is conducted appropriately and aligned to the Programme's good practice guidelines, or in the absence of such, the relevant industry codes of practice. The role includes ensuring all equipment is applicable to the task, staff or contractors are suitably trained and competent to undertake the work, relevant health and safety considerations and practices are employed and accurate data is collected and reported. The Operational Controller is deemed to have the duties of a PCBU under the Health and Safety at Work Act 2015.
Qualified person	The qualification requirements for handling a class 9 substance are defined in the Hazardous Substances (Hazardous Property Controls) Notice 2017 (EPA, 2017, Part 4 subpart C). This replaces the former Approved Handler Test Certificate process.
Regional Air Plans	Each regional council/territorial authority has a regional plan to protect air, land and water quality. Rules in these plans contain conditions regarding the discharge of agrichemicals. While there is some national commonality between rules around the use of agrichemicals for wilding conifer management, project managers and operational controllers should be aware at all times of the specific rules and conditions in place for the regions they are working in.
Relative span (RS) of droplet sizes	A measure of the range of droplet sizes. RS is calculated by subtracting the DV 0.1 value from the DV 0.9 value and dividing by the volume median diameter (VMD). A small relative span means droplets are of a more even size.
Rotor tip vortices	Circular patterns of rotating air at the tips of the rotating blades of a helicopter. Technical specifications aim to minimise the spray that enters the vortices to minimise spray drift.

12 http://apps.linz.govt.nz/coordinate-conversion/

TERM	DEFINITION
Run-off	The state when droplets of water coalesce into a film and start to flow or drip off the surface of a needle – for instance, when spray droplets become sufficiently dense to drip off the needle, or when rain on a surface wets the surface sufficiently to start flowing down-slope.
Shapefile	A shapefile is a common geospatial file type compatible with ESRI and other Geographical Information System (GIS) software. It spatially describes data in the shape of points, lines or polygons (areas).
Spray drift	Spray drift is the unintentional diffusion of a pesticide outside the application area, with a possible risk to human health, the environment, or property. Some spray drift invariably occurs; however, from a practicable viewpoint it only becomes an issue if it negatively impacts on a sensitive area. By following this good practice guidance the spray drift risk will be minimised.
Volume median diameter (VMD)	All nozzles produce a range of droplet sizes known as the droplet spectrum. One common method of characterising a droplet spectrum is with the VMD and relative span (RS). A median is a value or quantity lying at the midpoint of a frequency distribution of observed values or quantities. The VMD is the droplet diameter that splits a sample of droplets (the spectrum) into two halves by volume, such that 50% of the spray volume is in droplets with a larger diameter than this value and 50% of the spray volume is in droplets that have a smaller diameter than this value.

APPENDIX 2: SCION NOZZLE TEST SUMMARY OF RESULTS

Droplet spectra characterised in the University of Queensland wind tunnel using the TDPA spray mixture

NOZZLE	NOZZLE ANGLE (°)	PRESSURE (BAR)	AIRSPEED (KNOTS)	DT10	DT50 (VMD)	DT90	RELATIVE SPAN	VOLUME < 150 MM
CP-09, 0.125, 30° deflector	0	2	30	386.7	864.2	1482.1	1.27	0.66
CP-09, 0.078, 30° deflector	0	2	30	212.4	449.7	732.0	1.16	3.31
CP-09, 0.125, 5° deflector	0	2	30	599.7	1290.3	1957.2	1.05	0.09
CP-09, 0.078, 5° deflector	0	2	30	559.9	1235.8	1824.4	1.03	0.05
CP-09, 0.125, 30° deflector	45	2	30	302.9	478.0	770.6	0.98	0.02
CP-09, 0.078, 30° deflector	45	2	30	180.4	328.4	485.9	0.93	5.07
CP-09, 0.125, 5° deflector	45	2	30	392.5	891.9	2009.5	1.81	0.11
CP-09, 0.078, 5° deflector	45	2	30	319.0	616.7	1434.7	1.81	0.45
Accuflow 0.16	0	2	30	622.5	787.5	974.1	0.45	0.00
Accuflow 0.20	0	2	30	745.8	939.8	1162.8	0.44	0.00
Accuflow 0.28	0	2	30	933.0	1200.0	1486.5	0.46	0.00
Accuflow 0.20	0	2	35	723.5	937.8	1190.2	0.50	0.00
Accuflow 0.28	0	2	50	293.5	609.3	1022.8	1.20	1.76
Accuflow 0.16	45	2	30	616.4	779.1	969.1	0.45	0.00
Accuflow 0.20	45	2	30	725.3	916.4	1142.4	0.46	0.00
Accuflow 0.28	45	2	30	880.7	1162.4	1649.0	0.66	0.00
Accuflow 0.20	45	2	35	658.1	898.4	1175.1	0.58	0.00
Accuflow 0.28	45	2	50	184.0	418.5	704.5	1.25	6.60
AIC 11008	0	2	35	275.5	583.8	949.2	1.15	1.84
AIC 11008	0	3	35	272.9	559.6	849.4	1.03	1.97
AIC 11008	45	2	35	187.7	516.1	861.4	1.30	5.91
AIC 11008	45	3	35	176.4	501.4	808.3	1.26	7.28
AIC 11010	0	2	35	290.1	615.4	913.3	1.01	1.63
AIC 11010	0	3	35	299.6	624.4	973.6	1.08	1.69
AIC 11010	45	2	35	182.9	524.5	869.8	1.31	6.38
AIC 11010	45	3	35	172.6	529.5	832.5	1.25	7.84
D6-45	0	4	50	111.3	232.2	385.7	1.18	18.20

APPENDIX 3: MODELLING HERBICIDES IN WATERWAYS FROM SPRAY DEPOSITION

Table 1: Baseline and variable AGDISP inputs used when modelling herbicide concentrations within waterways.

INPUT VARIABLE	VALUE
Aircraft and spray block:	
Aircraft type	Eurocopter AS 350 B3, Squirrel
Release height above ground (m)	8
Speed (m/s)	18
Nominal lane separation (m)	10
Number of flight lines	20
Application technique:	
Nozzle location	Distributed evenly to 80% rotor diameter
Nozzles / drop spectra (VMD μm)	CP09, 30° (450); Accuflo ,16 (787)
Spray Material (TDPA mix):	
Active ingredient (% tank mix))	13.5
Additives (% tank mix)	7.25
Non-volatile fraction	0.2075
Total volume rate (water carrier) (L/ha)	400
Meteorology (2 m reference height):	
Wind speed (km/hr)	4, 10, 20
Wind direction (relative to flight lines)	Crosswind (-90°)
Temperature (°C)	18
Relative humidity (%)	75
Atmospheric stability	Overcast
Canopy:	
None present	

Table 2: Stream factor model inputs used when modelling herbicide concentrations within waterways.

INPUT VARIABLE	VALUE
Spray block	
Spray line length (parallel to stream) (m)	100
Number of flight lines	20
Helicopter turn-around time (s)	20
Riparian interception factor	0.0, 0.5
Instream chemical decay rate (1/day)	0
Recharge rate (m3 s-1 km-1)	0, 0.75, 1.5
Distance (m) from edge of spray block to stream centre	10, 20, 30, 50
Sampling location (m)	0, 500

Table 3: Modelled stream scenarios

STREAM SCENARIO	RIPARIAN INTERCEPT	RECHARGE RATE (M3/S/KM)	WIDTH (M)	DEPTH (M)	FLOW (M3/S)	FLOW SPEED (M/S)
1	0, 0.5	0, 1.5	2	0.5	1.5	1.5
2	0, 0.5	0, 0.75	3.5	0.4	0.8	0.5714

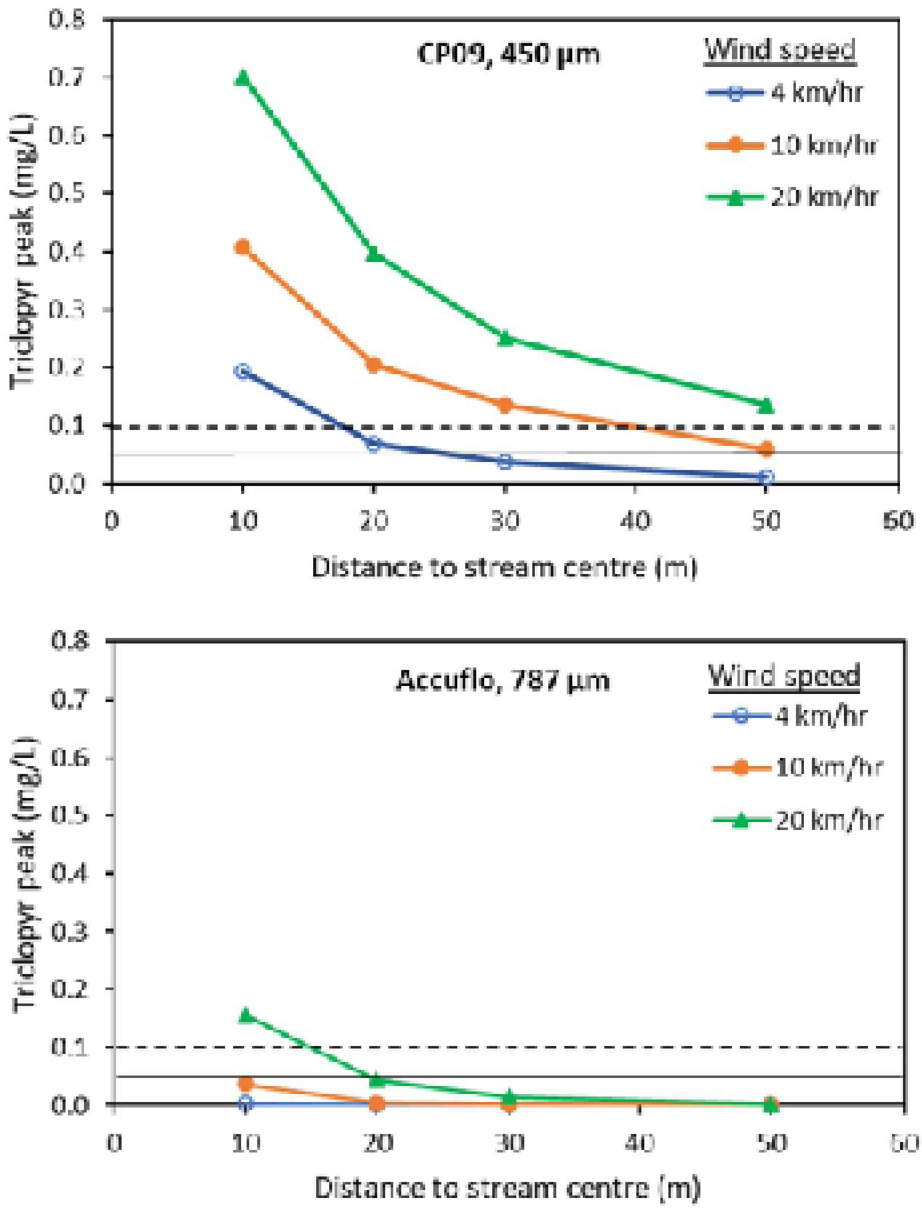

Figure 1. Results of modelling herbicide concentrations in waterways using AGDISP. Effect of wind speed and buffer distance (distance between the spray block and the stream centre) on peak triclopyr concentration (averaged across other factors) for the CP09 (top figure) and Accuflo (bottom figure) nozzles. The dashed horizontal line represents the MAV and solid horizontal line the EEL.

APPENDIX 4: WATER SAMPLING PROTOCOL

Aim of water sampling:

- To assess herbicide concentrations in waterways from spray drift
- To assess herbicide concentrations in waterways from run-off after rainfall

Laboratory analysis:

- Locate a laboratory that can undertake testing of water samples for the active ingredients in the herbicide mix you are using (note aminopyralid cannot currently be tested). It is preferable to use a laboratory that provides you with the bottles and a chain-of-custody sheet.
- The testing laboratory should inform you of the required volume of water per sample, appropriate bottles/ containers to collect the sample, whether to rinse the bottles before use, whether to leave air space at the top of the bottle, storage requirements between sampling and testing, and timeframes to get the sample tested. Check that the detection limit that the laboratory can test to, is suitable for the standards that you are testing against (see MAVs and EELs in main text as a guide).
- Urgent water testing (faster testing turnaround times but higher per-sample costs) may be required, where available, in some locations if there are nearby downstream water takes.

Where to sample:

- Should be agreed between project managers, fund managers and the national programme team either in a planning meeting or through email exchange.
- Waterbodies that are adjacent to or directly downstream of the spray area. The downstream corner of the spray area is a good option; or consider sampling from the section of waterbody that is closest to the spray block, as this is likely to capture the most spray drift and run off.
- Can include larger rivers and/or smaller streams that are flowing on the day of spraying.
- Should be at an accessible location.
- Record the exact location with GPS coordinates and ensure samples are taken from the same location each time.

When to sample:

At each sampling location:

- Take one water sample immediately before spraying (or within 24 hours before the spray event)
- Within the first hour after spraying finishes (and as soon as it is safe and practical to do so), take two composite water samples, each made up of two half-samples, with 15-minute intervals between samples. For example, if the volume required by the testing laboratory per sample is 1 Litre, take one 500 ml sample within the first 15 minutes after spraying, then a second 500 ml sample 15 minutes after the first sample. Combine these two samples to make the first composite (1 litre) sample. Then take one 500 ml sample 30 minutes after the first sample, and another 500 ml sample 45 minutes after the first sample. Combine these to make the second composite sample. Adjust the volumes per sample as needed depending on the volume required by the testing laboratory.
- In the second hour after spraying finishes (when safe and practical to do so) take one composite sample,

made up of four quarter samples (e.g., ¼ of bottle volume every 15 minutes). Repeat in the third hour after spraying finishes, if practical.

- Take one sample within 24 hours after the **first rainfall event*** (as soon as possible). Record the date and intensity of the rainfall event.
- If the first rainfall event was relatively small (around 10-20mm) and is followed by a larger rainfall event at a later date, consider taking a second sample within 24 hours after the larger rainfall event.
- Take ongoing weekly samples if herbicide concentrations are found to approach or exceed ecological or drinking water thresholds. Note the turnaround time for laboratory testing may be around 10 days, in which case samples should be taken at a similar interval.

***Rainfall events:** The amount of rain that is needed to see a peak in herbicide concentrations will vary with the waterbody and site characteristics. For instance, more rain would be needed for larger waterbodies, whereas less would be needed for smaller waterbodies or those with overhanging vegetation that may have captured spray drift. These factors should be considered when developing a sampling plan for your site. As a guide, if the first rainfall is within 48 hours of spraying, sample after ≥10 mm of rainfall. Lower rainfall thresholds could be considered for small streams, or if the stream has a lot of overhanging vegetation. If the first rainfall is >48hours after spraying, sample after ≥20 mm rainfall (note, for small waterbodies such as streams, it may be worth sampling after 10 mm of rain if this falls anytime within the first week after spraying).

How to sample:

- Calculate the number of bottles required (allow for a few extra). Order the bottles (or pick them up from the testing laboratory) well before spraying starts. Store the bottles in a secure location so they are not accidently contaminated or used for other purposes. Take extra bottles into the field as back-up.
- At the site, fill out the label/tag on the water bottle, also record this information in a notebook so that you have a back-up if the label/tag is damaged. You could also take a photo of the label as a back-up.
- Take waterflow measurements at the time of sampling (e.g. with a portable velocity meter), and waterbody width and depth estimates at the sampling location.
- Take the water sample upstream from where you enter the waterway, facing in an upstream direction so that you are sampling undisturbed water. Take the sample from the main part of the flow (if safe to do so; if a large/deep waterbody, sample from a flowing part of the waterbody that can be reached from the bank). Keep your fingers away from the mouth of the bottle and the inside of the lid to avoid contamination. Triple rinse the bottle first where appropriate (check with the lab) and empty the bottle out downstream of your sample point. Place the bottle open end downward into the water column and scoop upward in an upstream direction. Take care not to disturb the stream bottom. Ensure the lid is screwed on securely. Avoid sampling ponded/stagnant water or backwater areas. Check this sampling strategy is in line with laboratory requirements and amend if necessary.
- Place the sample in a suitable storage container to prevent contamination of the sample. Chillibins are often used for this purpose. Include freezer pads in the storage container if the sample requires chilling. Ensure samples are kept secure (i.e., lock vehicle if unattended) during transportation.
- Back at the office, fill out the chain-of-custody sheet, and keep a copy for your own records. Put the chain-of custody sheet in with the samples and courier/drop-off to the laboratory
- If retaining samples overnight, keep them in a secure (preferably lockable) place to maintain the integrity of the sampling process and, if required, under chilled conditions.
- Return any unused bottles to the laboratory

APPENDIX 5: ENVIRONMENTAL INCIDENT RESPONSE AND REPORTING PROCEDURE

Should an environmental incident occur in relation to the National Wilding Conifer Control Programme operations, the following response and reporting procedure is to be enacted.

An Environmental Incident within the National Wilding Conifer Control Programme is considered to have occurred where one or more of the following is observed:

- A single event where over 1 Litre of chemical concentrate or mixed equivalent has been accidently discharged (i.e. distributed outside of control polygon or onto non-target species) into the environment.
- A loss of a threatened species or harm (dieback) to a threatened ecosystem that can be related to control operations is identified.

All environmental incidents observed during control operations are to be notified and assessed within a 48 hour period of being noticed. An environmental incident report is to be compiled for each separate incident and these are to be reported in the monthly reporting to the National Programme.

However, where action could be immediately and safely taken to prevent immediate danger or further harm to people and/or the environment, that action should be undertaken to avoid or minimise immediate danger or further harm in conjunction with reporting the situation.

Some environmental events may also need to be reported to local authorities or others. Please check the respective local authority resource management plans and the NZ Standard for the Management of Agrichemicals 8409:2021 (Appendix R) to determine whether this is the case.

ENVIROMENTAL INCIDENT REPORT CARD

1. Incident Reported by:

2. When did the incident occur? **Day:** **Time:**

3. Where did the incident occur?

4. Type of incident:

- Chemical spill to land,
- Chemical contamination of water,
- Near miss,
- Other? E.g. Cumulative effects i.e. chronic chemical build-up in areas where refuelling often takes place.

5. Cause of incident:

6. The value of any receiving environment:

- Very High (threatened species or ecosystem),
- High (native or productive land),
- Medium (intermixed native or productive species /exotic),
- Low (unproductive exotic).

7. The magnitude (severity) of the incident:

- Severe (affected area >100m², or legacy effect >20 yrs)
- Moderate (area 10m² - 100m², or legacy effect 1-20 yrs).
- Low (area <10 m² or very short temporary effect <1 yr).

8. Using answers to 6 and 7 above, what is the (actual or potential) environmental impact of the incident (circle):

ENVIRONMENTAL IMPACT	VALUE OF RECEIVING ENVIRONMENT			
	LOW	MEDIUM	HIGH	VERY HIGH
LOW	Very low	Minor	Moderate	High
MODERATE	Minor	Moderate	High	Very High
SEVERE	Moderate	High	Very High	Very High

9. Actions taken to remedy the impact of environmental incident:

Contain:

Clean up:

Restore:

Prevent:

10. Any further actions needing to be taken: