IMAZAPIC [Plateau and Plateau DG]- Human Health and Ecological Risk Assessment Final Report

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LIST OF TABLES

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

a.e.	acid equivalents
a.i.	active ingredient
AEL	adverse-effect level
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	bioconcentration factor
bw	body weight
cm	centimeter
DG	dispersible granules
EC_{50}	concentration causing 50% inhibition of a process
EC_{100}	concentration causing complete inhibition of a process
EIS	environmental impact statement
F	female
F_1	first filial generation
FS	Forest Service
g	gram
GC	gas chromatography
GRAS	generally recognized as safe
HQ	hazard quotient
IARC	International Agency for Research on Cancer
i.p.	intraperitoneal
kg	kilogram
$K_{o/c}$	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
K_p	skin permeability coefficient
L	liter
lb	pound
LC_{50}	lethal concentration, 50% mortality
LD_{50}	lethal dose, 50% mortality
LD_{95}	lethal dose, 95% mortality
LOAEL	lowest-observed-adverse-effect level
m	meter
M	male
mg	milligram
mg/kg/day	milligrams of agent per kilogram of body weight per day
mL	milliliter
MSDS	material safety data sheet
MW	molecular weight
NCI	National Cancer Institute
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
NOEL	no-observed-effect level
NRC	National Research Council
ppm	parts per million

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (*continued*)

RBC	red blood cells
RfD	reference dose
UF	uncertainty factor
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency
USDA	United States Department of Agriculture
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
=	equal to
≃	approximately equal to

COMMON UNIT CONVERSIONS AND ABBREVIATIONS

To convert ...	Into ...	Multiply by ...
acres	hectares (ha)	0.4047
acres	square meters (m^2)	4,047
atmospheres	millimeters of mercury	760
centigrade	Fahrenheit	1.8C°+32
centimeters	inches	0.3937
cubic meters (m^3)	liters (L)	1,000
Fahrenheit	centigrade	0.556F°-17.8
feet per second (ft/sec)	miles/hour (mi/hr)	0.6818
gallons (gal)	liters (L)	3.785
gallons per acre (gal/acre)	liters per hectare (L/ha)	9.34
grams (g)	ounces, (oz)	0.03527
grams (g)	pounds, (oz)	0.002205
hectares (ha)	acres	2.471
hectares (ha)	square meters	10,000
inches (in)	centimeters (cm)	2.540
kilograms (kg)	ounces, (oz)	35.274
kilograms (kg)	pounds, (lb)	2.2046
kilograms per hectare (hg/ha)	pounds per acre (lb/acre)	0.892
kilometers (km)	miles (mi)	0.6214
liters (L)	cubic centimeters (cm^3)	1,000
liters (L)	gallons (gal)	0.2642
liters (L)	ounces, fluid (oz)	33.814
miles (mi)	kilometers (km)	1.609
miles per hour (mi/hr)	cm/sec	44.70
milligrams (mg)	ounces (oz)	0.000035
meters (m)	feet	3.281
ounces (oz)	grams (g)	28.3495
ounces per acre (oz/acre)	grams per hectare (g/ha)	70.1
ounces per acre (oz/acre)	kilograms per hectare (kg/ha)	0.0701
ounces fluid	cubic centimeters (cm^3)	29.5735
pounds (lb)	grams (g)	453.6
pounds (lb)	kilograms (kg)	0.4536
pounds per acre (lb/acre)	kilograms per hectare (kg/ha)	1.121
pounds per acre (lb/acre)	mg/square meter (mg/m^2)	112.1
pounds per acre (lb/acre)	µg/square centimeter ($µg/cm^2$)	11.21
pounds per gallon (lb/gal)	grams per liter (g/L)	119.8
square centimeters (cm^2)	square inches (in^2)	0.155
square centimeters (cm^2)	square meters (m^2)	0.0001
square meters (m^2)	square centimeters (cm^2)	10,000
yards	meters	0.9144

Note: All references to pounds and ounces refer to avoirdupois weights unless otherwise specified.

CONVERSION OF SCIENTIFIC NOTATION

Scientific Notation	Decimal Equivalent	Verbal Expression
$1 \cdot 10^{-10}$	0.0000000001	One in ten billion
$1 \cdot 10^{-9}$	0.000000001	One in one billion
$1 \cdot 10^{-8}$	0.00000001	One in one hundred million
$1 \cdot 10^{-7}$	0.0000001	One in ten million
$1 \cdot 10^{-6}$	0.000001	One in one million
$1 \cdot 10^{-5}$	0.00001	One in one hundred thousand
$1 \cdot 10^{-4}$	0.0001	One in ten thousand
$1 \cdot 10^{-3}$	0.001	One in one thousand
$1 \cdot 10^{-2}$	0.01	One in one hundred
$1 \cdot 10^{-1}$	0.1	One in ten
$1 \cdot 10^{0}$	1	One
$1 \cdot 10^{1}$	10	Ten
$1 \cdot 10^{2}$	100	One hundred
$1 \cdot 10^{3}$	1,000	One thousand
$1 \cdot 10^{4}$	10,000	Ten thousand
$1 \cdot 10^{5}$	100,000	One hundred thousand
$1 \cdot 10^{6}$	1,000,000	One million
$1 \cdot 10^{7}$	10,000,000	Ten million
$1 \cdot 10^{8}$	100,000,000	One hundred million
$1 \cdot 10^{9}$	1,000,000,000	One billion
$1 \cdot 10^{10}$	10,000,000,000	Ten billion

EXECUTIVE SUMMARY

Introduction

The USDA Forest Service uses the herbicide, imazapic, in its vegetation management programs. Two commercial formulations, Plateau and Plateau DG, may be used by the Forest Service. The present document provides risk assessments for human health effects and ecological effects to support an assessment of the environmental consequences of using imazapic in Forest Service programs.

The Forest Service has not conducted previous risk assessments on imazapic and no risk assessments on this compound have been published in the open literature. Moreover, almost all of the mammalian toxicology studies as well as ecotoxicology and environmental fate studies are unpublished reports submitted to the U.S. EPA as part of the registration process for this compound. The only studies on imazapic encountered in the published literature involved field trials assessing the efficacy of imazapic for the control of various weed species. Because of the lack of a detailed, recent review concerning imazapic and the preponderance of unpublished relevant data in U.S. EPA files, a complete search of the U.S. EPA files was conducted in the preparation of this risk assessment. Full text copies of the most relevant studies [n=95] were kindly provided by the U.S. EPA Office of Pesticide Programs and these studies for the basis of the current risk assessment..

Program Description

Imazapic is herbicide that is used in the control grasses, broadleaves, and vines, and for turf height suppression in noncropland areas. The Forest Service will typically use imazapic in grassland restoration. The Forest Service may use two commercial formulations of imazapic, Plateau and Plateau DG. Both of these formulation contain the ammonium salt of imazapic as the active ingredient. Plateau is a liquid formulation that contains imazapic (22.2%) at a concentration of 2 lbs per gallon and Plateau DG is a dispersible granule formulation that contains the ammonium salt of imazapic (70%).

Imazapic may be applied by directed foliar, broadcast foliar, or aerial methods. The most common method of application in Forest Service programs will involve broadcast foliar applications. For Plateau, the labeled application rates range from 0.03125 to 0.1875 lbs imazapic per acre. For Plateau DG, the labeled application rates range from about 0.0625 to 0.1875 lbs imazapic per acre. The Forest Service will not use imazapic at the highest labeled application rate. The maximum rate that will be used in Forest Service programs is 0.0624 lb/acre.

Formulations of imazapic have not been used in past Forest Service programs and no information on the amount of imazapic used in other applications has been encountered. Information on the amount of imazapic that the Forest Service will apply in the future will be published by the Forest Service in standard annual reports that are available to the public.

HUMAN HEALTH RISK ASSESSMENT

Hazard Identification

In experimental mammals, the acute oral LD_{50} for imazapic is greater than 5000 mg/kg, which indicates a low order of acute toxicity. Nevertheless, oral doses as low as 175 mg/kg bw/day were associated with increases in maternal mortality in a multiple dose study designed to assess the potential of imazapic to cause birth defects. While it is not clear if the maternal mortality at 175 mg/kg bw/day was attributable to the chemical or experimental dosing errors, a somewhat higher dose of 700 mg/kg bw/day was clearly associated with increased mortality attributed to the toxicity of imazapic.

Imazapic does not appear to be toxic to experimental rodents at relatively high concentration in the diet but is toxic to dogs, causing adverse effects on muscle, blood, and liver. The NOAEL in rats is about 1625 mg/kg bw in the 13-week study or 1133 mg/kg bw in the 2-year study. Dogs, however, appear to be more sensitive than rodents, and the major signs of toxicity include adverse effects on the muscle, blood, and liver. Doses as low as 150 mg/kg bw have been associated with treatment related effects were observed on skeletal muscle.

In several standard tests required for pesticide registration, imazapic has failed to show any indication of adverse effects on development or reproduction and no carcinogenic or mutagenic activity.

Skin absorption is the primary route of exposure for workers. Data regarding the dermal absorption kinetics of imazapic are not available in the published or unpublished literature. For this risk assessment, estimates of dermal absorption rates are based on quantitative structure-activity relationships. These estimates of dermal absorption rates are used in turn to estimate the amounts of imazapic that might be absorbed by workers, which then are used with the available dose-response data to characterize risk. The lack of experimental data regarding dermal absorption of imazapic adds uncertainty to this risk assessment. Uncertainties in the rates of dermal absorption, however, can be estimated quantitatively and are incorporated in the human health exposure assessment.

Based on standard studies required for pesticide registration, imazapic appears to be essentially non-irritating and non-sensitizing to the skin and minimally irritating to the eyes. Concentrations of imazapic in the air that would be much higher than any plausible concentrations in human exposure scenarios have been associated with lung congestion in rats. The potential inhalation toxicity of imazapic is not of substantial concern to this risk assessment because of the implausibility of inhalation exposure involving concentrations of this compound sufficiently high to induce effects.

Exposure Assessment

There are no occupational exposure studies in the available literature that are associated with the application of imazapic. Consequently, worker exposure rates are estimated from an empirical relationship between absorbed dose per kilogram of body weight and the amount of chemical

handled in worker exposure studies on nine different pesticides. Separate exposure assessments are given for boom spray ground, backpack, and aerial applications. For all three types of applications, central estimates of worker exposure range from about 0.0003 to 0.001 mg/kg/day and upper limits of the exposure from about 0.003 to 0.005 mg/kg/day.

Except in the case of accidental exposures, the levels of imazapic to which the general public might be exposed should be far less than the levels for workers. Longer-term exposure scenarios for the general public lead to central estimates of daily doses in the range of about 0.00000001 to 0.00002 mg/kg/day with upper limits of exposure in the range of 0.000001 to 0.0005 mg/kg/day. While these exposure scenarios are intended to be conservative, they are nonetheless plausible. Accidental exposure scenarios result in central estimates of exposure of up to 0.071 mg/kg/day with upper ranges of 0.34 mg/kg/day. All of the accidental exposure scenarios involve relatively brief periods of exposure, and most should be regarded as extreme, some to the extent of limited plausibility.

Dose-Response Assessment

The Office of Pesticide Programs of the U.S. EPA has derived an RfD of 0.5 mg/kg/day for imazapic. This RfD is based on a chronic rat LOAEL in dogs of 5000 ppm in the diet corresponding to an estimated daily dose of 137 mg/kg/day and an uncertainty factor of 300 - i.e., 0.456 mg/kg/day which rounds to 1 significant digit as 0.5 mg/kg/day. The dog LOAEL is based on adverse effects on skeletal muscle.

Risk Characterization

None of the exposure scenarios for workers or members of the general public result in levels that exceed the RfD. Based on central estimates of longer term exposure for workers and the general public, the levels of exposure will be below the RfD by factors of about 625 to 50,000,000 (50 million). Even for accidental exposures, the upper limits of the exposure estimates are below the RfD by factors of about 1.5 to 4,500. Thus, there is no basis for asserting that imazapic is likely to pose any identifiable risk to human health. This is consistent with the recent evaluation of imazapic by the U.S. EPA in which margins of exposure/safety were calculated to be over 1000.

The only reservation associated with this assessment of imazapic is the same reservation associated with any risk assessment in which no plausible hazards can be identified at the recommended use rates: ***Absolute safety cannot be proven and the absence of risk can never be demonstrated***. No chemical, including imazapic, is studied for all possible effects. Furthermore, using data from laboratory animals to estimate hazard or the lack of hazard to humans is an uncertain process. Prudence dictates that normal and reasonable care should be taken in the handling of this or any other chemical. Notwithstanding these reservations, the use of imazapic in Forest Service programs does not pose any identifiable hazard to workers or members of the general public.

Irritation to the skin and eyes can result from exposure to relatively high levels of imazapic. From a practical perspective, eye or skin irritation is likely to be the only overt effect as a

consequence of mishandling imazapic. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of the compound.

ECOLOGICAL RISK ASSESSMENT

Hazard Identification

The available data suggest that larger mammals, such as dogs and rabbits, may be more sensitive to imazapic than smaller mammals such as mice and rats. Essentially no toxic effects have been observed in rats and mice even at very high dietary concentrations of imazapic over prolonged periods of time. The chronic NOAEL in rats is about 1133 mg/kg bw/day. In dogs, however, imazapic has been associated with effects on muscle, blood, and liver at a dietary NOAEL of 5000 ppm, corresponding to an average daily dose of about 150 mg/kg bw. In rabbits, increased mortality has been noted after gavage doses from 175 mg/kg bw/day to 700 mg/kg bw/day. The chronic toxicity of imazapic to birds is comparable to that in dogs with a LOAEL of 113 mg/kg bw/day and a NOAEL of 170 mg/kg bw/day. Only one bioassay is available on terrestrial invertebrates - i.e., the honey bee with an acute LD_{50} of greater than 1075 mg/kg bw.

The toxicity of imazapic to terrestrial plants has been assayed in both pre-emergence and post-emergence studies. In the pre-emergence study, no effects on emergence were noted for any plants [NOEC=0.064 lb/acre] except ryegrass [NOEC=0.032 lb/acre]. NOEC values for survival were also 0.064 lb/acre except for ryegrass, which evidenced an NOEC of 0.016 lb/acre. Imazapic was much more toxic in the post-emergence assay, with 21-day NOEC values for visual injury of 0.001 lb/acre for cabbage, cucumber, and tomato; 0.002 lb ai/acre for onion, oat, and radish; 0.004 lb/acre for ryegrass, 0.008 for soybean, 0.016 for corn, and 0.032 for lettuce.

Aquatic animals appear to be relatively insensitive to imazapic exposures, with LC_{50} values of >100 mg/L for both acute toxicity and reproductive effects. Aquatic macrophytes may be much more sensitive, with an acute EC_{50} of 6.1 µg/L in duck weed (*Lemna gibba*). Aquatic algae appear to be much less sensitive, with EC_{50} values of greater than 45 µg/L. No toxicity studies have been encountered on the effects of imazapic on amphibians or microorganisms.

Exposure Assessment

Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation. In acute exposure scenarios and under the assumption of 100% dermal absorption, the highest exposures for small terrestrial vertebrates will occur after a direct spray and could reach up to about 2 mg/kg under typical exposure conditions and up to about 5 mg/kg under more extreme conditions. Other routes of exposure, like the consumption of contaminated water or contaminated vegetation, generally will lead to much lower levels of exposure. In chronic exposure scenarios, the maximum estimated daily doses for a small vertebrate is 0.003 mg/kg/day. Based on general relationships of body size to body volume, larger vertebrates will be exposed to lower doses and smaller animals, like insects, will be exposed to much higher doses under comparable exposure conditions. Because of the apparently low

toxicity of imazapic to animals, the rather substantial variations in the exposure assessments have little impact on the assessment of risk to terrestrial animals.

The primary hazards to non-target terrestrial plants are associated with unintended direct deposition or spray drift. Unintended direct spray will result in an exposure level equivalent to the application rate. At least some plants that are sprayed directly with imazapic at or near the recommended range of application rates will be damaged. Based on a monitoring study involving a ground application with a hydraulic sprayer, no more than 0.001 of the application rate would be expected to drift 100 m offsite. Based on monitoring studies involving low-flight agricultural applications of various pesticides and employing various types of nozzles under a wide range of meteorological conditions, the central estimates of off-site drift for single swath applications, expressed as a proportion of the nominal application rate, are approximately 0.03 at 100 feet, 0.002 at 500 feet, 0.0006 at 1000 feet, and 0.0002 at 2500 feet. Estimates of off-site deposition also can be based on Stoke's Law. Using this method and assuming a wind velocity of no more than 5 miles/hour perpendicular to the line of application, 100 µ particles falling from 3 feet above the surface could drift as far as 23 feet. A raindrop or 400 µ particle applied at 6 feet above the surface could drift about 3 feet.

In order to encompass a wide range of field conditions, GLEAMS simulations were conducted for both clay, loam, and sand at annual rainfall rates from 5 to 250 inches and the typical application rate of 0.0624 lb a.i./acre. Under arid conditions (i.e., annual rainfall of about 10 inches or less), there is no runoff and degradation, not dispersion, accounts for the decrease of imazapic concentrations in soil. At higher rainfall rates, plausible offsite movement of imazapic results in runoff losses that range from about 0.01 to 0.45 of the application rate, depending primarily on the amount of rainfall rather than differences in soil type.

Exposures to aquatic species are impacted by the same factors that influence terrestrial plants except the directions of the impact are reversed. In other words, in very arid environments substantial contamination of water is unlikely. In areas with increasing levels of rainfall, exposures to aquatic organisms are more likely to occur. Thus, the anticipated concentrations in ambient water encompass a very broad range, 0.00003 to 0.0114 mg/L, depending primarily on differences in rainfall rates.

Dose-Response Assessment

For terrestrial mammals, the dose-response assessment is based on the same data as the human health risk assessment (i.e., an estimated NOAEL of 50 mg/kg/day based on a LOAEL of 150 mg/kg/day and the application of an uncertainty factor of 3 to extrapolated from the LOAEL to a NOAEL). All of the potential exposures of terrestrial mammals to imazapic are substantially below this NOAEL. Consequently, a dose of 50 mg/kg/day is used to assess the consequences of all exposures. The limited available data suggest that the sensitivity of birds and terrestrial invertebrates to imazapic is less than that of mammals. For birds, a NOAEL of 113 mg/kg bw/day is used from a subchronic feeding study that assayed for both signs of systemic toxicity as well as reproductive capacity. For terrestrial invertebrates, the dose-response assessment is based

on a single study in honey bees in which a topically applied dose of 387 mg/kg bw caused no statistically significant increase in mortality.

Imazapic is a herbicide that causes adverse effects in a variety of target and non-target plant species. For exposures associated with direct sprays or drift, functional application rates as low as 0.001 lbs a.i./acre could be associated with growth inhibition in sensitive species and rates as high as 0.032 lbs a.i./acre could be a NOAEL in more tolerant species. With respect to soil contamination, functional application rates of 0.016 lb a.i./acre are used as a NOAEL for the most sensitive endpoint (survival) in the sensitive species (ryegrass).

Imazapic has a low order of toxicity to fish and aquatic invertebrates and exposures of up to 100 mg/L are not likely to be associated with mortality or reproductive effects based on the available data. Aquatic macrophytes are much more sensitive to imazapic than fish or invertebrates. For aquatic plants, a concentration of 0.004 mg/L, very close to the EC_{25} in an aquatic macrophyte, is used to assess the consequences of imazapic exposure for this group. This is probably a conservative approach because at least some species of freshwater algae may be much more tolerant, with LC_{50} values greater than 0.045 mg/L.

Risk-Characterization

None of the hazard quotients for mammals or birds approach a level of concern, even at the upper limit of exposure, for either signs of systemic toxicity or reproductive effects. The data on terrestrial invertebrates are limited to a single bioassay in honey bees. Based on this information, nonetheless, there is no basis for asserting that plausible levels of exposure to imazapic are likely to be acutely toxic to terrestrial invertebrates. Thus, as in the human health risk assessment, there is not basis for asserting that the use of imazapic in Forest Service programs will be associated with adverse effects on terrestrial animals.

For terrestrial plants, neither runoff nor drift appear to present a major hazard to nontarget species. For runoff, the highest hazard quotients are associated with loam at rainfall rates greater than or equal to 200 inches per year. For sensitive species in areas with high rates of rainfall, the hazard quotients are slightly above unity - e.g., the highest hazard quotient is about 1.8. The level of exposure, however, is still below the LOAEL. In arid environments - i.e., annual rainfall rates of about 15 inches per year or less - runoff of imazapic would result in exposures that are far below a level of concern. Hazard quotients for offsite drift indicate that, for relatively tolerant species, there is no indication that imazapic is likely to result in damage at distances of 100 feet from the application site after either aerial or ground applications. For sensitive species, the hazard quotient for aerial applications at 100 feet offsite is about 2 but falls to about 0.1 at a distance of 500 feet. Thus, for some sensitive species, visual injury might be observed at distances of approximately 100 feet from the application site after aerial applications. No effects are likely to be observed after ground applications even for sensitive species.

For both the accidental spill scenario as well as estimates of imazapic in ambient water, the hazard quotients for aquatic animals lead to an unambiguous interpretation: there is no indication that

aquatic organisms will be exposed to harmful levels of imazapic under the conditions of use specified by the Forest Service.

Like terrestrial plants, aquatic plants, particularly macrophytes, are much more sensitive than aquatic animals to imazapic exposure. In the case of an accidental spill into a small body of water, hazard quotients range from 70 to over 700 based on sensitive aquatic macrophytes. Thus, while this exposure scenario is dominated by situational variability, it is plausible that the accidental spill of a substantial quantity of imazapic into a small body of water would lead to adverse effects on at least some aquatic plants. In the typical use of imazapic, however, the hazard quotients do not exceed the level of concern even under extremely conservative exposure assumptions - i.e., very high rates of rainfall and soil conditions that favor runoff. Thus, under normal and anticipated conditions of use, there is no indication that imazapic contamination of water will cause adverse effects even in sensitive aquatic macrophytes.

1. INTRODUCTION

The USDA Forest Service uses the herbicide, imazapic, in its vegetation management programs. Two commercial formulations, Plateau and Plateau DG, may be used by the Forest Service. The present document provides risk assessments for human health effects and ecological effects to support an assessment of the environmental consequences of using imazapic in Forest Service programs.

This document has four chapters, including the introduction, program description, risk assessment for human health effects, and risk assessment for ecological effects or effects on wildlife species. Each of the two risk assessment chapters has four major sections, including an identification of the hazards associated with imazapic, an assessment of potential exposure to this compound, an assessment of the dose-response relationships, and a characterization of the risks associated with plausible levels of exposure. These are the basic steps recommended by the National Research Council of the National Academy of Sciences (NRC 1983) for conducting and organizing risk assessments.

This is a technical support document and it addresses some specialized technical areas. Nevertheless an effort was made to ensure that the document can be understood by individuals who do not have specialized training in the chemical and biological sciences. Certain technical concepts, methods, and terms common to all parts of the risk assessment are described in plain language in a separate document (SERA 2000). Some of the more complicated terms and concepts are defined, as necessary, in the text.

The Forest Service has not conducted previous risk assessments on imazapic and no risk assessments on this compound have been published in the open literature. Moreover, almost all of the mammalian toxicology studies as well as ecotoxicology and environmental fate studies are unpublished reports submitted to the U.S. EPA as part of the registration process for this compound. The only studies on imazapic encountered in the published literature that relate to toxicologic effects involved field trials assessing the efficacy of imazapic for the control of various weed species (e.g., Grichar and Sestak 1998; Noldin et al. 1998; Taylor and Oliver 1997).

As part of the registration process, the U.S. EPA has conducted risk assessments on and other evaluations of the potential effects of this compound on humans and ecological species (U.S. EPA 1995a; U.S. EPA 1996a; U.S. EPA 1999a,b). These risk assessments have been consulted as part of this current risk assessment for the Forest Service.

Because of the lack of a detailed, recent review concerning imazapic and the preponderance of unpublished relevant data in U.S. EPA files, a complete search of the U.S. EPA files was conducted in the preparation of this risk assessment. Full text copies of the most relevant studies [n=95] were kindly provided by the U.S. EPA Office of Pesticide Programs. The studies were reviewed, and synopses of the most relevant studies are included in the appendices to this document.

The human health and ecological risk assessments presented in this document are not, and are not intended to be, comprehensive summaries of all of the available information. The information presented in the appendices and the discussions in chapters 2, 3, and 4 of the risk assessment are intended to be detailed enough to support a review of the risk analyses; however, they are not intended to be as detailed as the information generally presented in Chemical Background documents or other comprehensive reviews.

For the most part, the risk assessment methods used in this document are similar to those used in risk assessments previously conducted for the Forest Service as well as risk assessments conducted by other government agencies. Details regarding the specific methods used to prepare the human health risk assessment are provided in SERA (2000).

Risk assessments are usually expressed with numbers; however, the numbers are far from exact. *Variability* and *uncertainty* may be dominant factors in any risk assessment, and these factors should be expressed. Within the context of a risk assessment, the terms *variability* and *uncertainty* signify different conditions.

Variability reflects the knowledge of how things may change. Variability may take several forms. For this risk assessment, three types of variability are distinguished: *statistical*, *situational*, and *arbitrary*. *Statistical variability* reflects, at least, apparently random patterns in data. For example, various types of estimates used in this risk assessment involve relationships of certain physical properties to certain biological properties. In such cases, best or maximum likelihood estimates can be calculated as well as upper and lower confidence intervals that reflect the statistical variability in the relationships. *Situational variability* describes variations depending on known circumstances. For example, the application rate or the applied concentration of a herbicide will vary according to local conditions and goals. As discussed in the following section, the limits on this variability are known and there is some information to indicate what the variations are. In other words, *situational variability* is not random. *Arbitrary variability*, as the name implies, represents an attempt to describe changes that cannot be characterized statistically or by a given set of conditions that cannot be well defined. This type of variability dominates some spill scenarios involving either a spill of a chemical on to the surface of the skin or a spill of a chemical into water. In either case, exposure depends on the amount of chemical spilled and the area of skin or volume of water that is contaminated.

Variability reflects a knowledge or at least an explicit assumption about how things may change, while *uncertainty* reflects a lack of knowledge. For example, the focus of the human health dose-response assessment is an estimation of an “acceptable” or “no adverse effect” dose that will not be associated with adverse human health effects. For imazapic and for most other chemicals, however, this estimation regarding human health must be based on data from experimental animal studies, which cover only a limited number of effects. Generally, judgment is the basis for the methods used to make the assessment. Although the judgments may reflect a consensus (i.e., be used by many groups in a reasonably consistent manner), the resulting estimations of risk cannot be proven analytically. In other words, the estimates regarding risk involve uncertainty. The

primary functional distinction between variability and uncertainty is that variability is expressed quantitatively, while uncertainty is generally expressed qualitatively.

In considering different forms of variability, almost no risk estimate presented in this document is given as a single number. Usually, risk is expressed as a central estimate and a range, which is sometimes very large. Because of the need to encompass many different types of exposure as well as the need to express the uncertainties in the assessment, this risk assessment involves numerous calculations.

Most of the calculations are relatively simple, and the very simple calculations are included in the body of the document. Some of the calculations, however, are cumbersome. For those calculations, a set of worksheets is included as an attachment to the risk assessment. The worksheets provide the detail for the estimates cited in the body of the document. The worksheets are divided into the following sections: general data and assumptions, chemical specific data and assumptions, exposure assessments for workers, exposure assessments for the general public, and exposure assessments for effects on nontarget organisms.

2. PROGRAM DESCRIPTION

2.1. OVERVIEW

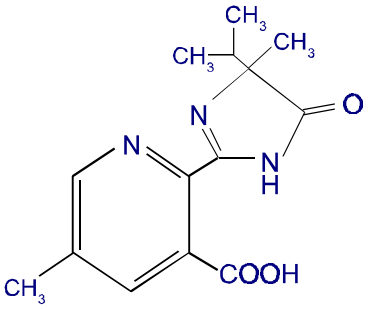
Imazapic is a herbicide that is used in the control of grasses, broadleaves, and vines, and for turf height suppression in noncropland areas. The Forest Service will typically use imazapic in grassland restoration. The Forest Service may use two commercial formulations of imazapic, Plateau and Plateau DG. Both of these formulation contain the ammonium salt of imazapic as the active ingredient. Plateau is a liquid formulation that contains imazapic (22.2%) at a concentration of 2 lbs per gallon and Plateau DG is a dispersible granule formulation that contains the ammonium salt of imazapic (70%).

Imazapic may be applied by directed foliar, broadcast foliar, or aerial methods. The most common method of application in Forest Service programs will involve broadcast foliar applications. For Plateau, the labeled application rates range from 2 to12 ounces of Plateau per acre, corresponding to 0.03125 to 0.1875 lbs imazapic/acre. For Plateau DG, the labeled application rates range from 1 to 2 water soluble pouches of Plateau DG per acre, corresponding to about 0.0625 to 0.1875 lbs imazapic per acre. The Forest Service will not use imazapic at the highest labeled application rate. The maximum rate that will be used in Forest Service programs is 4 oz/acre, corresponding to 0.0624 lb/acre.

Formulations of imazapic have not been used in past Forest Service programs and no information on the amount of imazapic used in other applications has been encountered. Information on the amount of imazapic that the Forest Service will apply in the future will be published by the Forest Service in standard annual reports that are available to the public.

2.2. CHEMICAL DESCRIPTION AND COMMERCIAL FORMULATIONS

Imazapic is the common name for (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1 *H*-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid and is identical to imazapyr with the addition of a methyl group on the pyridine ring:



Selected chemical and physical properties of imazapic are summarized in Table 2-1. Additional information is presented in worksheet B03.

Two commercial formulations of imazapic may be used in Forest Service programs, Plateau and Plateau DG, both produced by American Cyanamid and both containing the ammonium salt of imazapic. Plateau is a liquid formulation that contains imazapic (22.2%) at a concentration of 2 lbs per gallon and inerts (77.8%). Plateau DG is a dispersible granule formulation that contains the ammonium salt of imazapic (70%) and inerts (30%). Plateau and Plateau DG are recommended for the control of weeds, specifically grasses, broadleaves, and vines, and for turf height suppression in noncropland areas such as rights-of-way, fences rows, non-irrigation ditchbanks, and pipelines. Plateau and Plateau DG are not labeled for food or feed crops (American Cyanamid 1998c, 2000). The Forest Service will typically use imazapic in grassland restoration.

The identity of the inerts in the imazapic formulations are considered proprietary information; therefore, American Cyanamid does not identify the inerts on the general or supplemental product labels or material safety data sheets (American Cyanamid 1997, 1998c, 2000). This lack of disclosure indicates that none of the inerts present at a concentration of 0.1% or greater is classified as hazardous. Nonetheless, as discussed by Levine (1996), the testing requirements for inerts are less rigorous than the testing requirements for active ingredients (i.e., imazapic). The identity of the inerts has been disclosed to the U.S. EPA as part of the registration process (American Cyanamid 1998a,b; Birk 1999) and this information has been obtained and reviewed in the preparation of this risk assessment. Specific information on the inerts, however, cannot and are not disclosed in this risk assessment.

Information about the impurities in technical grade imazapic was submitted to the U.S. EPA (Birk 1999; Steller 1998) and reviewed during the preparation of this risk assessment. Since the identities of the impurities are considered proprietary by American Cyanamid, this information cannot be disclosed in this document. The potential impact of impurities on this risk assessment is discussed in section 3.

2.3. APPLICATION METHODS

Imazapic may be applied by directed foliar, broadcast foliar, or aerial methods. The most common method of application for imazapic in Forest Service programs will involve broadcast foliar applications. Broadcast foliar ground applications will most often involve the use of a two to six nozzle boom mounted on a tractor or other heavy duty vehicle. With this equipment, workers will typically treat 2 to 6 acres per hour, with the low end of this range representative of a four-wheel drive vehicle in tall grass and the upper end of the range representative of a large bulldozer. This rate of treatment is substantially lower than the typical rates used in herbicide applications - i.e., 11 to 21 acres/hour (USDA 1989b, p 2-9 to 2-10). For this risk assessment, the treatment rates of 2 to 6 acres per hour are used in worker exposure assessments to define the upper and lower limits of exposure and 4 acres per hour is used as a central value (Worksheet A03b).

In selective foliar applications, the herbicide sprayer or container is carried by backpack and the herbicide is applied to selected target vegetation. Application crews may treat up to shoulder high

brush, which means that chemical contact with the arms, hands, or face is plausible. To reduce the likelihood of significant exposure, application crews are directed not to walk through treated vegetation. Usually, a worker treats approximately 0.5 acre/hour with a plausible range of 0.25-1.0 acre/hour (Worksheet A03a).

Plateau, but not Plateau DG, is registered for aerial applications by fixed-wing aircraft or helicopter (American Cyanamid 1998c, 2000). In Forest Service programs, aerial applications for imazapic would be restricted to helicopter only. Plateau is applied under pressure through specially designed spray nozzles and booms. The nozzles are designed to minimize turbulence and maintain a large droplet size, both of which contribute to a reduction in spray drift. In aerial applications, approximately 40-100 acres may be treated per hour (Worksheet A03c).

2.4. MIXING AND APPLICATION RATES

For Plateau, the labeled application rates range from 2 to12 ounces of Plateau/acre. This corresponds to about 0.015625 to 0.09375 gallons [128 ounces per gallon] of Plateau per acre which in turn corresponds to about 0.03125 to 0.1875 lbs imazapic a.e. per acre [2 lbs a.e. per gallon × 0.015625 to 0.09375 gallons/acre]. For Plateau DG, the labeled application rates range from 1 to 2 water soluble pouches of Plateau DG/acre. Since each water soluble pouch contains 0.0625 lbs imazapic a.e., this corresponds to about 0.0625 to 0.1875 lbs imazapic a.e. per acre. The Forest Service will not use imazapic at the highest labeled application rate. The maximum rate that will be used in Forest Service programs is 4 oz/acre, corresponding to 0.03125 gallons/acre or 0.0624 lb a.e./acre.

For this risk assessment, the lower and upper limits of the application rate are 0.03125 and 0.0624 lbs a.e./acre, respectively, based on the lower limit of the labeled rates and the upper limit that has been set by the Forest Service. Because of the narrow range of application rates that the Forest Service plans on using, the typical application rate will also be taken as 0.0624 lb a.e./acre.

Mixing volumes for imazapic vary only modestly depending on the type of vegetation to be treated as well as the application method. For ground applications of Plateau and Plateau DG, 2 to 10 gallons of water per acre are recommended (American Cyanamid 1998c; American Cyanamid 2000). For aerial applications, 5 or more gallons of water are recommended (American Cyanamid 2000).

For this risk assessment, the extent to which a formulation of imazapic is diluted prior to application primarily influences dermal and direct spray scenarios, both of which are dependent on ‘field dilution’(i.e., the concentration of imazapic in the applied spray). In all cases, the higher the concentration of imazapic - equivalent to the lower dilution of imazapic - the greater the risk. For this risk assessment, the lowest dilution is taken as 2 gallons/acre, the minimum recommended for ground applications. The highest dilution is based on 10 gallons of water per acre, the highest application volume specifically recommended for ground applications. This range encompasses the range of concentrations that might be used in aerial applications. A typical dilution rate is taken as 6 gallons/acre, the arithmetic mean of the range. Details regarding the calculation of field

dilution rates are given in worksheet B01, and the calculations following this worksheet are summarized in worksheet B02.

In addition to dilution rates, the area that the Forest Service might treat has a major impact on the estimates of concentrations of imazapic that could occur in ambient water. Most standard Forest Service risk assessments involve a very conservative chronic exposure scenario for a 10-acre rights-of-way (435,600 sq. ft.) with dimensions of 50 feet wide and 8712 feet long that is assumed to run next to a 10-acre pond that is 1 meter deep. For imazapic, rights-of-way maintenance is not a primary use in Forest Service programs. An alternative chronic exposure scenario for this compound involves the treatment of a 100 acre block - i.e., 4,356,000 sq. ft. with dimensions of approximately 2087 feet by 2087 feet - that is adjacent to a 10-acre pond that is 1 meter deep. This is a more conservative exposure scenario - i.e., will result in higher estimates of concentrations in ambient water - and better represents the types of applications that could be made by the Forest Service. In any such application, however, the Forest Service would employ a buffer area between the application site and any body of standing water. For this risk assessment, a buffer zone is not quantitatively considered in the exposure assessment. The consequences of this approach on the interpretation of the risk assessment are detailed in the risk characterizations for human health (Section 3.4) and ecological effects (Section 4.4).

2.5. USE STATISTICS

Formulations of imazapic have not been used in past Forest Service programs and no information on the amount of imazapic used in other applications has been encountered. Thus, at this time, it is not possible to estimate reliably the amount of imazapic that the Forest Service might use each year. As these statistics become available, they will be published by the Forest Service in standard annual reports that are available to the public.

Table 2-1. Selected physical and chemical properties of imazapic.

Synonyms	AC 263,222, CL 263,222, Imazameth
U.S. EPA Reg. No.	241-365
Commercial Formulations	Plateau, Plateau DG, Contend
CAS number	104098-48-8 (ammonium salt) (American Cyanamid, 1997) 81334-60-3 (acid) (Birk 1999)
Molecular weight	275.31 (SRC 2000)
Specific Gravity	1.07-1.09 g/mL (American Cyanamid, 1997)
Appearance, ambient	clear liquid, pale yellow to green color (American Cyanamid, 1997)
Vapor pressure (mm Hg)	not available (American Cyanamid, 1997)
pH	6.4-7.0 (American Cyanamid, 1997)
Water solubility (mg/L)	miscible (American Cyanamid, 1997) >2670 mg/L (Barker et al. 1998a) 36,000 mg/L at pH 7 and 25°C (Mangels. 1992, U.S. EPA 1995) 2,150 mg/L at pH 5 and 25°C (Mangels. 1992)
log $K_{o/w}$	2.47 (experimental) (SRC 2000)
Soil adsorption, K_d (L/kg)	0.13 to 4.07 (U.S. EPA 1995) 0.13 to 4.05 (Mangels 1992)
Soil sorption, $K_{o/c}$	260 to 8140 (U.S. EPA 1995) 7 to 267 (Mangels 1992)
Field dissipation half-time (days)	256 days (prairiegrass) (Salzman and Nejad 1998, p.24) 410 days (bareground) (Salzman and Nejad 1998, p.24) 31 days (bareground) (Schaefer et al. 1994)
Foliar half-time (days)	<7 days (bermudagrass) (Hallman and Leonard 1999)
Soil half-time (days)	106 days (photolysis)(Ta 1994) 113 days (aerobic soil metabolism, sandy loam) (Ta 1997)
Anaerobic sediment (aqueous) half-time (days)	2440 days (Madsen 1993).
Water half-time (days)	30 (U.S. EPA 1995)

3. HUMAN HEALTH RISK ASSESSMENT

3.1. HAZARD IDENTIFICATION

3.1.1. Overview. In experimental mammals, the acute oral LD_{50} for imazapic is greater than 5000 mg/kg, which indicates a low order of acute toxicity. Nevertheless, oral doses as low as 175 mg/kg bw/day were associated with increases in maternal mortality in a multiple dose study designed to assess the potential of imazapic to cause birth defects. While it is not clear if the maternal mortality at 175 mg/kg bw/day was attributable to the chemical or experimental dosing errors, a somewhat higher dose of 700 mg/kg bw/day was clearly associated with increased mortality attributed to the toxicity of imazapic.

Imazapic does not appear to be toxic to experimental rodents at relatively high concentrations in the diet but is toxic to dogs, causing adverse effects on muscle, blood, and liver. The NOAEL in rats is about 1625 mg/kg bw in the 13-week study or 1133 mg/kg bw in the 2-year study. Dogs, however, appear to be more sensitive than rodents, and the major signs of toxicity include adverse effects on the muscle, blood, and liver. Doses as low as 150 mg/kg bw have been associated with treatment related effects on skeletal muscle.

In several standard tests required for pesticide registration, imazapic has failed to show any indication of adverse effects on development or reproduction and no carcinogenic or mutagenic activity.

As discussed in the exposure assessment, skin absorption is the primary route of exposure for workers. Data regarding the dermal absorption kinetics of imazapic are not available in the published or unpublished literature. For this risk assessment, estimates of dermal absorption rates—both zero order and first order—are based on quantitative structure-activity relationships. These estimates of dermal absorption rates are used in turn to estimate the amounts of imazapic that might be absorbed by workers, which then are used with the available dose-response data to characterize risk. The lack of experimental data regarding dermal absorption of imazapic adds uncertainty to this risk assessment. Uncertainties in the rates of dermal absorption, however, can be expressed quantitatively in the regression equation used to estimate dermal absorption rates and this uncertainty is incorporated in the human health exposure assessment.

Based on standard studies required for pesticide registration, imazapic appears to be essentially non-irritating and non-sensitizing to the skin and minimally irritating to the eyes. Concentrations of imazapic in the air that would be much higher than any plausible concentrations in human exposure scenarios have been associated with lung congestion in rats. The potential inhalation toxicity of imazapic is not of substantial concern to this risk assessment because of the implausibility of inhalation exposure involving high concentrations of this compound.

3.1.2. Acute Toxicity. Other than standard bioassays for acute toxicity that were conducted as part of the registration process, little information is available on the acute toxicity of imazapic. The most common measure of acute oral toxicity is the LD_{50}, the estimate of a dose that is most

likely to cause 50% mortality in the test species after a single oral dose. As summarized in Appendix 1, two acute oral studies on imazapic are available: Lowe (1992) and Fischer (1993). In both of these studies a single oral dose of 5000 mg/kg caused no mortality or other signs of toxicity in groups of five male and female rats. Because the acute oral LD_{50} for this compound is thus over 5,000 mg/kg, the U.S. EPA (1996a) classified imazapic as Risk Category IV: no hazard from acute oral exposure.

As discussed in Section 3.1.4, rabbits may be more sensitive to imazapic than rats. In a teratology study, mortality rates of 15% to 55% were noted in dams given imazapic by gavage at doses of 175 mg/kg bw/day to 700 mg/kg bw/day on days 7 to 19 of gestation (MacKenzie 1992).

3.1.3. Subchronic or Chronic Systemic Toxic Effects. No studies have been published on the subchronic or chronic toxicity of imazapic to humans or mammals. Four unpublished studies have been submitted to the U.S. EPA to support the registration of imazapic. As summarized in Appendix 1, there is one subchronic (13-week) study in rats (Fischer 1992), a chronic (1-year) study in dogs (Wolford 1993), chronic (2-year) studies in rats (Fischer 1994a) and mice (Fischer 1994b). Imazapic does not appear to be toxic to experimental rodents at relatively high concentrations in the diet (except in pregnant rabbits) but is toxic to dogs, causing adverse effects on muscle, blood, and liver.

No signs of toxicity were observed in studies on rats or mice at the highest doses tested - i.e., 20,000 ppm or approximately 1625 mg/kg bw in the 13-week study or 1133 mg/kg bw in the 2-year study in rats and 7,000 ppm or about 1288 mg/kg bw in the 2-year study in mice.

Dogs, however, appear to be more sensitive than rodents. At the highest dose tested - 40,000 ppm in the diet over a period of one year, corresponding to about 1000 mg/kg bw/day - signs of toxicity in dogs included adverse effects on the blood and bone marrow, muscular degeneration, as well as biochemical markers of liver toxicity. Similar but less severe effects were observed at 20,000 ppm corresponding to about 500 mg/kg bw. Even at the lowest dose tested, 5000 ppm in the diet corresponding to about 150 mg/kg bw, treatment related effects were observed on skeletal muscle. While these effects were not considered adverse by Wolford (1993), the U.S. EPA (1996) classified the 5000 ppm exposure as a LOAEL. As discussed in Section 3.3., the U.S. EPA (1996) derived an RfD for imazapic based on this study in dogs.

3.1.4. Reproductive and Teratogenic Effects. Imazapic has been tested for its ability to cause birth defects (i.e., teratogenicity) as well as its ability to cause reproductive impairment. Teratogenicity studies typically entail gavage administration to pregnant rats or rabbits on specific days of gestation. Two such studies (each of which is detailed in Appendix 1) were conducted on imazapic: one in rats (Schardein 1992) and one in rabbits (MacKenzie 1992). No signs of maternal toxicity, teratogenicity or fetal toxicity were noted in the rat study at the highest dose tested - i.e., 1000 mg/kg/day.

In the rabbit study, maternal mortality was noted at all tested dose levels: 20% mortality at 175 mg/kg bw, 25% mortality at 350 mg/kg bw, 25% mortality at 500 mg/kg bw, and 60% mortality at 700 mg/kg bw compared to a control group mortality of 5% (MacKenzie 1992). The U.S. EPA (1996, p. 7) asserts that the mortalities in the control group and all dose groups below 700 mg/kg bw were due to gavage error rather than toxicity. The basis for this assertion is unclear but it is a common experience in gavage studies that pulmonary intubation, leading to death, can occur. The study reports that: *All treated animals that died during the study had one or a combination of the following effects: oral discharge, nasal discharge, fluid-filled trachea and or lungs, reddened trachea, and stomach lesions.* The study does not specify whether or not the animal that died in the control group evidenced these signs of toxicity. In any event, no dose-related developmental abnormalities were observed in any dose groups. Because of the high mortality at 700 mg/kg bw, the U.S. EPA (1996) set the fetal NOAEL at 500 mg/kg bw, identical to their assessment of the NOAEL for maternal toxicity.

Another type of reproduction study involves exposing more than one generation of the test animal to the compound. One such study (Schroeder 1994) was conducted on imazapic. In this study, 56 day old Sprague-Dawley rats were given imazapic in the diet at concentrations of 0, 5000, 10,000, or 20,000 ppm and were allowed to mate. The F1 generation was similarly exposed to imazapic in the diet for 14 weeks and allowed to mate. No signs of toxicity in either the parental or F1 generation were observed and there was no indication of any effect on reproductive performance (Schroeder 1994). Based on measured food consumption, the NOAEL of 20,000 ppm corresponded to daily doses of approximately 1,200 to 1,700 mg/kg bw/day. This is consistent with the NOAEL values noted for rats in subchronic and chronic toxicity studies - i.e., 1133 mg/kg bw in the 2-year study and 1625 mg/kg bw in the 13-week study (Section 3.1.3).

3.1.5. Carcinogenicity and Mutagenicity. The two-year feeding studies in rats (Fischer 1994a) and mice (Fischer 1994b), discussed in Section 3.1.3 and summarized in detail in Appendix 1, involved complete histopathology in order to assess the potential carcinogenicity of imazapic. No statistically significant increase in any tumor type was found in either study. As reviewed by U.S. EPA (1996), imazapic was also negative in four assays for mutagenicity: reverse mutation assays with *Salmonella typhimurium*, the rat bone marrow in vivo cytogenetic assay, the *in vitro* Chinese hamster ovary assay, and the induction of forward mutations in Chinese hamster ovary cells. Thus, there is no basis for asserting that exposures to imazapic are likely to be associated with a carcinogenic risk. Based on this information, the U.S. EPA (1996) concluded that:

> *...the chemical [imazapic] should be classified as "**Group E**", evidence of non-carcinogenicity for humans; i.e. the chemical is **not likely** to be carcinogenic to humans via relevant routes of exposures. ... It should be noted, however, that the designating of an agent as being in Group E is based on the available evidence and should not be interpreted as a definitive conclusion that the agent will not be a carcinogen under any circumstances.*

3.1.6. Effects on the Skin and Eyes.
When applied directly and repeatedly to the skin, technical grade imazapic did not cause skin irritation or sensitization to guinea pigs (Costello 1992; Reilly 1992). When applied to the skin of rabbits for four hours, erythema was barely perceptible after one hour in 2/6 animals. No effect was apparent after 24 hours in any treated animal (Lowe 1993b). Similarly, when instilled directly into the eyes of rabbits and allowed to remain for 24 hours, 4/6 animals had slight redness of the conjunctivae after 1 hours and this effect was reversed at 24 hours (Fischer 1987c). In a second similarly designed study (Lowe 1993a), somewhat greater irritation was observed including corneal opacity, slight conjunctival irritation, and slight chemosis in some animals after 48 hours. No effects were apparent after 72 hours.

Based on these studies, the U.S. EPA (1996, p. 4) has classified imazapic as non-irritating (Category IV) to the skin of rabbits, non-sensitizing to the skin of guinea pigs, and minimally irritating to the eyes of rabbits (Category III).

3.1.7. Systemic Toxic Effects from Dermal Exposure. Most of the occupational exposure scenarios and many of the exposure scenarios for the general public involve the dermal route of exposure. For these exposure scenarios, dermal absorption is estimated and compared to an estimated acceptable level of oral exposure based on subchronic or chronic toxicity studies. Thus, it is necessary to assess the consequences of dermal exposure relative to oral exposure and the extent to which imazapic is likely to be absorbed from the surface of the skin.

The available toxicity studies summarized in Appendix 1 indicate that dermal exposures to single acute doses of up to 5000 mg/kg imazapic were below the LD_{50} for rabbits (Fischer 1987a; Lowe 1993b,c; Moore 1992). No signs of systemic toxicity were reported in any of the test animals.

The kinetics of dermal absorption of imazapic are not documented in the open literature and no studies on the kinetics of dermal absorption have been submitted to U.S. EPA. Such studies are not required for pesticide registration.

As detailed in SERA (2000), dermal exposure scenarios involving immersion or prolonged contact with chemical solutions use Fick's first law and require an estimate of the permeability coefficient, K_p, expressed in cm/hour. Using the method recommended by U.S. EPA (1992), the estimated dermal permeability coefficient for imazapic is 0.0000722 cm/hour with a 95% confidence interval of 0.0000385 to 0.0001354 cm/hour. The details of the U.S. EPA (1992) method for estimating K_p based on the molecular weight and octanol-water partition coefficient are given in worksheet A07b. The application of this method to imazapic is detailed in worksheet B05. The estimated K_p is used in all exposure assessments in this document that are based on Fick's first law.

For exposure scenarios like direct sprays or accidental spills, which involve deposition of the compound on the skin's surface, dermal absorption rates (proportion of the deposited dose per unit time) rather than dermal permeability rates are used in the exposure assessment. Using the

methods detailed in SERA (2000), the estimated first-order dermal absorption coefficient is 0.00109 $hour^{-1}$ with 95% confidence intervals of 0.00044 to 0.0027 $hour^{-1}$. The details of the method specified in SERA (2000) for estimating the first-order dermal absorption coefficient based on the molecular weight and octanol-water partition coefficient are given in worksheet A07a. The application of this method to imazapic is detailed in worksheet B04.

The lack of experimental data regarding the dermal absorption of imazapic adds uncertainty to this risk assessment. Nonetheless, the available data, albeit relatively sparse, do not suggest that imazapic is likely to be absorbed through the skin in amounts that may cause systemic toxic effects. This is detailed further in the risk characterization. Uncertainties in the rates of dermal absorption, although they are substantial, can be estimated quantitatively and are incorporated in the human health exposure assessment (Section 3.2).

3.1.8. Inhalation Exposure. As summarized in Appendix 1, there are two inhalation toxicity studies on imazapic (Hershman 1993a,b). Both studies follow a relatively standard protocol involving acute (4-hour) exposure of rats to relatively high concentrations ranging from 2.38 mg/L (2,380 mg/m^3) to 4.83 mg/L (4,830 mg/m^3). The second study (Hershman 1993b) was apparently conducted in response to initial concerns from U.S. EPA (1996) that the particle size in the study by Hershman 1993a - i.e., median aerodynamic diameter of 6.47 to 8.28 μm - was too large. The study by Hershman (1993b) involved a particle size of 1.97μm. In any event, no mortality or gross tissue pathology was observed in either study.

These extremely limited data suggest only that imazapic can induce irritant effects and perhaps systemic toxic effects at very high exposure levels. As discussed in Section 3.3, this finding is not directly relevant to this risk assessment because of the implausibility of exposure to such high concentrations of the compound.

3.1.9. Impurities, Metabolites, and Formulation Additives.

3.1.9.1. Impurities -- There is no published information regarding the impurities in technical grade imazapic or any of its commercial formulations. Information on all of the impurities in technical grade imazapic were disclosed to the U.S. EPA (Birk 1999), and the information was obtained and reviewed as part of this risk assessment. Because this information is classified as confidential business information, details about the impurities cannot be disclosed. Nonetheless, all of the toxicology studies on imazapic involve technical imazapic, which is presumed to be the same as or comparable to the active ingredient in the formulation used by the Forest Service. Thus, if toxic impurities are present in technical imazapic, they are likely to be encompassed by the available toxicity studies using technical grade imazapic.

3.1.9.2. Metabolites -- The metabolism of imazapic was studied in rats (Cheng 1993), hens (Afzal 1994; Gatterdam. 1993a,b) and goats (Kao 1993a,b; Sharp and Thalacker 1999). All of these studies were submitted to the U.S. EPA but have not been published in the open literature. The studies on hens are discussed in Section 4.1.3, toxicity to birds. While information on the toxicity of the metabolites of imazapic is limited, all toxicity studies used quantitatively in this risk

assessment (Section 3.3) involved *in vivo* exposures and thus the potential toxicity of the metabolites is encompassed by these studies.

In rats, oral and intravenous studies were conducted using ^{14}C-labeled imazapic. The compound is readily absorbed after oral exposure (95%) and virtually completely excreted, mostly as parent compound, in the urine with greater than 50% elimination within 6 hours of dosing. Less than 3.5% of the administered dose is excreted in the feces (Cheng 1993).

In the goat metabolism study by Kao (1993a,b), 3 goats were exposed to ^{14}C-imazapic at doses of 0, 3.76 and 15.1 mg in gelatin capsules for seven consecutive days. These levels were considered to be 0, 33X, and 197X of maximum residue that foraging animals would likely receive in the diet. The limits of detection for imazapic were 0.02 ppm in fat and 0.01 ppm for milk, blood, tissues, and feces. Daily blood and milk residues were below the limits of detection as were all tissue concentrations with the exception of the kidney: 0.01 ppm at the low dose and 0.05 ppm at the high dose. Urine accounted for 67.2% and 94% of the excretion and feces for 7% and 9.6% of the excretion at the low and high doses, respectively. Residues from the kidney consisted of 30% parent compound. The urine contained essentially all unchanged parent compound. In the feces, 58% of the residues consisted of the parent compound. The major metabolite was characterized as a hydroxymethyl analog in feces that accounted for 10% of residue. In a separate study on this metabolite (Kao 1994), the metabolite was found to be excreted mainly in the feces and not detectable in milk samples.

Sharp and Thalacker (1999) studied the metabolism of imazapic in one lactating goat. Most of the imazapic was eliminated in the urine (81.7%) with lesser amounts in the feces (6.57%) and very little (0.03%) in milk. The total recovered in edible tissues and blood was 0.01%. As in the rats, elimination was rapid with 75% excreted in 24 hours following each dose.

3.1.9.3. Inerts -- Plateau and Plateau DG, the commercial formulations of imazapic used by the Forest Service, contains materials other than imazapic that are included as adjuvants to improve either efficacy or ease of handling and storage. The identity of these materials is confidential. The additives were disclosed to the U.S. EPA (American Cyanamid Company 1998a,b) and were reviewed in the preparation of this risk assessment. All that can be disclosed explicitly is that none of the additives is classified by the U.S. EPA as toxic. This is consistent with the MSDS for Plateau (American Cyanamid Company 1997) that does not disclose the occurrence of toxic inerts in the formulation.

As reviewed by Levine (1996), testing requirements for pesticide inerts that have been used as additives or adjuvants for many years are minimal, and this is a general problem in many pesticide risk assessments. For new inerts, the U.S. EPA does require more extensive testing (Levine 1996).

3.1.10. Toxicological Interactions. American Cyanamid Company (1996) has suggested combinations of imazapic with glyphosate for the control of tall fescue and this combination may

be considered by the Forest Service. No information on the potential interactions of imazapic and glyphosate have been encountered in the published literature or U.S. EPA files.

Acute studies have been submitted to the U.S. EPA involving mixtures of imazapic with 2,4-D by oral (Lowe 1999); ocular (Boczon 1999a), dermal (Boczon 1999b,c), and inhalation (Hoffman 1999) exposures. A detailed review of these studies is beyond the scope of the current assessment. These studies have been reviewed but are not detailed in Appendix 1. It is apparent, however, that the toxicity of mixtures of imazapic and 2,4-D are more toxic and irritating than imazapic alone. This is not to suggest, however, that these two compounds display a toxicologic interaction. For example, the acute oral LD_{50} of an approximately 1:3:1 mixture of imazapic:2,4-D:inerts is about 3,066 mg/kg bw for male rats. Given that 2,4-D was about 60% of the mixture, the LD_{50} expressed as 2,4-D is about 1840 mg/kg [3,066 mg/kg × 0.6]. As summarized in the SERA risk assessment on 2,4-D (SERA 1998), the acute oral LD_{50} of 2,4-D in rats is about 1800 mg/kg. Thus, while the imazapic:2,4-D mixture is more toxic than imazapic alone, the data on the mixture are consistent with the assumption that the toxicity of the mixture is attributable entirely to 2,4-D with no indication of any toxic interaction. This is consistent with the very low oral toxicity of imazapic as summarized in Section 3.2.

3.2. EXPOSURE ASSESSMENT

3.2.1. Overview. There are no occupational exposure studies in the available literature that are associated with the application of imazapic. Consequently, worker exposure rates are estimated from an empirical relationship between absorbed dose per kilogram of body weight and the amount of chemical handled in worker exposure studies on nine different pesticides (SERA 2000). Separate exposure assessments are given for broadcast ground spray (boom spray), backpack, and aerial applications.

For all three types of applications, central estimates of worker exposure are similar: about 0.0003 mg/kg/day for broadcast ground spray, 0.0008 mg/kg/day for backpack applications, and 0.001 mg/kg/day for aerial applications. The upper limits of the exposure estimates are about 0.003 mg/kg/day for broadcast ground spray, 0.005 mg/kg/day for backpack applications, and 0.005 mg/kg/day for aerial applications. Using a different methodology, the U.S. EPA (1996a, p. 18) has estimated occupational exposures for boom spray workers to range from 0.0000038 to 0.004 mg/kg/day. This is very close to the range of about 0.000004 to 0.003 mg/kg/day for boom spray workers estimated in this risk assessment.

Except in the case of accidental exposures, the levels of imazapic to which the general public might be exposed should be far less than the levels for workers. Longer-term exposure scenarios for the general public lead to central estimates of daily doses in the range of about 0.00000001 to 0.00002 mg/kg/day with upper limits of exposure in the range of 0.000001 to 0.0005 mg/kg/day. While these exposure scenarios are intended to be conservative, they are nonetheless plausible. Accidental exposure scenarios result in central estimates of exposure of up to 0.071 mg/kg/day with upper ranges of 0.34 mg/kg/day. All of the accidental exposure scenarios involve relatively

brief periods of exposure, and most should be regarded as extreme, some to the extent of limited plausibility.

3.2.2. Workers. A summary of the exposure assessments for workers is presented in Table 3-1. Two types of exposure assessments are considered: general and accidental/incidental. The term *general* exposure assessment is used to designate those exposures that involve estimates of absorbed dose based on the handling of a specified amount of a chemical during specific types of applications. The accidental/incidental exposure scenarios involve specific types of events that could occur during any type of application. Details regarding all of these exposure assessments are presented in the worksheets that accompany this risk assessment, as indicated in Table 3-1.

3.2.2.1. General Exposures **--** The assumptions used in worker exposure assessments are detailed in worksheets A03a (backpack), A03b (boom spray), and A03c (aerial). No worker exposure studies with imazapic were found in the literature. As described in SERA (2000), worker exposure rates are expressed in units of mg of absorbed dose per kilogram of body weight per pound of chemical handled. These exposure rates are based on worker exposure studies on nine different pesticides with molecular weights ranging from 221 to 416 and log K_{ow} values at pH 7 ranging from -0.75 to 6.50. The estimated exposure rates are based on estimated absorbed doses in workers as well as the amounts of the chemical handled by the workers (Rubin et al. 1998, Table 2). As summarized in Table 2-1 of this risk assessment, the molecular weight of imazapic is 275.31 and the log K_{ow} at pH 7 is about 2.47. Thus, both of these values are within the range of values used in the empirical relationships for worker exposure. As described in SERA (2000), the ranges of estimated occupational exposure rates vary substantially among individuals and groups, (i.e., by a factor of 50 for backpack applicators and a factor of 100 for mechanical ground sprayers). While this adds substantial uncertainty to the exposure assessment, this variability has little practical impact on this risk assessment because even the upper limits of exposure are below levels of concern (Section 3.4.2).

Except for hydraulic ground spray workers, the estimated number of acres treated per hour is taken from previous USDA risk assessments (USDA 1989a,b,c). As noted in Section 2.2, it is estimated that hydraulic ground spray workers will typically treat 2 to 6 acres per hour. Although this rate of treatment is substantially lower than the typical rates used in herbicide ground broadcast applications - i.e., 11 to 21 acres/hour (USDA 1989b, p 2-9 to 2-10) - these lower values are better estimates of plausible treatment rates for imazapic given the types of equipment that will be used and the areas that will be treated.

The number of hours worked per day is expressed as a range, the lower end of which is based on an 8-hour work day with 1 hour at each end of the work day spent in activities that do not involve herbicide exposure. The upper end of the range, 8 hours per day, is based on an extended (10-hour) work day, allowing for 1 hour at each end of the work day to be spent in activities that do not involve herbicide exposure.

It is recognized that the use of 6 hours as the lower range of time spent per day applying herbicides is not a true lower limit. It is conceivable and perhaps common for workers to spend much less time in the actual application of a herbicide if they are engaged in other activities. Thus, using 6 hours can be regarded as conservative. In the absence of any published or otherwise documented work practice statistics to support the use of a lower limit, this conservative approach is used.

The range of acres treated per hour and hours worked per day is used to calculate a range for the number of acres treated per day. For this calculation as well as others in this section involving the multiplication of ranges, the lower end of the resulting range is the product of the lower end of one range and the lower end of the other range. Similarly, the upper end of the resulting range is the product of the upper end of one range and the upper end of the other range. This approach is taken to encompass as broadly as possible the range of potential exposures.

The central estimate of the acres treated per day is taken as the arithmetic average of the range. Because of the relatively narrow limits of the ranges for backpack and boom spray workers, the use of the arithmetic mean rather than some other measure of central tendency, like the geometric mean, has no marked effect on the risk assessment.

The range of application rates and the typical application rate are taken directly from the program description (see Section 2.4): 0.0624 lb a.e./acre with a range from 0.03125 to 0.0624 lbs a.e./acre. As detailed in Section 2, the central estimate of 0.0624 lb a.e./acre is also the upper limit currently proposed for Forest Service programs. Because of the very narrow range in application rates - i.e., a factor of about 2 - the calculation of a separate 'central' estimate for the application rate does not seem justified and the upper end of the range is used.

As detailed in worksheets C01a though C01c, the central estimate of the amount handled per day is calculated as the product of the central estimates of the acres treated per day and the application rate. The ranges for the amounts handled per day are calculated as the product of the range of acres treated per day and the range of application rates. Similarly, the central estimate of the daily absorbed dose is calculated as the product of the central estimate of the exposure rate and the central estimate of the amount handled per day. The ranges of the daily absorbed dose are calculated as the range of exposure rates and the ranges for the amounts handled per day. The lower and upper limits are similarly calculated using the lower and upper ranges of the amount handled, acres treated per day, and worker exposure rate.

3.2.2.2. Accidental Exposures -- Typical occupational exposures may involve multiple routes of exposure (i.e., oral, dermal, and inhalation); nonetheless, dermal exposure is generally the predominant route for herbicide applicators (van Hemmen 1992). Typical multi-route exposures are encompassed by the methods used in Section 3.2.2.1 on general exposures. Accidental exposures, on the other hand, are most likely to involve splashing a solution of herbicides into the eyes or to involve various dermal exposure scenarios.

Imazapic can cause mild irritant effects to the skin and eyes (see Section 3.1.6). The available literature does not include quantitative methods for characterizing exposure or responses associated with splashing a solution of a chemical into the eyes; furthermore, there appear to be no reasonable approaches to modeling this type of exposure scenario quantitatively. Consequently, accidental exposure scenarios of this type are considered qualitatively in the risk characterization (Section 3.4).

There are various methods for estimating absorbed doses associated with accidental dermal exposure (U.S. EPA 1992, SERA 2000). Two general types of exposure are modeled: those involving direct contact with a solution of the herbicide and those associated with accidental spills of the herbicide onto the surface of the skin. Any number of specific exposure scenarios could be developed for direct contact or accidental spills by varying the amount or concentration of the chemical on or in contact with the surface of the skin and by varying the surface area of the skin that is contaminated.

For this risk assessment, two exposure scenarios are developed for each of the two types of dermal exposure, and the estimated absorbed dose for each scenario is expressed in units of mg chemical/kg body weight. As specified in Table 3-1, the details of these exposure estimates are presented in the worksheets appended to this risk assessment.

Exposure scenarios involving direct contact with solutions of the chemical are characterized by immersion of the hands for 1 minute or wearing contaminated gloves for 1 hour. Generally, it is not reasonable to assume or postulate that the hands or any other part of a worker will be immersed in a solution of a herbicide for any period of time. On the other hand, contamination of gloves or other clothing is quite plausible. For these exposure scenarios, the key element is the assumption that wearing gloves grossly contaminated with a chemical solution is equivalent to immersing the hands in a solution. In either case, the concentration of the chemical in solution that is in contact with the surface of the skin and the resulting dermal absorption rate are essentially constant.

For both scenarios (the hand immersion and the contaminated glove), the assumption of zero-order absorption kinetics is appropriate. Following the general recommendations of U.S. EPA (1992), Fick's first law is used to estimate dermal exposure.

Exposure scenarios involving chemical spills on to the skin are characterized by a spill on to the lower legs as well as a spill on to the hands. In these scenarios, it is assumed that a solution of the chemical is spilled on to a given surface area of skin and that a certain amount of the chemical adheres to the skin. The absorbed dose is then calculated as the product of the amount of the chemical on the surface of the skin (i.e., the amount of liquid per unit surface area multiplied by the surface area of the skin over which the spill occurs and the concentration of the chemical in the liquid) the first-order absorption rate, and the duration of exposure. For both scenarios, it is assumed that the contaminated skin is effectively cleaned after 1 hour. As with the exposure assessments based on Fick's first law, this product (mg of absorbed dose) is divided by body

weight (kg) to yield an estimated dose in units of mg chemical/kg body weight. The specific equation used in these exposure assessments is taken from SERA (2000).

3.2.3. General Public.

3.2.3.1. General Considerations -- Under normal conditions, members of the general public should not be exposed to substantial levels of imazapic. Nonetheless, any number of exposure scenarios can be constructed for the general public, depending on various assumptions regarding application rates, dispersion, canopy interception, and human activity. Several highly conservative scenarios are developed for this risk assessment.

The two types of exposure scenarios developed for the general public include acute exposure and longer-term or chronic exposure. All of the acute exposure scenarios are primarily accidental. They assume that an individual is exposed to the compound either during or shortly after its application. Specific scenarios are developed for direct spray, dermal contact with contaminated vegetation, as well as the consumption of contaminated fruit, water, and fish. Most of these scenarios should be regarded as extreme, some to the point of limited plausibility. The longer-term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application.

The exposure scenarios developed for the general public are summarized in Table 3-2, and the details regarding the assumptions and calculations involved in these exposure assessments are provided in worksheets D01-D09. The remainder of this section focuses on a qualitative description of the data supporting each of the assessments.

3.2.3.2. Direct Spray -- Direct sprays involving ground applications are modeled in a manner similar to accidental spills for workers (see Section 3.2.2.2.). In other words, it is assumed that the individual is sprayed with a solution containing the compound and that an amount of the compound remains on the skin and is absorbed by first-order kinetics. As with the similar worker exposure scenarios, the first-order absorption kinetics are estimated from the empirical relationship of first-order absorption rate coefficients to molecular weight and octanol-water partition coefficients (SERA 2000), as defined in worksheet A07a.

For direct spray scenarios, it is assumed that during a ground application, a naked child is sprayed directly with imazapic. The scenario also assumes that the child is completely covered (that is, 100% of the surface area of the body is exposed), which makes this an extremely conservative exposure scenario that is likely to represent the upper limits of plausible exposure. An additional set of scenarios are included involving a young woman who is accidentally sprayed over the feet and legs. For each of these scenarios, some assumptions are made regarding the surface area of the skin and body weight. These assumptions are detailed and referenced in Worksheet A04.

3.2.3.3. Dermal Exposure from Contaminated Vegetation -- In this exposure scenario, it is assumed that the herbicide is sprayed at a given application rate and that an individual comes in

contact with sprayed vegetation or other contaminated surfaces at some period after the spray operation.

For these exposure scenarios, some estimates of dislodgeable residue and the rate of transfer from the contaminated vegetation to the surface of the skin must be available. No such data are directly available for imazapic, and the estimation methods of Durkin et al. (1995) are used as defined in worksheet D03. Other estimates used in this exposure scenario involve estimates of body weight, skin surface area, and first-order dermal absorption rates. The estimates of body weight and surface area are detailed in Worksheet A04 and the estimated first-order dermal absorption rate is detailed in Worksheet B04.

3.2.3.4. Contaminated Water -- Water can be contaminated from runoff, as a result of leaching from contaminated soil, from a direct spill, or from unintentional contamination from aerial applications. For this risk assessment, the two types of estimates made for the concentration of imazapic in ambient water are acute/accidental exposure from an accidental spill and longer-term exposure to imazapic in ambient water that could be associated with the typical application of this compound to a 100 acre block.

3.2.3.4.1. ACUTE EXPOSURE -- As detailed in worksheet D06, the acute exposure scenario assumes that a young child (2- to 3-years old) consumes 1 L of contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre. Because this scenario is based on the assumption that exposure occurs shortly after the spill, no dissipation or degradation of imazapic is considered. This is an extremely conservative scenario dominated by arbitrary variability. The actual concentrations in the water would depend heavily on the amount of compound spilled, the size of the water body into which it is spilled, the time at which water consumption occurs relative to the time of the spill, and the amount of contaminated water that is consumed. Based on the spill scenario used in this risk assessment, the concentration of imazapic in a small pond is estimated to range from 0.28 mg/L to 3.0 mg/L with a central estimate of 0.95 mg/L.

3.2.3.4.2. LONGER-TERM EXPOSURE -- The scenario for chronic exposure to imazapic from contaminated water is detailed in worksheet D07. This scenario assumes that an adult (70 kg male) consumes contaminated ambient water for a lifetime.

There are no monitoring studies available on imazapic that permit an assessment of concentrations in ambient water associated with ground or aerial applications of the compound over a wide area. Consequently, for this component of the exposure assessment, estimates of levels in ambient water are made based on the GLEAMS model.

GLEAMS is a root zone model that can be used to examine the fate of chemicals in various types of soils under different meteorological and hydrogeological conditions (Knisel et al. 1992). As with many environmental fate and transport models, the input and output files for GLEAMS can be complex. The general application of the GLEAMS model to estimating concentrations in

ambient water are given in Attachment I. Note that all models were run at a normalized application rate of 1 lb a.e./acre. The resulting estimates of concentrations of imazapic in ambient water are made in the worksheets as necessary.

For the current risk assessment, the methods used in Attachment 1 were used with the following exceptions. First, the application site was assumed to consist of a 100 acre square area rather than a 10 acre rights-of-way. This difference leads to higher estimates of water contamination and is more representative of a large application that might be conducted in Forest Service programs. The other difference from the general methods given in Attachment 1 involves the impact of rain or runoff water on the volume of the contaminated water. For the current risk assessment, estimates of rain and runoff water were not used to adjust the volume of 10 acre pond. This results in higher and perhaps implausibly high estimates of concentrations of imazapic in ambient water. For the current risk assessment, this approach has not impact on the risk characterization because of the very low toxicity of this compound (Section 3.4). The chemical specific parameters used in the GLEAMS modeling are given in Table 3-3 along with notes giving the rationale for and source of each of the values that were used.

The results of the GLEAMS modeling is summarized in Table 3-4. The specific estimates of concentrations of imazapic in ambient water that are used in this risk assessment are summarized in Worksheet B07. These estimates are expressed as the water contamination rates (WCR) - i.e., the concentration of the compound in water in units of mg/L normalized for an application rate of 1 lb a.e./acre. The typical water contamination rate is taken as 0.01 mg/L per lb a.e./acre. This is about the peak concentrations that could be expected at rainfall rates of about 100 inches per year as well as the average concentration at rainfall rates of 250 inches per year. The upper range is taken as 0.06 mg/L per lb a.e./acre and is approximately the peak concentration from sandy soils at rainfall rates of 250 inches per year. The lower limit, 0.001 mg/L per lb a.e./acre, is the average concentration (rounded to one significant decimal) from clay or loam soil at an annual rainfall rate of 25 inches per year. This is a somewhat arbitrary lower limit in that no water contamination is modeled at rainfall rates below 10 inches per year. Using these water contamination rates, the expected concentrations of imazapic in ambient water range from about 0.000031 to 0.0037 mg/L with a central value of 0.00062 mg/L (Worksheet B07).

3.2.3.5. Oral Exposure from Contaminated Fish **--** Many chemicals may be concentrated or partitioned from water into the tissues of animals or plants in the water. This process is referred to as bioconcentration. Generally, bioconcentration is measured as the ratio of the concentration in the organism to the concentration in the water. For example, if the concentration in the organism is 5 mg/kg and the concentration in the water is 1 mg/L, the bioconcentration factor (BCF) is 5 L/kg [5 mg/kg ÷ 1 mg/L]. As with most absorption processes, bioconcentration depends initially on the duration of exposure but eventually reaches steady state. Details regarding the relationship of bioconcentration factor to standard pharmacokinetic principles are provided in Calabrese and Baldwin (1993).

The only available study regarding the bioconcentration of imazapic is a standardized test that is required as part of the registration process (Robinson 1994). In this study, bluegill sunfish were placed in water containing ^{14}C-labeled imazapic at a concentration of 0.5 mg/L for 28 days. Over this period, the BCF in whole fish was measured at BCF 0.11 ± 0.02 L/kg with 3 days as the time to 90% steady state. Because of the very low bioconcentration factor in whole fish and the rapid time to steady state, the distinctions between acute and chronic BCFs and edible and inedible fractions is not necessary and are not used in this risk assessment..

For both the acute and longer-term exposure scenarios involving the consumption of contaminated fish, the water concentrations of imazapic used are identical to the concentrations used in the contaminated water scenarios (see Section 3.2.3.4). The acute exposure scenario is based on the assumption that an adult angler consumes fish taken from contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre. No dissipation or degradation is considered. Because of the available and well-documented information and substantial differences in the amount of caught fish consumed by the general public and native American subsistence populations (U.S. EPA 1996), separate exposure estimates are made for these two groups, as illustrated in worksheet D08. The chronic exposure scenario is constructed in a similar way, as detailed in worksheet D09, except that estimates of imazapic concentrations in ambient water are based on GLEAMS modeling as discussed in Section 3.2.3.4.

3.2.3.6. Oral Exposure from Contaminated Vegetation **--** Under normal circumstances and in most types of applications, it is extremely unlikely that humans will consume vegetation contaminated with imazapic. Nonetheless, any number of scenarios could be developed involving either accidental spraying of crops or the spraying of edible wild vegetation, like berries. Again, in most instances and particularly for longer-term scenarios, treated vegetation would probably show signs of damage from exposure to imazapic (Section 4.3.2.4), thereby reducing the likelihood of consumption that would lead to significant levels of human exposure.

Notwithstanding that assertion, it is conceivable that individuals could consume contaminated vegetation. One of the more plausible scenarios involves the consumption of contaminated berries after treatment of a right-of-way or some other area in which wild berries grow. The two accidental exposure scenarios developed for this exposure assessment include one scenario for acute exposure, as defined in Worksheet D04 and one scenario for longer-term exposure, as defined in Worksheet D05. In both scenarios, the concentration of imazapic on contaminated vegetation is estimated using the empirical relationships between application rate and concentration on vegetation developed by Hoerger and Kenaga (1972). These relationships are defined in worksheet A05a. For the acute exposure scenario, the estimated residue level is taken as the product of the application rate and the residue rate given in worksheet A05a.

For the longer-term exposure scenario, a duration of 90 days is used and the dissipation on the vegetation is estimated using a foliar half-time of 7 days. This is a somewhat conservative

approach in that the foliar halftime of imazapic has been estimated at <7 days (Hallman and Leonard 1999).

Although the duration of exposure of 90 days may appear to be somewhat arbitrarily chosen, it is intended to represent the consumption of contaminated vegetation that might be available over one season. Longer durations could be used for certain kinds of vegetation but would lower the estimated dose (i.e., would result in a less conservative exposure assessment). The central estimate of dose for the longer-term exposure period is taken as the geometric mean of the initial concentration and concentration after 90 days.

For the acute exposure scenario, it is assumed that a woman consumes 1 lb (0.4536 kg) of contaminated fruit. Based on statistics summarized in U.S. EPA (1996) and presented in worksheet D04, this consumption rate is approximately the mid-range between the mean and upper 95% confidence interval for the total vegetable intake for a 64 kg woman. The range of exposures presented in Table 3-2 is based on the range of concentrations on vegetation from Hoerger and Kenaga (1972) and the range of application rates for imazapic. The longer-term exposure scenario is constructed in a similar way, except that the estimated exposures include the range of vegetable consumption (U.S. EPA 1996) as well as the range of concentrations on vegetation and the range of application rates for imazapic.

3.3. DOSE-RESPONSE ASSESSMENT

3.3.1. Overview. The Office of Pesticide Programs of the U.S. EPA has derived an RfD of 0.5 mg/kg/day for imazapic. This RfD is based on a chronic LOAEL in dogs of 5000 ppm in the diet corresponding to an estimated daily dose of 137 mg/kg/day and an uncertainty factor of 300 - i.e., 0.456 mg/kg/day which rounds to 1 significant digit as 0.5 mg/kg/day. The dog LOAEL is based on adverse effects on skeletal muscle.

3.3.2. Existing Guidelines. U.S. EPA's Office of Pesticide Programs (U.S. EPA 1996) has derived an RfD of 0.5 mg/kg/day for imazapic. This RfD is based on a 52-week dietary exposure study using dogs. The dogs were given imazapic in the diet at concentrations of 0 (control), 5000, 20000, or 40000 ppm for 52 weeks (Wolford 1993). Based on measured food consumption, these dietary concentrations corresponded to average daily doses of 0, 137, 501, and 1,141 mg/kg/day in males and 0, 180, 534, and 1,092 mg/kg/day in females. Signs of toxicity in dogs included effects on the blood and bone marrow, muscular degeneration, as well as biochemical markers of liver toxicity. Similar but less severe effects were observed at 20000 ppm corresponding to about 500 mg/kg bw. Even at the lowest dose tested, 5000 ppm in the diet, corresponding to about 150 mg/kg bw, treatment related effects were observed on skeletal muscle.

In deriving the RfD, the U.S. EPA classified the 5000 ppm exposure group as a LOAEL, used the daily intake at 137 mg/kg/day for male dogs, and used an uncertainty factor of 300. The uncertainty factor consists of three components: a factor of 10 for extrapolating from animals to humans, a factor of 10 for extrapolating to sensitive individuals within the human population, and

a factor of 3 for extrapolating from a LOAEL to a NOAEL. Thus, the functional NOAEL for imazapic is taken as 50 mg/kg/day - i.e., 150 mg/kg/day ÷ 3.

3.3.3. Dose-Severity-Duration Relationships. As summarized in Section 3.2, all estimated levels of exposure to imazapic are substantially less than the RfD, and most estimated levels are below the RfD by factors of over 10 to nearly 10 billion. Consequently, there is no need to develop elaborate dose-severity relationships to characterize risk or to develop an acute RfD for this compound. The U.S. EPA (1996, p. 14) uses a short-term NOAEL of 350 mg/kg/day for assessing the consequences of short-term (1 to 7 days) exposures to imazapic. Using an uncertainty factor of 100, this would correspond to a short-term RfD of 0.35 mg/kg/day. This is not substantially different from the chronic RfD and the use of this value would not assist in the risk characterization. Thus, the RfD of 0.5 mg/kg/day is used for both acute and chronic exposures.

3.4. RISK CHARACTERIZATION

3.4.1. Overview. None of the exposure scenarios for workers or members of the general public result in levels that exceed the RfD. Based on central estimates of longer term exposure for workers and the general public, the levels of exposure will be below the RfD by factors of about 625 to 50,000,000 (50 million). Even for accidental exposures, the upper limits of the exposure estimates are below the RfD by factors of about 1.5 to 4,500. Thus, there is no basis for asserting that imazapic is likely to pose any identifiable risk to human health. This is consistent with the recent evaluation of imazapic by the U.S. EPA (1996) in which margins of exposure/safety were calculated to be over 1000.

The only reservation associated with this assessment of imazapic is the same reservation associated with any risk assessment in which no plausible hazards can be identified: ***Absolute safety cannot be proven and the absence of risk can never be demonstrated***. No chemical, including imazapic, is studied for all possible effects. Furthermore, using data from laboratory animals to estimate hazard or the lack of hazard to humans is an uncertain process. Prudence dictates that normal and reasonable care should be taken in the handling of this or any other chemical. Notwithstanding these reservations, the use of imazapic in Forest Service programs does not pose any identifiable hazard to workers or members of the general public.

Irritation to the skin and eyes can result from exposure to relatively high levels of imazapic. From a practical perspective, eye or skin irritation is likely to be the only overt effect as a consequence of mishandling imazapic. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of the compound.

3.4.2. Workers. A quantitative summary of the risk characterization for workers is presented in Table 3-5. The quantitative risk characterization is expressed as the hazard quotient, which is the ratio of the estimated exposure doses from Table 3-1 to the RfD of 0.5 mg/kg/day, as derived in Section 3.3.2.

Given the very low hazard quotients for accidental exposure, the risk characterization is reasonably unambiguous. None of the accidental exposure scenarios approach a level of concern. While the accidental exposure scenarios are not the most severe one might imagine (e.g., complete immersion of the worker or contamination of the entire body surface for a prolonged period of time) they are representative of reasonable accidental exposures. Given that the highest hazard quotient for any accidental exposure scenario - i.e., 0.013 as the upper range of the hazard quotient for wearing contaminated gloves for one hour - is a factor of over 75 lower than the level of concern, far more severe and less plausible scenarios are required to suggest a potential for systemic toxic effects. As discussed in Section 3.2, confidence in this assessment is diminished by the lack of information regarding the dermal absorption kinetics of imazapic in humans. Nonetheless, the statistical uncertainties in the estimated dermal absorption rates, both zero-order and first-order, are incorporated into the exposure assessment and risk characterization. Again, these estimates would have to be in error by a factor of greater than 75 in order for the basic characterization of risk to change.

Similarly, the hazard quotients for all of the application methods are below a level of concern by a factor of 100 or more for upper limits and 525 for central estimates. As with the accidental exposures, there are uncertainties in these exposure assessments; however, given the very low hazard quotients, these uncertainties do not have a substantial impact on the characterization of risk.

As discussed in Section 3.1.6, imazapic can cause mild irritation to the skin and eyes. Quantitative risk assessments for irritation are not derived; however, from a practical perspective, eye or skin irritation is likely to be the only overt effect as a consequence of mishandling imazapic. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of the compound.

3.4.3. General Public. The quantitative hazard characterization for the general public is summarized in Table 3-6. Like the quantitative risk characterization for workers, the quantitative risk characterization for the general public is expressed as the hazard quotient using the U.S. EPA RfD of 0.5 mg/kg/day.

None of the accidental or longer-term exposure scenarios approach a level of concern. The highest hazard quotient for any accidental exposure scenario, 0.68, is associated with the upper limit of exposure after an accidental spill of imazapic into a small pond. As detailed in Section 3.2.3.4.1, this exposure scenario is dominated by situational variability dependent on the amount spilled, the volume of water that is contaminated and the amount of water that is consumed. Although there are several uncertainties in the longer-term exposure assessments for the general public, as discussed in Section 3.2, the upper limits for hazard indices are below a level of concern by factors of about 3,800 to 525,000. The risk characterization is thus relatively unambiguous: based on the available information and under the foreseeable conditions of application, there is no route of exposure or exposure scenario suggesting that the general public will be at risk from longer-term exposure to imazapic.

3.4.4. Sensitive Subgroups. There is no information to assess whether or not specific groups or individuals may be especially sensitive to the systemic effects of imazapic. As indicated in Section 3.1.3, the most sensitive effect of imazapic appears to be damage to skeletal muscle in dogs. However, as detailed in Section 3.4.2, there is no basis for asserting that plausible or even accidental exposures to imazapic as part of Forest Service programs would lead to levels of exposure that would cause this effect.

3.4.5. Connected Actions. As discussed in Section 3.1.10, the manufacturer of imazapic has recommended tank mixtures of this herbicide with glyphosate. No data are available on the combined toxicity of these two herbicides. Studies have been conducted on mixtures of 2,4-D and imazapic. While these combinations are more toxic than imazapic alone, there appears to be no basis for asserting that synergistic effects are likely because the toxic action is probably due to 2,4-D alone.

3.4.6. Cumulative Effects. This risk assessment specifically considers the effect of repeated exposure in that the chronic RfD is used as an index of acceptable exposure even for acute exposure scenarios. Consequently, the risk characterizations presented in this risk assessment encompass the potential impact of long-term exposure and cumulative effects.

Table 3-1: Summary of Worker Exposure Scenarios

Scenario	Dose (mg/kg/day or event)			Exposure Assessment Worksheet
	Typical	Lower	Upper	
General Exposures (dose in mg/kg/day)				
Directed ground spray (Backpack)	8.00e-04	1.41e-05	4.99e-03	WSC01a
Broadcast ground spray (Boom spray)	3.49e-04	3.75e-06	2.70e-03	WSC01b
Aerial applications	9.73e-04	1.50e-05	4.99e-03	WSC01c
Accidental/Incidental Exposures (dose in mg/kg/event)				
Immersion of Hands, 1 minute	1.81e-05	2.85e-06	1.08e-04	WSC02
Contaminated Gloves, 1 hour	1.08e-03	1.71e-04	6.50e-03	WSC02
Spill on hands, 1 hour	1.31e-04	1.56e-05	1.04e-03	WSC03
Spill on lower legs, 1 hour	3.22e-04	3.85e-05	2.56e-03	WSC03

Table 3-2: Summary of Exposure Scenarios for the General Public

Scenario	Target	Dose (mg/kg/day)			Worksheet
		Typical	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	0.00494	0.00059	0.039	WSD01
Direct spray, lower legs	Woman	0.000496	0.0000593	0.0039	WSD02
Dermal, contaminated vegetation	Woman	0.000134	0.000025	0.000332	WSD03
Contaminated fruit, acute exposure	Woman	0.0007	0.00033	0.003	WSD04
Contaminated water, acute exposure	Child	0.071	0.013	0.34	WSD06
Consumption of fish, general public	Man	0.00001	4.40e-06	0.000752	WSD08
Consumption of fish, subsistence populations	Man	0.000121	0.00004	0.0036663	WSD08
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	4.68e-06	2.34e-06	0.00005	WSD05@@
Consumption of water	Man	1.78e-05	6.25e-07	1.28e-04	WSD07
Consumption of fish, general public	Man	9.81e-09	4.91e-10	9.30e-07	WSD09
Consumption of fish, subsistence populations	Man	7.94e-08	3.98e-09	4.53e-06	WSD09

Table 3-3: Pesticide specific parameters used in GLEAMS modeling and estimation of concentrations in ambient water

Parameter	Clay	Loam	Sand	Comment/ Reference
Halftimes (days)				
Aquatic Sediment	2400	2400	2400	Madsen. 1993. See Note 1
Foliar	4	4	4	See Note 2
Soil	113	113	113	Ta 1997 See Note 3.
Water	30	30	30	U.S. EPA (1995a).
Ko/c	112	112	112	Mangels (1992) See Note 4
K_d	4.05	0.58	0.13	Mangels (1992) See Note 5
Water Solubility, mg/L	36000	36000	36000	pH 7, Mangels (1992) See Note 6

Note 1 Study of anaerobic aquatic metabolism in sandy loam sediment using ^{14}C-labeled imazapic. No studies available in other sediments.

Note 2 Approximate geometric mean of 1.2 and 12 days reported by Hallman and Leonard 1999.

Note 3 Aerobic metabolism in sandy loam soil. Differences will occur in different soils but will be more dependent on microflora than soil types. The value from Ta (1997) is used for all soil types in the absence of specific data in other soil types.

Note 4 Average value from 6 soils. There was a wide range, 7 to 267, but no correlation with organic matter (Mangels 1992)

Note 5 Value of 4.05 measured in clay loam soil. Value of 0.13 measured in loamy sand. Value of 0.6 measured in loam. Mangels (1992)

Note 6 In acidic waters (pH 5), the water solubility is only 2,150 mg/L. (Mangels 1992)

Table 3-4: Estimated concentrations of imazapic in ambient water (µg/L) based on GLEAMS modeling with different soil types and annual rainfall rates and using a normalized application rate of 1 lb a.e./acre.

Annual Rainfall[1]	Concentrations in Ambient Water (µg a.e./L per lb a.e./acre)					
	Clay		Loam		Sand	
	Average	Maximum	Average	Maximum	Average	Maximum
15	0.10032	0.30353	0.00000	0.00000	0.00000	0.00000
20	0.47277	1.48921	0.27958	0.59534	5.37367	12.36265
25	0.76820	2.57684	0.96802	1.75781	7.30584	16.99913
50	2.12358	8.75733	3.46763	6.68227	9.00130	38.62730
100	4.00504	20.59742	5.15182	12.73380	9.42999	51.36006
150	5.18265	30.13948	5.75624	15.66290	9.54550	56.19481
200	5.99008	39.18572	6.07086	17.29863	9.59804	58.81848
250	6.57864	46.16125	6.27142	18.46138	9.62853	60.13554

[1] No water contamination estimated at annual rainfall rates of 10 inches or less.

Table 3-5: Summary of risk characterization for workers[1]

RfD	0.5	mg/kg/day	Sect. 3.3.3.	
Scenario	Hazard Quotient			Exposure Assessment Worksheet
	Typical	Lower	Upper	
General Exposures				
Directed ground spray (Backpack)	1.6e-03	2.8e-05	1.0e-02	WSC01a
Broadcast ground spray (Boom spray)	7.0e-04	7.5e-06	5.4e-03	WSC01b
Aerial applications	1.9e-03	3.0e-05	1.0e-02	WSC01c
Accidental/Incidental Exposures				
Immersion of Hands, 1 minute	3.6e-05	5.7e-06	2.2e-04	WSC02
Contaminated Gloves, 1 hour	2.2e-03	3.4e-04	1.3e-02	WSC02
Spill on hands, 1 hour	2.6e-04	3.1e-05	2.1e-03	WSC03
Spill on lower legs, 1 hour	6.4e-04	7.7e-05	5.1e-03	WSC03

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Table 3-1 for summary of exposure assessment.

Table 3-6: Summary of risk characterization for the general public [1].

Chronic RfD		0.5	mg/kg/day	Sect. 3.3.3.	
Acute RfD		0.5	mg/kg/day	Sect. 3.3.3.	
Scenario	Target	Hazard Quotient			Worksheet
		Typical	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	9.9e-03	1.2e-03	7.8e-02	WSD01
Direct spray, lower legs	Woman	9.9e-04	1.2e-04	7.8e-03	WSD02
Dermal, contaminated vegetation	Woman	2.7e-04	5.1e-05	6.6e-04	WSD03
Contaminated fruit, acute exposure	Woman	1.4e-03	6.6e-04	6.0e-03	WSD04
Contaminated water, acute exposure	Child	1.4e-01	2.6e-02	6.8e-01	WSD06
Consumption of fish, general public	Man	3.0e-05	8.8e-06	1.5e-03	WSD08
Consumption of fish, subsistence populations	Man	2.4e-04	7.1e-05	7.3e-03	WSD08
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	9.4e-06	4.7e-06	1.0e-04	WSD05
Consumption of water	Man	3.6e-05	1.3e-06	2.6e-04	WSD07
Consumption of fish, general public	Man	2.0e-08	9.8e-10	1.9e-06	WSD09
Consumption of fish, subsistence populations	Man	1.6e-07	8.0e-09	9.1e-06	WSD09

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Table 3-2 for summary of exposure assessments.

4. ECOLOGICAL RISK ASSESSMENT

4.1. HAZARD IDENTIFICATION

4.1.1. Overview. The available data appear to suggest that larger mammals, such as dogs and rabbits, may be more sensitive to imazapic than smaller mammals such as mice and rats. Essentially no toxic effects have been observed in rats and mice even at very high dietary concentrations of imazapic over prolonged periods of time. The chronic NOAEL in rats is about 1133 mg/kg bw/day. In dogs, however, imazapic has been associated with effects on muscle, blood, and liver at a dietary LOAEL of 5000 ppm, corresponding to an average daily dose of about 150 mg/kg bw over a period of two years. In rabbits, increased mortality has been noted after gavage doses from 175 mg/kg bw/day to 700 mg/kg bw/day. The chronic toxicity of imazapic to birds is comparable to that in dogs with a NOAEL of 113 mg/kg bw/day and a LOAEL of 170 mg/kg bw/day. Only one bioassay is available on terrestrial invertebrates - i.e., the honey bee with an acute LD_{50} of greater than 1075 mg/kg bw.

The toxicity of imazapic to terrestrial plants has been assayed in both pre-emergence and post-emergence studies. In the pre-emergence study, no effects on emergence were noted for any plants [NOEC=0.064 lb/acre] except ryegrass [NOEC=0.032 lb/acre and EC_{25} of 0.055 lb/acre]. NOEC values for survival were also 0.064 lb/acre except for ryegrass, which evidenced an NOEC of 0.016 lb/acre. Imazapic was much more toxic in the post-emergence assay, with 21-day NOEC values for visual injury of 0.001 lb/acre for cabbage, cucumber, and tomato; 0.002 lb ai/acre for onion, oat, and radish; 0.004 lb/acre for ryegrass, 0.008 for soybean, 0.016 for corn, and 0.032 for lettuce.

Aquatic animals appear to be relatively insensitive to imazapic exposures, with LC_{50} values of >100 mg/L for both acute toxicity and reproductive effects. Aquatic macrophytes may be much more sensitive, with an acute EC_{50} of 6.1 µg/L in duck weed (*Lemna gibba*). Aquatic algae appear to be much less sensitive, with EC_{50} values of greater than 45 µg/L.

No toxicity studies have been encountered on the effects of imazapic on amphibians or microorganisms.

4.1.2. Toxicity to Terrestrial Organisms.

4.1.2.1. Mammals– As summarized in the human health risk assessment (Section 3.1), there are several standard toxicity studies in experimental mammals that were conducted as part of the registration process. Essentially no toxic effects have been observed in rats and mice even at very high dietary concentrations of imazapic over prolonged periods of time (Section 3.1.3). In dogs, however, dietary concentrations of imazapic have been associated with effects on muscle, blood, and liver. As discussed in section 3.1.3., the most sensitive effect in dogs is damage to muscle tissue with a dietary LOAEL of 5000 ppm corresponding to an average daily dose of about 150 mg/kg bw.

The acute toxicity of imazapic is relatively low, with an oral LD_{50} of >5000 mg/kg in rats. Rabbits may be more sensitive to imazapic than rats, with increased mortality noted in rabbits after gavage doses from 175 mg/kg bw/day to 700 mg/kg bw/day (MacKenzie 1992).

The limited available data appear to suggest that larger mammals, such as dogs and rabbits, may be more sensitive to imazapic than smaller mammals such as mice and rats. Because relatively few studies are available to support this speculation, allometric relationships will not be developed for interspecies extrapolation. Instead, it will be assumed that wildlife species may be as sensitive to imazapic as the most sensitive species - i.e., the dog. As detailed further in Section 4.4, this conservative assumption has relatively little impact on this risk assessment because levels that are likely to be toxic to the dog are still far below levels of exposure that might occur in Forest Service programs.

4.1.2.2. Birds– Both acute and subchronic toxicity studies are available in mallard ducks and bobwhite (Appendix 2). These studies are required by the U.S. EPA for pesticide registration and were submitted to the U.S. EPA during the registration process.

Consistent with the gavage studies in rats (Section 3.1 and Appendix 1), the acute toxicity of imazapic to birds appears to be low, with no mortality observed after singe gavage doses of 2150 mg/kg in quail (Fletcher and Sullivan 1993a) and ducks (Fletcher and Sullivan 1993b). In ducks, however, there was a slight decrease in food consumption over the 20-day post-dosing observation period (Fletcher and Sullivan 1993b). After 8-day exposures to imazapic in the diet at concentrations of up to 5000 ppm, no effects were observed in either quail (Pedersen et al. 1993a) or ducks (Pedersen et al. 1993b).

Imazapic has also been assayed for subchronic toxicity and reproductive effects in both ducks (Mortensen et al. 1998) and quail (Miller et al. 1998). No signs of systemic toxicity or reproductive effects (egg production, hatchability, survival of hatchlings) was observed in ducks over a 22 week exposure to imazapic in the diet at a concentration of up to 1658 ppm (Mortensen et al. 1998). In quail, no signs of systemic toxicity were observed at dietary concentrations of imazapic up to 1907 ppm, corresponding to a NOAEL of approximately 170 mg/kg bw/day. At this concentration, however, there was a statistically significant decrease in 14-day body weights of hatchlings. No other signs of reproductive effects were observed. No effects on hatchling body weight were observed at the next lower dietary concentration - i.e., 1187 ppm corresponding to a dose of approximately 113 mg/kg bw/day (Miller et al. 1998).

In addition to these toxicity studies, pharmacokinetic studies have been conducted in hens (Gatterdam 1993a,b; Afzal 1994). These studies are consistent with the pharmacokinetic studies in mammals (Section 3.1.9.2), indicating that imazapic is rapidly excreted and does not accumulate in body tissue. In addition, no detectable concentrations of imazapic were found in eggs (limit of detection of 0.01 ppm).

4.1.2.3. Terrestrial Invertebrates– Only one study has been encountered on the toxicity of imazapic to terrestrial invertebrates: a standard acute contact toxicity bioassay in honey bees (Hoxter et al. 1993). This type of study is required by the U.S. EPA for the registration of pesticides. In this study, imazapic dissolved in acetone was applied to the thorax of groups of 50 bees (1 to 7 days old) at levels of 0, 13, 22, 36, 60, or 100 μg/bee. Two groups of bees were used at each dose level - i.e., a total of 100 bees per dose group - and four groups of bees were used as controls - i.e., a total of 200 bees. Combined mortality rates were 11/200 (0 dose), 7/100 (13 μg/bee), 9/100 (22 μg/bee), 9/100 (36 μg/bee), 22/100 (60 μg/bee), and 25/100 (100 μg/bee). Using the Fisher exact test, the combined mortality in the 36 μg/bee dose group was not statistically significant from the control response ($p=0.18$) but was significant ($p=0.000034$) in the 22 μg/bee dose group.

4.1.2.4. Terrestrial Plants (Macrophytes)– Two sets of phytotoxicity studies have been conducted to support the registration of imazapic: a seed germination and seedling emergence study (Chetram et al. 1994a) which essentially mimics pre-emergence applications and a vegetative vigor assay (Chetram et al. 1994b) which mimics post-emergence applications.

The pre-emergence study consisted of two assays: a petri dish assay and seedling emergence assay in treated soil. The seedling/petri assay used technical grade imazapic to assay effects on seed germination in soybeans, lettuce, radishes, tomatoes, cucumbers, cabbage, oats, ryegrass, corn, and onions. Imazapic was applied to blotter paper in petri plates (10 seeds per plate) a nominal rates of 0.004, 0.008, 0.016, 0.032, and 0.064 lb a.e./acre. At 0.064 lb ai/acre, the proportion of germinating onion seeds was 73%, compared to 95% in the matched control group (Table III, p.30 of Chetram et al. 1994a), a statistically significant decrease ($p<0.05$). No statistically significant effects were apparent in any other treatment groups.

In the seedling emergence assay, the same species were used with imazapic applied to the surface of soil at the same equivalent application rates used in the petri assay. Responses were assayed by a visual (0-5 scale) subjective evaluation on days 7, 14, and 21 and percent emergence was assayed on day 14, except for oats which were assayed on day 17. No effects on emergence were noted for any plants [NOEC=0.064 lb/acre] except ryegrass [NOEC=0.032 lb/acre and EC_{25} of 0.055 lb/acre]. NOECs for survival were 0.064 lb/acre except for ryegrass, which evidenced an NOEC of 0.016 lb/acre (Chetram et al. 1994b) .

In the post-emergence assay, 1-3 leaf stage soybeans, lettuce, radishes, tomatoes, cucumbers, cabbage, oats, ryegrass, corn, and onions were treated with imazapic at nominal application rates of 0.004, 0.008, 0.016, 0.032, and 0.064 lb ai/acre, as in the seed germination and emergence assays. Because of greater than anticipated toxicity in radish, tomato, cucumber, cabbage, oat, and onion, an additional assay was run at nominal application rates of 0.00025, 0.0005, 0.001, 0.002, and 0.004 lb ai/acre. After 21 days, NOEC's for visual injury were 0.001 lb/acre for cabbage, cucumber, and tomato; 0.002 lb ai/acre for onion, oat, and radish; 0.004 lb/acre for ryegrass, 0.008 for soybean, 0.016 for corn, and 0.032 for lettuce.

4.1.2.5. Terrestrial Microorganisms– No information has been encountered in the published literature or in the EPA registration files on the toxicity of imazapic to terrestrial microorganisms.

4.1.3. Aquatic Organisms.

4.1.3.1. Fish– Standard toxicity bioassays to assess the effects of imazapic on fish are summarized in Appendix 3. In acute toxicity studies, all tested species (channel catfish, bluegill sunfish, trout, and sheepshead minnow) evidenced 96-hour LC_{50} values of >100 mg/L - i.e., nominal concentrations of 100 mg/L caused less than 50% mortality over the 96-hour exposure period (Yurk et al. 1992a,b; Barker and Skorczynski 1998). Similarly, no effects on reproductive parameters were seen in a 32-day egg and fry study using fathead minnow (Barker et al. 1998a).

The very low toxicity of imazapic to fish is probably related to very low rate of uptake of this compound by fish. In a 28-day flow-through assay, the bioconcentration of imazapic was measured at 0.11 L/kg (Barker et al. 1998a) indicating that the concentration of imazapic in the water was greater than the concentration of the compound in fish.

4.1.3.2. Amphibians– Neither the published literature nor the U.S. EPA files include data regarding the toxicity of imazapic to amphibian species.

4.1.3.3. Aquatic Invertebrates– Standard toxicity bioassays to assess the effects of imazapic on aquatic invertebrates are summarized in Appendix 3. As with fish, no adverse effects have been observed at nominal concentrations of imazapic of up to 100 mg/L in acute toxicity studies.

4.1.3.4. Aquatic Plants– Standard toxicity bioassays to assess the effects of imazapic on aquatic plants were submitted to the U.S. EPA in support of the registration of imazapic and are summarized in Appendix 3. The most sensitive species on which data are available is the aquatic macrophyte, *Lemna gibba*, with an LC_{50} of 6.1 µg/L and an LC_{25} of 4.23 µg/L. Unicellular algae are much less sensitive with LC_{50} values greater than 45 µg/L (Hughes et al. 1994).

4.1.3.5. Other Aquatic Microorganisms– Neither the published literature nor the U.S. EPA files include data regarding the toxicity of imazapic to other aquatic microorganisms.

4.2. EXPOSURE ASSESSMENT

4.2.1. Overview. Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation. In acute exposure scenarios and under the assumption of 100% dermal absorption, the highest exposures for small terrestrial vertebrates will occur after a direct spray and could reach up to about 2 mg/kg under typical exposure conditions and up to about 5 mg/kg under more extreme conditions. Other routes of exposure, like the consumption of contaminated water or contaminated vegetation, generally will lead to much lower levels of exposure. In chronic exposure scenarios, the maximum estimated daily doses for a small vertebrate is 0.003 mg/kg/day. Based on general relationships of body size to body volume, larger vertebrates will be exposed to lower doses and smaller animals, like

insects, will be exposed to much higher doses under comparable exposure conditions. Because of the apparent low toxicity of imazapic to animals, the rather substantial variations in the exposure assessments have little impact on the assessment of risk to terrestrial animals.

The primary hazards to non-target terrestrial plants are associated with unintended direct deposition or spray drift. Unintended direct spray will result in an exposure level equivalent to the application rate. At least some plants that are sprayed directly with imazapic at or near the recommended range of application rates will be damaged. Based on a monitoring study involving a ground application with a hydraulic sprayer, no more than 0.001 of the application rate would be expected to drift 100 m offsite. Based on monitoring studies involving low-flight agricultural applications of various pesticides and employing various types of nozzles under a wide range of meteorological conditions, the central estimates of off-site drift for single swath applications, expressed as a proportion of the nominal application rate, are approximately 0.03 at 100 feet, 0.002 at 500 feet, 0.0006 at 1000 feet, and 0.0002 at 2500 feet. Estimates of off-site deposition also can be based on Stoke's Law. Using this method and assuming a wind velocity of no more than 5 miles/hour perpendicular to the line of application, 100 µ particles falling from 3 feet above the surface could drift as far as 23 feet. A raindrop or 400 µ particle applied at 6 feet above the surface could drift about 3 feet.

In order to encompass a wide range of field conditions, GLEAMS simulations were conducted for both clay, loam, and sand at annual rainfall rates from 5 to 250 inches and the typical application rate of 0.0624 lb a.e./acre. Under arid conditions (i.e., annual rainfall of about 10 inches or less), there is no runoff and degradation, not dispersion, accounts for the decrease of imazapic concentrations in soil. At higher rainfall rates, plausible offsite movement of imazapic results in runoff losses that range from about 0.01 to 0.45 of the application rate, depending primarily on the amount of rainfall rather than differences in soil type.

Exposures to aquatic species are impacted by the same factors that influence terrestrial plants except the directions of the impact are reversed. In other words, in very arid environments substantial contamination of water is unlikely. In areas with increasing levels of rainfall, exposures to aquatic organisms are more likely to occur. Thus, the anticipated concentrations in ambient water encompass a very broad range, 0.00003 to 0.0114 mg/L, depending primarily on differences in rainfall rates.

4.2.2. Terrestrial Animals. Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation.

In this exposure assessment, estimates of oral exposure are expressed in the same units as the available toxicity data (i.e., oral LD_{50} and similar values). As in the human health risk assessment, these units are usually expressed as mg of agent per kg of body weight and abbreviated as mg/kg body weight. For dermal exposure, the units of measure usually are expressed in mg of agent per cm^2 of surface area of the organism and abbreviated as mg/cm^2. In estimating dose, however, a

distinction is made between the exposure dose and the absorbed dose. The *exposure dose* is the amount of material on the organism (i.e., the product of the residue level in mg/cm^2 and the amount of surface area exposed), which can be expressed either as mg/organism or mg/kg body weight. The *absorbed dose* is the proportion of the exposure dose that is actually taken in or absorbed by the animal.

For the exposure assessments discussed below, general allometric relationships are used to model exposure. In the biological sciences, allometry is the study of the relationship of body size or mass to various anatomical, physiological, or pharmacological parameters (e.g., Boxenbaum and D'Souza 1990). Allometric relationships take the general form:

$$y = aW^x$$

where ***W*** is the weight of the animal, ***y*** is the variable to be estimated, and the model parameters are **a** and **x**.

For most allometric relationships used in this exposure assessment, **x** ranges from approximately 0.65 to 0.75. These relationships dictate that, for a fixed level of exposure (e.g., levels of a chemical in food or water), small animals will receive a higher dose, in terms of mg/kg body weight, than large animals.

For many compounds, allometric relationships for interspecies sensitivity to toxicants indicate that for exposure levels expressed as mg toxicant per kg body weight (mg/kg body weight), large animals, compared with small animals, are more sensitive. As discussed in Sections 3.1.2 and 3.1.3, larger mammals such as rabbits and dogs appear to be more sensitive to imazapic than rats and mice but the data are not adequate to support the development of quantitative allometric relationships for toxicity. Consequently, estimates of exposure are given for both a small and a large mammal as well as a small and a large bird.

The exposure assessments for terrestrial animals are summarized in Table 4-1. As with the human health exposure assessment, the computational details for each exposure assessment presented in this section are provided in the attached worksheets (worksheets F01 through F12).

4.2.2.1. Direct Spray – In the broadcast application of any herbicide, wildlife species may be sprayed directly. This scenario is similar to the accidental exposure scenarios for the general public discussed in section 3.2.3.2. In a scenario involving exposure to direct spray, the extent of dermal contact depends on the application rate, the surface area of the organism, and the rate of absorption.

For this risk assessment, three groups of direct spray exposure assessments are conducted. The first, which is defined in worksheet F01, involves a 20 g mammal that is sprayed directly over one half of the body surface as the chemical is being applied. The range of application rates as well as the typical application rate is used to define the amount deposited on the organism. The absorbed

dose over the first day (i.e., a 24-hour period) is estimated using the assumption of first-order dermal absorption. In the absence of any data regarding dermal absorption in a small mammal, the estimated absorption rate for humans is used (see section 3.1.7). An empirical relationship between body weight and surface area (Boxenbaum and D'Souza 1990) is used to estimate the surface area of the animal. The estimates of absorbed doses in this scenario may bracket plausible levels of exposure for small mammals based on uncertainties in the dermal absorption rate of imazapic.

Other, perhaps more substantial, uncertainties affect the estimates for absorbed dose. For example, the estimate based on first-order dermal absorption does not consider fugitive losses from the surface of the animal and may overestimate the absorbed dose. Conversely, some animals, particularly birds and mammals, groom frequently, and grooming may contribute to the total absorbed dose by direct ingestion of the compound residing on fur or feathers. Furthermore, other vertebrates, particularly amphibians, may have skin that is far more permeable than the skin of most mammals (Moore 1964).

Quantitative methods for considering the effects of grooming or increased dermal permeability are not available. As a conservative upper limit, the second exposure scenario, detailed in worksheet F02, is developed in which complete absorption over day 1 of exposure is assumed.

Because of the relationship of body size to surface area, very small organisms, like bees and other terrestrial insects, might be exposed to much greater amounts of imazapic per unit body weight, compared with small mammals. Consequently, a third exposure assessment is developed using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993) and the equation above for body surface area proposed by Boxenbaum and D'Souza (1990). Because there is no information regarding the dermal absorption rate of imazapic by bees or other invertebrates, this exposure scenario, detailed in worksheet F03, also assumes complete absorption over the first day of exposure.

Direct spray scenarios are not given for large mammals. As noted above, allometric relationships dictate that large mammals will be exposed to lesser amounts of a compound in any direct spray scenario than smaller mammals. As detailed further in Section 4.4, the direct spray scenarios for the small mammal are substantially below a level of concern. Consequently, elaborating direct spray scenarios for a large mammal would have no impact on the characterization of risk.

4.2.2.2. Indirect Contact – As in the human health risk assessment (see section 3.2.3.3), the only approach for estimating the potential significance of indirect dermal contact is to assume a relationship between the application rate and dislodgeable foliar residue. The study by Harris and Solomon (1992) (worksheet A04) is used to estimate that the dislodgeable residue will be approximately 10 times less than the nominal application rate.

Unlike the human health risk assessment in which transfer rates for humans are available, there are no transfer rates available for wildlife species. As discussed in Durkin et al. (1995), the transfer

rates for humans are based on brief (e.g., 0.5- to 1-hour) exposures that measure the transfer from contaminated soil to uncontaminated skin. Species of wildlife are likely to spend longer periods of time, compared to humans, in contact with contaminated vegetation.

It is reasonable to assume that for prolonged exposures a steady-state may be reached between levels on the skin, rates of absorption, and levels on contaminated vegetation, although there are no data regarding the kinetics of such a process. The bioconcentration data on imazapic (section 3.2.3.5) as well as its high water solubility and low octanol/water partition coefficient suggest that imazapic is not likely to partition from the surface of contaminated vegetation to the surface of skin, feathers, or fur. Thus, a plausible partition coefficient is unity (i.e., the concentration of the chemical on the surface of the animal will be equal to the dislodgeable residue on the vegetation).

Under these assumptions, the absorbed dose resulting from contact with contaminated vegetation will be one-tenth that associated with comparable direct spray scenarios. As discussed in the risk characterization for ecological effects (section 4.4), the direct spray scenarios result in exposure levels far below those of toxicological concern. Consequently, details of the indirect exposure scenarios for contaminated vegetation are not further elaborated in this document.

4.2.2.3. Ingestion of Contaminated Vegetation or Prey – Since imazapic will be applied to vegetation, the consumption of contaminated vegetation is an obvious concern and separate exposure scenarios are developed for acute and chronic exposure scenarios for a small mammal (Worksheets F04 and F05) and large mammal (Worksheets F10 and F11) as well as small birds (Worksheet F14) and large birds (Worksheets F08, F09, F12, F13, F14).

A small mammal is used because allometric relationships indicate that small mammals will ingest greater amounts of food per unit body weight, compared with large mammals. The amount of food consumed per day by a small mammal (i.e., an animal weighing approximately 20 g) is equal to about 15% of the mammal's total body weight (U.S. EPA 1989). When applied generally, this value may overestimate or underestimate exposure in some circumstances. For example, a 20 g herbivore has a caloric requirement of about 13.5 kcal/day. If the diet of the herbivore consists largely of seeds (4.92 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 14% of its body weight [(13.5 kcal/day ÷ 4.92 kcal/g)÷20g = 0.137]. Conversely, if the diet of the herbivore consists largely of vegetation (2.46 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 27% of its body weight [(13.5 kcal/day ÷ 2.46 kcal/g)÷20g = 0.274] (U.S. EPA 1993, pp.3-5 to 3-6).

A large herbivorous mammal is included because empirical relationships of concentrations of pesticides in vegetation, discussed below, indicate that grasses may have substantially higher pesticide residues than other types of vegetation such as forage crops or fruits (worksheet A05a). Grasses are an important part of the diet for some large herbivores, but small mammals do not consume grasses as a substantial proportion of their diet. So, even though using residues from grass to model exposure for a small mammal is the most conservative approach, it is not generally applicable to the assessment of potential adverse effects. Hence, in the exposure scenarios for

large mammals, the consumption of contaminated range grass is modeled for a 70 kg herbivore, like a deer. Caloric requirements for herbivores and the caloric content of vegetation are used to estimate food consumption based on data from U.S. EPA (1993). Details of these exposure scenarios are given in worksheets F10 and F11.

The consumption of contaminated vegetation is also modeled for a large bird. This scenario is included because, as discussed in section 4.1.2.2, decreased growth in hatchlings has been noted in birds after subchronic exposure to imazapic. For this exposure scenario, the consumption of range grass by a 4 kg herbivorous bird, like a Canada Goose, is modeled for both acute (Worksheet F12) and chronic (Worksheet F13) exposures.

For this component of the exposure assessment, the estimated amounts of pesticide residue in vegetation are based on the relationship between application rate and residue rates on different types of vegetation. As summarized in worksheet A05a, these residue rates are based on the relationships derived by Hoerger and Kenaga (1972). This is the same approach taken by U.S. EPA (1995a) in their ecological risk assessment of imazapic.

Similarly, the consumption of contaminated insects is modeled for a small (10g) bird. No monitoring data have been encountered on the concentrations of imazapic in insects. Following the approach used by U.S. EPA (1995), the empirical relationships developed by Hoerger and Kenaga (1972) are used as surrogates as detailed in worksheet F14.

In addition to the consumption of contaminated vegetation and insects, imazapic may reach ambient water and bioconcentrate in fish. Thus, a separate exposure scenario is developed for the consumption of contaminated fish by a predatory bird in both acute (worksheet F08) and chronic (worksheet F09) exposures. Because predatory birds usually consume more food per unit body weight than do predatory mammals (U.S. EPA 1993, pp. 3-4 to 3-6), a separate exposure scenario for the consumption of contaminated fish by a predatory mammal is not developed.

4.2.3. Terrestrial Plants. In general, the primary hazard to non-target terrestrial plants associated with the application of most herbicides is unintended direct deposition or spray drift. In addition, herbicides may be transported off-site by percolation or runoff or by wind erosion of soil.

4.2.3.1. Direct Spray – Unintended direct spray will result in an exposure level equivalent to the application rate. At least some plants that are sprayed directly with imazapic at or near the recommended range of application rates will be damaged (section 4.3.2.4).

4.2.3.2. Off-Site Drift – Data regarding the drift of imazapic during ground or aerial applications were not found in the literature. Because off-site drift is more or less a physical process that depends on droplet size and meteorological conditions rather than the specific properties of the herbicide, estimates of off-site drift can be made based on data for other compounds. The potential for spray drift was investigated in numerous field studies reviewed recently by Bird

(1995), as summarized in Worksheet A06. The monitoring studies involved low-flight agricultural applications of pesticides and employed various types of nozzles under a wide range of meteorological conditions. The central estimates of off-site drift for single swath applications, expressed as a proportion of the nominal application rate, were approximately 0.03 at 100 feet, 0.002 at 500 feet, 0.0006 at 1000 feet, and 0.0002 at 2500 feet (Bird 1995, Figure 2, p. 204).

No comparable reviews have been located for the assessment of drift from ground applications. Yates et al. (1978) studied the kinetics of glyphosate drift over a flat field after ground and aerial applications involving the use of various nozzles and various spray application rates. During the application, wind speeds were about 2–4 m/second, which is about 4.4–8.8 miles/hour. Glyphosate deposition 25 m (about 83 feet) downwind from the application site ranged from approximately $5 \cdot 10^{-6}$ to $7 \cdot 10^{-4}$ of the nominal application rate, based on drift deposited on Mylar fallout sheets (Yates et al. 1978, p. 600, Figure 1). In addition, this study demonstrates that the deposition between 25 and 800 m generally followed a double log linear relationship (i.e., the log of the distance down wind plotted against the log of the deposition yielded a straight line for most applications, although curvilinear relationships were noted for some applications). For the current risk assessment, an offsite drift ratio of 0.0007 at 83 feet is compared to the value of 0.03 at 100 feet from the Bird (1995) review of aerial studied. Based on this comparison, the estimate will be made that offsite drift from ground applications will be 0.023 [0.0007÷0.03 = 0.023333] of the drift from aerial applications. Based on this assessment, the drift rates for both ground and aerial applications are summarized in Worksheet G05.

Another approach to estimating drift involves the use of Stoke's law, which describes the viscous drag on a moving sphere. According to Stoke's law:

$$v = \frac{D^2 \cdot g}{18n}$$

or

$$v = 2.87 \cdot 10^5 \cdot D^2$$

where v is the velocity of fall (cm sec^{-1}), D is the diameter of the sphere (cm), g is the force of gravity (980 cm sec^{-2}), and n is the viscosity of air ($1.9 \cdot 10^{-4}$ g sec^{-1} cm^{-1} at 20°C) (Goldstein et al. 1974).

In typical backpack ground sprays, droplet sizes are greater than 100 µ, and the distance from the spray nozzle to the ground is 3 feet or less. In mechanical sprays, raindrop nozzles might be used. These nozzles generate droplets that are usually greater than 400 µ, and the maximum distance above the ground is about 6 feet. In both cases, the sprays are directed downward.

Thus, the amount of time required for a 100 µ droplet to fall 3 feet (91.4 cm) is approximately 3.2 seconds,

$$91.4 \div (2.87 \cdot 10^5 (0.01)^2).$$

The comparable time for a 400 µ droplet to fall 6 feet (182.8 cm) is approximately 0.4 seconds,

$$182.8 \div (2.87 \cdot 10^5(0.04)^2).$$

For most applications, the wind velocity will be no more than 5 miles/hour, which is equivalent to approximately 7.5 feet/second (1 mile/hour = 1.467 feet/second). Assuming a wind direction perpendicular to the line of application, 100 µ particles falling from 3 feet above the surface could drift as far as 23 feet (3 seconds · 7.5 feet/second). A raindrop or 400 µ particle applied at 6 feet above the surface could drift about 3 feet (0.4 seconds · 7.5 feet/second).

For backpack applications, wind speeds of up to 15 miles/hour are allowed in Forest Service programs. At this wind speed, a 100 µ droplet can drift as far as 68 feet (3 seconds · 15 · 1.5 feet/second). Smaller droplets will of course drift further, and the proportion of these particles in the spray as well as the wind speed will affect the proportion of the applied herbicide that drifts off-site.

4.2.3.3. Runoff – Imazapic or any other herbicide may be transported to off-site soil by runoff or percolation. Both runoff and percolation are considered in estimating contamination of ambient water. For assessing off-site soil contamination, however, only runoff is considered. This is similar to the approach used by U.S. EPA (1995) in their exposure assessment for terrestrial plants. The approach is reasonable because off-site runoff will contaminate the off-site soil surface and could impact non-target plants. Percolation, on the other hand, represents the amount of the herbicide that is transported below the root zone and thus may impact water quality but should not effect off-site vegetation.

Based on the results of the GLEAMS modeling (Section 3.2.3.4.2), the proportion of the applied imazapic was estimated for clay, loam, and sand at rainfall rates ranging from 5 inches to 250 inches per year. These results are summarized in Worksheet G04.

4.2.3.4. Wind Erosion – Wind erosion is a major transport mechanism for soil (e.g., Winegardner 1996) and is associated with the environmental transport of herbicides (Buser 1990). Although numerous models were developed for wind erosion (e.g., Strek and Spaan 1997, Strek and Stein 1997), the quantitative aspects of soil erosion by wind are extremely complex and site specific. Field studies conducted on agricultural sites found that annual wind erosion may account for soil losses ranging from 2 to 6.5 metric tons/ha (Allen and Fryrear 1977). The upper range reported by Allen and Fryrear (1977) is nearly the same as the rate of 2.2 tons/acre (5.4 tons/ha) recently reported by the USDA (1998). The temporal sequence of soil loss (i.e., the amount lost after a specific storm event involving high winds) depends heavily on soil characteristics as well as meteorological and topographical conditions.

This risk assessment uses average soil losses ranging from 1 to 10 tons/ha·year, with a typical value of 5 tons/ha·year. The value of 5 tons/ha·year is equivalent to 500 g/m^2 [1 ton=1000 kg and 1 ha = 10,000 m^2] or 0.05 g/cm^2 [1m^2=10,000 cm^2]. Thus, using a soil bulk density of 1.5 g/cm^3

(Knisel et al. 1992, p. 56), the depth of soil removed from the surface per year would be 0.033 cm[(0.05 g/cm^2)÷ (1.5 g/cm^3)]. The average amount per day would be about 0.00007 cm/day [0.033 cm per year ÷ 365 days/year]. The upper range of the typical daily loss would thus be about 0.00009 cm/day.

The amount of imazapic that might be transported by wind erosion depends on several factors, including the application, the depth of incorporation into the soil, the persistence in the soil, the wind speed, and the topographical and surface conditions of the soil. Under desirable conditions, like relatively deep (10 cm) soil incorporation, low wind speed, and surface conditions that inhibit wind erosion, it is likely that wind transport of imazapic would be neither substantial or nor significant.

Any number of undesirable exposure scenarios could be constructed. As a reasonable 'worst case' scenario, it is assumed that imazapic is applied to arid soil, that it is incorporated into the top 1 cm of soil, that minimal rainfall occurs for a 2-month period, that the degradation and dispersion of imazapic in the soil is negligible over the 2-month period, and that local conditions favor a high rate of soil loss (i.e., smooth, sandy surface with high wind speeds) that is a factor at the upper limit of the typical rate (i.e., 0.00009 cm/day). Under those conditions, 0.0054 [0.00009 cm/day × 60 days ÷ 1 cm] of the applied imazapic would be lost due to wind erosion. This is between the estimates of off-site contamination that is expected to drift in aerial applications between 100 and 500 feet - i.e., 0.002 to 0.03 (Section 4.2.3.2).

The deposition of the imazapic contaminated soil also will vary substantially with local conditions. Under desirable conditions, the soil might be dispersed over a very large area and be of no toxicological consequence. In some cases, however, local topographical conditions might favor the deposition and concentration of contaminated dust from a large treated area into a relatively small off-site area. An objective approach for modeling these types of events was not available in the literature. For this risk assessment, neither concentration nor dispersion is considered quantitatively.

4.2.4. Aquatic Organisms. The potential for effects on aquatic species are based on estimated concentrations of imazapic in water that are identical to those used in the human health risk assessment (Section 3.2.3.4). Thus, for an accidental spill, the central estimate for the concentration of imazapic in a small pond is estimated at 0.95 mg/L with a range from 0.28 mg/L to 3.0 mg/L (Section 3.2.3.4.1). For longer term exposure scenarios, the expected concentrations of imazapic in ambient water range from about 0.000031 to 0.0037 mg/L with a central value of 0.00062 mg/L (Section 3.2.3.4.2).

4.3. DOSE-RESPONSE ASSESSMENT

4.3.1. Overview. For terrestrial mammals, the dose-response assessment is based on the same data as the human health risk assessment (i.e., an estimated NOAEL of 50 mg/kg/day based on a LOAEL of 150 mg/kg/day and the application of an uncertainty factor of 3 to extrapolate from the LOAEL to a NOAEL). All of the potential exposures of terrestrial mammals to imazapic are

substantially below this NOAEL. Consequently, a dose of 50 mg/kg/day is used to assess the consequences of all exposures. For birds, a NOAEL of 113 mg/kg bw/day is used from a subchronic feeding study that assayed for both signs of systemic toxicity as well as reproductive capacity. For terrestrial invertebrates, the dose-response assessment is based on a single study in honey bees in which a dose of 387 mg/kg bw caused no statistically significant increase in mortality.

Imazapic is a herbicide that causes adverse effects in a variety of target and non-target plant species. For exposures associated with direct sprays or drift, functional application rates as low as 0.001 lbs a.e./acre could be associated with growth inhibition in sensitive species and rates as high as 0.032 lbs a.e./acre could be a NOAEL in more tolerant species. With respect to soil contamination, functional application rates of 0.032 lb a.e./acre are used as a NOAEL for sensitive species.

Imazapic has a low order of toxicity to fish and aquatic invertebrates and exposures of up to 100 mg/L are not likely to be associated with mortality or reproductive effects based on the available data. Aquatic macrophytes are much more sensitive to imazapic than fish or invertebrates. For aquatic plants, a concentration of 0.004 mg/L, very close to the EC_{25} in an aquatic macrophyte, is used to assess the consequences of imazapic exposure for this group. This is probably a conservative approach because at least some species of freshwater algae may be much more tolerant, with LC_{50} values greater than 0.045 mg/L.

4.3.2. Toxicity to Terrestrial Organisms.

4.3.2.1. Mammals– As summarized in the dose-response assessment for the human health risk assessment (Section 3.3.3.), the functional NOAEL in experimental mammals is taken as 50 mg/kg/day. This is based on a LOAEL of 150 mg/kg/day and the application of an uncertainty factor of 3 to extrapolate from the LOAEL to a NOAEL. None of the exposure scenarios for mammals approach this estimated NOAEL (Table 4-1); thus, it is not necessary to elaborate on this dose-response assessment.

As detailed in Section 3.1.4, imazapic has also been assayed for reproductive effects in experimental mammals. The most relevant study for assessing the possible effects of imazapic on reproductive effects is the study by Schroeder (1994) in which two generations of rats were given imazapic in the diet at concentrations of up to 20,000 ppm.. No effects on reproductive effects were seen at the highest concentration, corresponding to daily doses of 1,200 to 1,700 mg/kg. For the risk characterization, the lower end of this range is used to characterize risks of adverse reproductive effects.

4.3.2.2. Birds – As noted in section 4.1.2.2, the most sensitive endpoint for imazapic in birds appears to be decreased body weight gain in chicks after the subchronic oral administration of imazapic to quail (Miller et al. 1998). The NOAEL for this effect - a dietary concentration of 1187 ppm corresponding to a dose of approximately 113 mg/kg bw/day - is thus used to assess the consequences of imazapic exposure in birds. As with mammals, the estimated exposures of

birds to imazapic are substantially below this NOAEL and further elaboration of the dose-response relationship is unnecessary.

4.3.2.3. Terrestrial Invertebrates– As discussed in Section 4.1.2.3, a standard bioassay was conducted on the toxicity of imazapic to honey bees (Hoxter et al. 1993). At the highest dose tested, 100 μg/bee, mortality was observed in 25% of the treated animals. At 36 μg/bee, mortality was not statistically significantly higher than controls. Using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993), the 36 µg/bee dose corresponds to 387 mg/kg bw [0.036 mg/0.000093 kg]. This value will be used in the risk characterization for assessing effects on terrestrial invertebrates. Given the large number of species of terrestrial invertebrates, the use of this single study on a single species obviously leads to uncertainty in the risk assessment.

4.3.2.4. Terrestrial Plants (Macrophytes)– As discussed in Section 4.1.2.4, two studies are available on the toxicity of imazapic to nontarget plants, one study involving pre-emergence applications (Chetram et al. 1994a) and the other involving post-emergence application (Chetram et al. 1994b).

For exposures involving the off-site drift of imazapic, the range of NOAEL values for post-emergence applications is used in the risk characterization - i.e., 0.001 lb/acre for cabbage, cucumber, and tomato and 0.032 for lettuce. This 32-fold range is intended to represent plausible differences between the most sensitive and most resistant non-target plant species.

For exposures involving off-site transport through runoff, direct deposition on the nontarget plants is less plausible and the exposures are more likely to occur through direct soil contamination. Thus, for this exposure scenario, the consequences of exposure are assessed using the most sensitive NOAEL for target plants - i.e., a NOAEL of 0.016 lb/acre for survival in ryegrass with a corresponding LOAEL for survival of 0.032 lb/acre. The least sensitive species is not used for these exposures because, as detailed in Section 4.4, none of the hazard quotients for less sensitive species do not exceed unity.

4.3.2.5. Terrestrial Microorganisms– As discussed in section 4.1.2.5, no information is available on the toxicity of imazapic to terrestrial microorganisms. Thus, no dose-response assessment for this group is possible.

4.3.3. Aquatic Organisms.

4.3.3.1. Animals– As indicated in sections 4.1.3.1 through 4.1.3.3 and detailed in Appendix 3, fish and aquatic invertebrates appear to have a similar sensitivity to imazapic. The available data indicate that exposures of up to 100 mg/L will not be associated with mortality or reproductive effects. This concentration is used to assess the potential effects on both fish and aquatic invertebrates.

4.3.3.2. Aquatic Plants– The relevant data on the toxicity of imazapic to aquatic plants is also summarized in Appendix 3. Aquatic macrophytes are much more sensitive to imazapic than fish

or invertebrates. The EC_{25} value for *Lemna gibba*, a freshwater macrophyte, based on decreased frond counts is 0.00423 mg/L, a factor of about 24,000 below the apparent NOAEL in fish and invertebrates. Thus, a concentration of 0.004 mg/L is used to assess the consequences of imazapic exposure to aquatic plants. As noted in Section 4.1.3.4, at least some species of freshwater algae may be much more tolerant than *Lemna gibba*, with LC50 values greater than 0.045 mg/L.

4.3.3.3. Aquatic Microorganisms– As with terrestrial microorganisms, no data are available on the toxicity of imazapic to aquatic microorganisms other than algae and a separate dose-response assessment cannot be made for this group.

4.4. RISK CHARACTERIZATION

4.4.1. Overview. None of the hazard quotients for mammals or birds approach a level of concern, even at the upper limit of exposure, for either signs of systemic toxicity or reproductive effects. The data on terrestrial invertebrates are limited to a single bioassay in honey bees. Based on this information, nonetheless, there is no basis for asserting that plausible levels of exposure to imazapic are likely to be acutely toxic to terrestrial invertebrates. Thus, as in the human health risk assessment, there is no basis for asserting that the use of imazapic in Forest Service programs will be associated with adverse effects on terrestrial animals.

For terrestrial plants, neither runoff nor drift appear to present a major hazard to nontarget species. For runoff, the highest hazard quotients are associated with loam at rainfall rates greater than or equal to 200 inches per year. For sensitive species in areas with high rates of rainfall, the hazard quotients are slightly above unity - e.g., the highest hazard quotient is about 1.8. The level of exposure, however, is still below the LOAEL. In arid environments - i.e., annual rainfall rates of about 15 inches per year or less - runoff of imazapic would result in exposures that are far below a level of concern. Hazard quotients for offsite drift indicate that, for relatively tolerant species, there is no indication that imazapic is likely to result in damage at distances of 100 feet from the application site after either aerial or ground applications. For sensitive species, the hazard quotient for aerial applications at 100 feet offsite is about 2 but falls to about 0.1 at a distance of 500 feet. Thus, for some sensitive species, visual injury might be observed at distances of approximately 100 feet from the application site after aerial applications. No effects are likely to be observed after ground applications even for sensitive species at distances greater than 500 feet from the application site.

For both the accidental spill scenario as well as estimates of imazapic in ambient water, the hazard quotients for aquatic animals lead to an unambiguous interpretation: there is no indication that aquatic organisms will be exposed to harmful levels of imazapic under the conditions of use specified by the Forest Service.

Like terrestrial plants, aquatic plants, particularly macrophytes, are much more sensitive than aquatic animals to imazapic exposure. In the case of an accidental spill into a small body of water, hazard quotients range from 70 to over 700 based on sensitive aquatic macrophytes. Thus, while

this exposure scenario is dominated by situational variability, it is plausible that the accidental spill of a substantial quantity of imazapic into a small body of water would lead to adverse effects on at least some aquatic plants. In the typical use of imazapic, however, the hazard quotients do not exceed the level of concern even under extremely conservative exposure assumptions - i.e., very high rates of rainfall and soil conditions that favor runoff. Thus, under normal and anticipated conditions of use, there is no indication that imazapic contamination of water will cause adverse effects even in sensitive aquatic macrophytes.

4.4.2. Terrestrial Organisms

4.4.2.1. Terrestrial Animals– The quantitative risk characterization for terrestrial animals is summarized in Table 4-2. For the mammals, the hazard quotients are based on the levels of exposure summarized in Table 4-1 and the long term NOAEL of 50 mg/kg/day for systemic toxicity (Section 4.3.2.1). For some exposure scenarios, risks are also characterized using the reproductive NOAEL of 1200 mg/kg/day (Section 4.3.2.1). Potential risks to birds are characterized using the NOAEL of 113 mg/kg/day from a subchronic feeding study (Section 4.3.2.2). This study (Schroeder 1994) assayed for both signs of systemic toxicity in adult birds as well as signs of reproductive impairment.

None of the hazard quotients for mammals or birds approach a level of concern, even at the upper limit of exposure, for either signs of systemic toxicity or reproductive effects. As detailed in Section 4.2.2, these exposure scenarios are based on exposure assumptions that are likely to overestimate exposure. For imazapic, further refinement of the exposure assessment would have little impact on the risk characterization because the hazard quotients are below a level of concern by factors of at least 10 for acute exposure scenarios (systemic toxicity in a large mammal consuming vegetation) and 100 for chronic exposure scenarios (reproductive effects in a large bird consuming vegetation).

For the honey bee, the hazard quotient is based on the non-lethal acute dose level of 387 mg/kg from the study by Hoxter et al. (1993). Even at the upper range of exposure associated with a direct spray, the hazard quotient is below the level of concern by a factor of about 12 - i.e., $1 \div 0.08 = 12.5$). Thus, there is not basis for expecting mortality in bees directly sprayed with imazapic.

The simple verbal interpretation of this quantitative risk characterization for terrestrial animals is similar to that of the human health risk assessment: the weight of evidence suggests that no adverse effects in terrestrial animals are plausible using typical or even very conservative worst case exposure assumptions. As with the human health risk assessment, this characterization of risk must be qualified. Imazapic has been tested in only a limited number of species and under conditions that may not well represent populations of free-ranging non-target animals. Given the very large number of nontarget terrestrial animal species and the limit requirements and capacity to testing nontarget species, this limitation is common to virtually all ecological risk assessments. Notwithstanding this limitation, the available data are sufficient to assert that no adverse effects

can be anticipated in terrestrial animals from the use of this compound in Forest Service programs.

4.4.2.2. Terrestrial Plants– The quantitative risk characterizations for terrestrial plants are summarized in Worksheet G04 for the offsite movement of imazapic in runoff and Worksheet G05 for offsite movement of imazapic by drift and wind erosion.

The runoff estimates are based on GLEAMS modeling using three different soils (clay, loam, and sand) at annual rainfall rates of 5 to 250 inches and using the highest application rate that the Forest Service is considering, 0.0624 lb a.e./acre. The toxicity index is based on the preemergence NOAEL for survival of 0.016 lb a.e./acre for the most sensitive species - i.e., rye grass. The highest hazard quotients - i.e., less than 1.8 - are associated with loam at rainfall rates greater than or equal to 200 inches per year. This is somewhat above the NOAEL but still below the LOAEL of 0.032 lb a.e./acre. Thus, while effects on sensitive plant species are plausible, it is also possible that no effects would be seen. In more arid environments - i.e., annual rainfall rates of about 50 inches per year or less - runoff of imazapic would result in exposures that are below a level of concern.

Hazard quotients for offsite drift (Worksheet G05) are based on the NOAEL values for both sensitive species, 0.001 lb a.e./acre, as well as the NOAEL for tolerant species, 0.032 lb a.e./acre. As discussed in Section 4.2.2.4, the estimates for offsite drift encompass plausible exposures attributable to wind erosion. For relatively tolerant species, there is no indication that imazapic is likely to result in damage at distances of 100 feet from the application site after either aerial or ground applications. For sensitive species, the hazard quotient for aerial applications at 100 feet offsite is about 2 but falls to about 0.1 at a distance of 500 feet. Thus, for some sensitive species, visual injury might be observed at distances of approximately 100 feet from the application site after aerial applications. No effects are likely to be observed after ground applications.

4.4.3. Aquatic Organisms. The quantitative risk characterization for aquatic species is summarized in Table 4-3. As in the drinking water scenarios in the human health risk assessment, exposures to aquatic organisms are given for both an accidental spill as well as ambient concentrations of imazapic that could be expected in ambient water.

For both the accidental spill scenario as well as estimates of imazapic in ambient water, the hazard quotients for aquatic animals lead to an unambiguous interpretation: there is no indication that aquatic organisms will be exposed to harmful levels of imazapic under the conditions of use specified by the Forest Service. While the accidental spill scenario is dominated by situational variability, the spill scenario leads to hazard quotients that are factors of 33 to 333 below a level of concern. For ambient exposures that could be plausibly anticipated in the use of imazapic by the Forest Service, hazard quotients are below the level of concern by factors of 25,000 to over 3 million.

Like terrestrial plants, aquatic plants, particularly macrophytes, are much more sensitive than aquatic animals to imazapic exposure. In the case of an accidental spill into a small body of water, hazard quotients range from 70 to over 700. Thus, while this exposure scenario is dominated by situational variability, it is plausible that the accidental spill of a substantial quantity of imazapic into a small body of water would lead to adverse effects on at least some aquatic plants. In the typical use of imazapic, however, the hazard quotients do not exceed the level of concern even under extremely conservative exposure assumptions - i.e., very high rates of rainfall and soil conditions that favor runoff. Thus, under normal and anticipated conditions of use, there is no indication that imazapic contamination of water will cause adverse effects even in sensitive aquatic macrophytes.

Table 4-1: Summary of Exposure Scenarios for Terrestrial Animals.

Scenario	Dose (mg/kg/day)			Worksheet
	Typical	Lower	Upper	
Acute/Accidental Exposures				
Direct spray				
small mammal, first-order absorption	0.039	0.008	0.100	WSF01
small animal, 100% absorption	2	1	2	WSF02
bee, 100% absorption	10	5	10	WSF03
Contaminated vegetation				
small mammal	0.3	0.2	1	WSF04
large mammal	0.4	0.2	2	WSF10
large bird	0.7	0.3	2	WSF12
Contaminated water				
small mammal	0.2	0.07	0.8	WSF06
Contaminated insects				
small bird	1.7	0.1	3.0	WSF14
Contaminated fish				
predatory bird	0.010	0.0015	0.050	WSF08
Longer-term Exposures				
Contaminated vegetation				
small mammal	4.00e-04	1.70e-06	6.79e-06	WSF05
large mammal	1.54e-03	2.57e-04	1.83e-02	WSF10
large bird	2.43e-03	4.06e-04	2.89e-02	WSF13
Contaminated water				
small mammal	2.00e-04	8.00e-06	1.00e-03	WSF07
Contaminated fish				
predatory bird	6.86e-06	1.72e-07	6.18e-05	WSF09

Table 4-2: Summary of quantitative risk characterization for terrestrial animals[1]

Scenario	Hazard Quotient[2] Typical	Lower	Upper
Acute/Accidental Exposures			
Direct spray			
small mammal, first-order absorption	8e-04	2e-04	2e-03
small animal, 100% absorption	3e-02	2e-02	3e-02
bee, 100% absorption	1e-02	5e-03	1e-02
Contaminated vegetation			
small mammal, toxicity	7e-03	3e-03	2e-02
small mammal, reproduction	3e-04	1e-04	1e-03
large mammal, toxicity	9e-03	4e-03	3e-02
large mammal, reproduction	4e-04	2e-04	1e-03
large bird, reproduction	6e-03	3e-03	2e-02
Contaminated water			
small mammal, toxicity	5e-03	1e-03	2e-02
small mammal, reproduction	2e-04	6e-05	6e-04
Contaminated insects			
small bird, reproduction	2e-02	7e-04	3e-02
Contaminated fish			
predatory bird, reproduction	2e-02	7e-04	4e-04
Longer-term Exposures			
Contaminated vegetation			
small mammal, toxicity	8e-06	3e-08	1e-07
small mammal, reproduction	3e-07	1e-09	6e-09
large mammal, toxicity	3e-05	5e-06	4e-04
large mammal, reproduction	1e-06	2e-07	2e-05
large bird, reproduction	2e-05	4e-06	1e-02
Contaminated water			
small mammal	4e-06	2e-07	1e-03
Contaminated fish			
predatory bird	6e-08	2e-09	6e-02
Toxicity Indices [3]			
General toxicity value for mammal - NOAEL		50	mg/kg/day
Reproductive toxicity value for mammal - NOAEL		1200	mg/kg/day
Reproductive toxicity value for bird - NOAEL		113	mg/kg/day
Toxicity value for bee - $<LD_{50}$		1075	mg/kg

[1] See Worksheet G01 (Table 4-1 in text) for summary of exposure assessment.
[2]Estimated dose ÷ toxicity index
[3] See Section 4.3 for a discussion of the toxicity indices.
[4] Calculated as a LD_{50} >0.1 mg/ 0.000093 kg bee. At this exposure level, 25% mortality was observed (Section 4.1.2.3).

Table 4-3: Quantitative Risk Characterization for Aquatic Species.

Risk Quotients	**Central**	**Lower**	**Upper**	**Endpoint**
Fish				
Acute	9e-03	3e-03	3e-02	Mortality
Chronic	7e-06	3e-07	4e-05	LOAEL
Aquatic Invertebrates				
Acute	9e-03	3e-03	3e-02	Mortality
Chronic	6e-06	3e-07	4e-05	NOAEL
Aquatic Plants				
Acute (spill)	**237**	**70**	**757**	NOEC
Chronic (ambient)	0.2	0.008	0.9	NOEC

Exposures (mg/L)	Central	Lower	Upper	Worksheet
Acute	0.95	0.28	3.0	F08/D03[1]
Longer-term	0.00062	0.000031	0.0037	F09

Toxicity values (mg/L)			
	Value (mg/L)	Endpoint	Section
Fish, acute	100	Mortality	4.3.3.2.
Fish, chronic	96	Growth and development	4.3.3.2.
Aquatic Invertebrates, acute	100	Mortality	4.3.3.3
Aquatic Invertebrates, chronic	100	No data found. Acute value used.	4.3.3.3
Aquatic plants	0.004	Frond counts EC_{25}	4.3.3.4.

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Yurk J; Ward G; Wisk J. 1993a. Acute Toxicity of AC 263,222 to Rainbow Trout (Oncorhynchus mykiss) under Static Test Conditions: Lab Project Number: 3923013-0600: 954-92-118. Unpublished study prepared by Environmental Science & Engineering, Inc. 71 p. MRID No. 42711435

Yurk J; Ward G; Wisk J. 1993b. Acute Toxicity of AC 263,222 to Water Flea (Daphnia magna) under Static Test Conditions: Lab Project Number: 3913013-0200: 954-92-117. Unpublished study prepared by Environmental Science & Engineering, Inc. 69 p. MRID No. 42711437

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Appendix 1: Toxicity of Imazapic to experimental mammals

Animal	Dose/Exposure	Response	Reference
ORAL -acute			
Rats, Sprague-Dawley albino, 5 males, 5 females, 7 weeks old at time of testing	single gavage dose of 5000 mg/kg bw of AC 263222 technical in corn oil. Observation period of 14 days.	No signs of toxicity, no effects on body weight gains, no gross pathological changes at time of termination. LD_{50} >5000 mg/kg bw	Lowe 1992 MRID 42711407
Rats, Sprague-Dawley, 5 males and 5 females/ dose group, 8-9 weeks old at start of test	single exposure to 5000 mg/kg bw AC 263222 2 ASU formulation by gavage. Observation period of 14 days.	No overt signs of mortality or toxicity, no changes in body weight gain, no significant gross lesions at necropsy. LD_{50} >5000 mg/kg bw	Fischer 1993 MRID 42711413
ORAL -subchronic			
Rats, Charles River, 4 weeks old, weighing 85-99 g (males) and 79-91 g (females) 20/sex/dose group	0, 5000, 10,000, or 20,000 ppm AC 263222 in diet for 13 consecutive weeks. Average doses for both sexes combined were 0, 408, 804, or 1625 mg/kg bw.	No mortality; no overt signs of toxicity; no effects on food consumption or total body weight gain; no hematological effects, no significant ($p<0.05$) changes in absolute or relative organ weights; and no gross or microscopic changes associated with test material.	Fischer 1992 MRID 42711419
ORAL -reproduction/teratology			
Rats, Charles River, mated females, 25/dose group	0, 250, 500, or 1000 mg/kg/day AC 263222 in corn oil by gavage on days 6 through 15 of gestation (single daily dose).	No maternal toxicity observed at any dose level. No evidence of fetotoxicity, embryotoxicity, or aberrant fetal development at any dose level. NOEL = 1000 mg/kg/day for developmental toxicity	Shardein 1992 MRID 42711422

Appendix 1: Toxicity of Imazapic to experimental mammals

Animal	Dose/Exposure	Response	Reference
ORAL -reproduction/teratology *(continued)*			
Rats, Sprague-Dawley, 56 days old, 30/sex/dose group	**P_1 generation**: dietary concentration of 0, 5000, 10,000, or 20,000 ppm AC 263222 for 14 weeks prior to mating and continuing until P_1 animals were sacrificed **F_1 generation**: dietary concentration of 0, 5000, 10,000, or 20,000 ppm AC 263222 for 14 weeks prior to mating and continuing until F_1 animals were sacrificed	No treatment related adverse effects on parental parameters (mortality, body weight, food consumption, physical examination data, gestation body weight and food consumption data, and lactation body weights), reproductive performance or parturition data were observed in either generation (P_1, F_1) at dietary concentrations up to 20,000 ppm. Similarly, no adverse effect of treatment at a dietary level up to 20,000 ppm was observed during either litter interval (F_1, F_2) with respect to pup growth, survival, or development. NOEL (for parental and reproductive toxicity in 2-generation reproduction study) = 20,000 ppm (equivalent to 1205-1703 mg/kg/day). Used 1200 mg/kg bw as reproductive NOAEL in risk assessment.	Schroeder 1994 MRID 43320305
Rabbits, New Zealand white, inseminated females, 20/dose group	0, 175, 350, 500, or 700 mg/kg bw AC 263222 in 0.4% carboxymethyl-cellulose on days 7 through 19 of gestation	**NOEL for maternal toxicity = 500 mg/kg** based on increased mortality at highest dose level (i.e., 700 mg/kg) **NOEL for embryo/fetotoxicity and tertogenicity = 700 mg/kg**	MacKenzie 1992 MRID 42711423

Additional notes on MacKenzie 1992 : Survival rate: 95%(controls), 80% (175 mg/kg) 75%(350 and 500 mg/kg), and 40% (700 mg/kg). [Note: The U.S. EPA (1996) summary gives somewhat different survival rates. The survival rates reported here are from Table 1, p. 23, of the full study.] Overall pregnancy = 90-100% for study. At 700 mg/kg there was an increased incidence of "few or no feces," attributed to treatment. Food consumption was significantly lower in the 700 mg/kg group on days 9-19; at 500 mg/kg food consumption was significantly lower on days 15 and 16. *All treated animals that died during the study had one or a combination of the following effects: oral discharge, nasal discharge, fluid-filled trachea and or lungs, reddened trachea, and stomach lesions.*

Appendix 1: Toxicity of Imazapic to experimental mammals

Animal	Dose/Exposure	Response	Reference
ORAL -chronic			
Rats, Sprague-Dawley, 5 weeks old, weighing 125-170 g (males) and 113-152 g (females), 65/sex/dose group	0, 5000, 10,000, or 20,000 ppm AC 263222 in diet for 24 consecutive months (10/sex/dose group sacrificed at 12 months).	No overt signs of toxicity; no adverse effects on mortality, food consumption, total body weight gain, hematological parameters, absolute or relative organ weight changes, and no gross or microscopic changes attributable to treatment with AC 263222 in any tissue. NOEL for chronic toxicity and carcinogenicity >20,000 ppm (equivalent to an average daily intake of >1029-1237 mg/kg bw).	Fischer 1994a MRID 43320307
Mice, Charles River CD-1, 6 weeks old, weighing 23.0-37.0 g (males) and 21.6-30.8 g (females), 65/ sex/dose group	0, 1750, 3500, or 7000 ppm AC 263222 in the diet for 18 consecutive months (10/sex/dose group sacrificed at 12 months).	No overt signs of toxicity; no adverse effects on mortality, food consumption, total body weight gain, hematological parameters, absolute or relative organ weight changes, and no gross or microscopic changes attributable to treatment with AC 263222 in any tissue. NOEL for chronic toxicity or carcinogenicity >7000 ppm (equivalent to an average daily intake of >1134-1442 mg/kg bw).	Fischer 1994b MRID 43320306
Dogs, beagle, 6-6.5 months old, 6/sex/group, weighing 8.3-10.9 kg (males) and 6.6-8.9 kg (females)	Dietary concentrations of 0, 5000, 20,000, or 40,000 ppm (equivalent to daily doses averaged for both sexes of 0, 158.5, 517.5, or 1116.5 mg/kg) AC 263222 for 1 year.	At 40,000 ppm toxic effects included vomiting, increased salivation, decreased body weight and food consumption. Degeneration of esophageal muscle in females. Decreased hemoglobin and increased macrocytes, poikilocytes, polychromatic cells, and target cells in blood as well as increased incidence of congestion of the bone marrow. Biochemical markers for liver damage. At 20,000 ppm, effects on the target organs were observed, but the effects were less severe than at the higher dose. At 5000 ppm, the only effect observed was minimal skeletal muscle effects determined microscopically in individual muscle fibers. These effects occurred in only a few fibers/tissue section and were not observed consistently in all skeletal muscle sites/animal. Furthermore, the effects occurred in the absence of serum chemistry changes or associated clinical observations.	Wolford 1993 MRID 42711421

Appendix 1: Toxicity of Imazapic to experimental mammals

Animal	Dose/Exposure	Response	Reference
DERMAL			
Guinea pigs, Hartley, males, 400-438 g, 10 treated, 10 naive controls, 10 positive controls (DNCP)	Induction phase: 0.43 g AC 263222 applied to intact skin 3 times a week for 6 hours (total of 9 applications to same test site). Challenge phase took place after 2-week respite. Test material was applied to clipped area on right flank for 6 hours.	AC 263222 is not a skin irritant, fatiguing agent, or skin sensitizer.	Costello 1992 MRID 42711412
Guinea pigs, Hartley, males, 362-600 g, 10 treated, 10 naive controls, 10 positive controls (DNCP)	Induction phase: 0.4 mL AC 263222 2ASU formulation applied to intact skin 3 times a week for 6 hours (total of 9 applications to same test site). Challenge phase took place after 2-week respite. Test material was applied to clipped area on right flank for 6 hours.	AC 263222 2ASU formulation is not a primary skin irritant or skin sensitizer in albino guinea pigs.	Reilly 1992 MRID 42711418
Rabbits, New Zealand white, 5 males and 5 females, mean body weight 3.07 (males) and 2.85 (females) at start of test	5000 mg/kg AC 263222 2ASU formulation applied to intact skin (approximately 10% of total body surface area) for continuous, occluded 24-hour contact.	LD_{50} >5000 mg/kg bw Category = Class IV (nontoxic)	Fischer 1987a MRID 42711414
Rabbits, New Zealand white, 5 males, 5 females, 10-16 weeks old	single topical application of 2000 mg/kg bw AC 263222 technical to intact skin for 24 hours. Test site occluded for duration of exposure. 14-day observation period.	No overt signs of toxicity, no changes in body weight gain, no gross pathological changes at termination of study. LD_{50} >2000 mg/kg bw	Lowe 1993c MRID 42711408

Appendix 1: Toxicity of Imazapic to experimental mammals

Animal	Dose/Exposure	Response	Reference
DERMAL *(continued)*			
Rabbits, New Zealand white, 6 males	0.5 mL AC 263222 2ASU formulation applied to intact skin covered with occlusive wrapping for 4 hours, after which remaining test material was removed with tap water. 72-hour observation period.	Two treated animals had diarrhea at 4 hours after dosing but not at any other observation period. There were no other overt signs of toxicity. AC 263222 2ASU formulation was not irritating to rabbit skin.	Fischer 1987b MRID 42711417
Rabbits, New Zealand white, 2.44-3.27 g, 6 males and 6 females per dose group	topical application of 0, 250, 500, or 1000 mg/kg (adjusted level for 93.7 % purity was 0, 266.8, 533.6, or 1067.2 mg/kg) AC 263222 to approximately 10% body surface (clipped) 5/days/week for 3 consecutive weeks.	No treatment related effects on any endpoints tested. NOEL = 1000 mg/kg bw (highest dose tested)	Moore 1992 MRID 42711420
Rabbits, New Zealand white, 6 males, 10-16 weeks old at start of test	0.5 g AC 263222 technical applied to intact, shaved skin using 1" square gauze pad for 4 hours, followed by tap water removal of testing material.	At 1 hour, erythema was barely perceptible in 2/6 animals. All signs of irritation resolved at 24 hours. There were no overt signs of toxicity during the course of the study.	Lowe 1993b MRID 42711411
INHALATION			
Rats, outbred Sprague-Dawley, 231-298 g, 10 males, 10 females	4-hour exposure to 3.65 or 4.83 mg/L (mass median aerodynamic diameter of 6.47 or 8.28 μm)	LC_{50} >4.83 mg/L [Note: U.S. EPA (1996) indicates that the concentration was 5.52 mg/L. The highest concentration reported in the study is 4.83 mg/L analytical corresponding to a gravimetric concentration of 5.31 mg/L. Table 1(b), p. 13 on fiche.] Animals evidenced signs of distress - eye clenching and huddling - and were covered with dust. No signs of toxicity.	Hershman 1993a MRID 42711409
Rats, outbred Sprague-Dawley, 210-279 g, 10 males, 10 females	4-hour exposure to 2.38 mg/L (mass median aerodynamic diameter of 1.97μm)	LC_{50} >2.38 mg/L. Congested lungs noted in 2 males and 1 female. No mortality or overt signs of toxicity.	Hershman 1993b MRID 42711415

Appendix 1: Toxicity of Imazapic to experimental mammals

Animal	Dose/Exposure	Response	Reference
OCULAR			
Rabbits, New Zealand white, 6 males	instillation of 0.1 g AC 263222 2ASU formulation into left conjunctival sac of each rabbit (right eyes served as controls) for 24-hour exposure. Eyes examined at -4 (pretreatment), 1, 24, 48, and 72 hours	At 1 hour after treatment, 4/6 animals had slight redness of the conjunctivae; at 24 hours, all irritation had resolved. No signs of irritation were observed at 48 or 72 hours. AC 263222 2ASU formulation was not irritating to the rabbit eye.	Fischer 1987c MRID 42711416
Rabbits, New Zealand white, 6 females, 10-16 weeks old	instillation of 0.1 g AC 263222 into left conjunctival sac of each rabbit (right eyes served as controls) for 24-hour exposure. Eyes examined at -4 (pretreatment), 1, 24, 48, and 72 hours	No overt signs of toxicity. Eye irritation at 1 hour: slight (3/6) to moderate (3/6) redness of conjunctivae, slight (4/6) to moderate (2/6) chemosis, and moderate (5/6) to copious (1/6) ocular discharge. Eye irritation at 24 hours: scattered and diffuse areas of corneal involvement (2/6), moderate redness of the conjunctivae (3/6), slight redness of the conjunctivae (3/6), slight chemosis (6/6), and no ocular discharge (4/6) to slight ocular discharge (2/6). Eye irritation at 48 hours: scattered and diffuse corneal opacity (2/6), slight conjunctival irritation (6/6), and slight chemosis (1/6) At 72 hours, all signs of irritation had resolved. AC 263222 produced moderate irritation to the rabbit eye; category III.	Lowe 1993a MRID 42711410

Appendix 2: Toxicity of Imazapic to birds.

Animal	Dose	Response	Reference
ORAL			
Ducks, Mallard, 20 weeks and 1 day old at start, weighing 875-1390 g (males) and 841-1208 g (females), 3 groups of 16 males and 16 females/group, 1 control group of 16 males and 16 females.	Dietary administration of imazapic (AC 263222) in nominal concentrations of 0, 650, 1300, or 1950 ppm (equivalent to mean measured concentrations of 538, 994, or 1658 ppm)for 22 weeks and 3 days.	No mortality, no signs of toxicity, no treatment-related effects on body weight, food consumption, or gross pathology. No treatment-related effects on reproduction endpoints (i.e., egg production, hatchability, survival of hatchlings). NOEC = 1658 ppm	Mortensen et al. 1998 MRID 44638101
Ducks, Mallard (*Anas platyrhynchos*) 44-59 weeks old, 10 per dose group.	single gavage dose of 0, 1470, or 2150 mg/kg bw AC 263222 technical in tap water. Observation period of 20 days.	No mortality; no clinical signs of toxicity other than a slight decrease in food consumption at 2150 mg/kg. No gross pathological findings at necropsy. NOEL (based on mortality) = 2150 mg/kg bw NOEL (based on clinical signs [i.e., decreased food consumption]) = 1470 mg/kg bw LD_{50} >2150 mg/kg bw	Fletcher and Sullivan 1993b MRID 42711430
Ducks, Mallard (*Anas platyrhynchos*) 7 days old, 10 per dose group	nominal dietary concentrations of 0, 312, 625, 1250, 2500, or 5000 ppm AC 263222 for 5 consecutive days; test terminated after 8 days.	No mortality; no clinical signs of toxicity; no unusual gross pathological findings. NOEC = 5000 ppm LC_{50} >5000 ppm	Pedersen et al. 1993b MRID 42711433

Appendix 2: Toxicity of Imazapic to birds.

Animal	Dose	Response	Reference
ORAL			
Quail, Northern bobwhite (*Colinus virginianus*), 20 weeks and 1 day old at start, weighing 180.2-271.5 g (males) and 185.7-274.5 g (females), 3 groups of 19 males and 19 females/ group, 1 control group of 19 males and 19 females.	Dietary administration of imazapic (AC 263222) in nominal concentrations of 0, 650, 1300, or 1950 ppm (equivalent to mean measured concentrations of 607, 1187, or 1907 ppm) for 24 weeks and 2 days. Controls received acetone vehicle only in diet. Mean food consumption was about 20 g/bird with a range of about 15 to 30 g/bird over the 24 weeks (Table II, p. 26). Mean body weight was about 230 g/bird. Thus, the approximate fractional food consumption was 0.087 g food/g bw. This is used to convert ppm to mg/kg bw.	No mortality, no signs of toxicity, no treatment-related effects on body weight, food consumption, or gross pathology. Statistically significant reduction in 14-day hatchling body weights in the 1950 ppm group; no treatment-related effects on other reproduction endpoints (i.e., egg production, hatchability, survival of hatchlings). NOEC = 1300 ppm Approx. 113 mg/kg bw LOAEL = 1950 ppm Approx. 170 mg/kg bw	Miller et al. 1998 MRID 44638102
Quail, bobwhite, (*Colinus virginianus*), 23 weeks old, 10 per dose group	single gavage dose of 0, 1470, or 2150 mg/kg bw AC 263222 technical in tap water. Observation period of 20 days.	No mortality; no clinical signs of toxicity; no statistically significant differences in body weight; no differences in food consumption. NOEL = 2150 mg/kg bw LD_{50} >2150 mg/kg bw	Fletcher and Sullivan 1993a MRID 42711431
Quail, bobwhite, (*Colinus virginianus*), 10 days old, 10 per dose group	nominal dietary concentrations of 0, 312, 625, 1250, 2500, or 5000 ppm AC 263222 for 5 consecutive days; test terminated after 8 days.	No mortalities; no clinical signs of toxicity, no gross or pathological findings at necropsy. NOEC = 5000 ppm LC_{50} (dietary) >5000 ppm	Pedersen et al. 1993a MRID 42711432

Appendix 3: Toxicity of imazapic to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Fish			
Channel catfish (*Ictalurus punctatus*), juvenile, ~0.78 g, 34-47 mm long, 10 per dose group	nominal concentration of 0 or 100 mg/L AC 263222 for 96 hours under static test conditions	96-hour LC_{50} >100 mg/L	Yurk et al. 1992b MRID 42711436
Bluegill sunfish (*Lepomis macrochirus*), juvenile, ~0.44 g, 25-34 mm long, 10 per dose group	nominal concentration of 0 or 100 mg/L AC 263222 for 96 hours under static test conditions	96-hour LC_{50} >100 mg/L	Yurk et al. 1992a MRID 42711434
Bluegill sunfish (*Lepomis macrochirus*)	0.5 ppm ^{14}C-CL 263222 for 28 days under flow-through conditions	^{14}C-CL 263222 does not bioaccumulate in fish. BCF 0.11 ± 0.02. Time to 90% steady state 3 days. K_1 = 0.081 mg/kg fish per mg/L. K_2 = 0.77 per day. Time to 50% depuration 0.91 days.	Robinson 1994 MRID 433320315
Rainbow trout (*Oncorhynchus mykiss*), juvenile, ~2.11 g, 36-60 mm long, 10 per dose group	nominal concentration of 0 or 100 mg/L AC 263222 for 96 hours under static test conditions	96-hour LC_{50} >100 mg/L	Yurk et al. 1993a MRID 42711435
Fathead minnow (*Pimephales promelas*), less than 24-hours old at start, 5 groups of 80 minnows plus negative control group	Nominal concentrations of 0, 6.3, 13, 25, 50, or 100 mg a.i./L (equivalent to mean measured concentrations of 5.7, 12, 25, 46, or 96 mg a.i./L) AC 263222 for 32 days.	No treatment related effects on time to hatch, hatching success, survival or growth of minnow for 28 days post-hatch. NOEC = 96 mg a.i./L LOEC and MATC >96 mg a.i./L	Barker et al. 1998a MRID 44728202
Sheepshead minnow (*Cyprinodon variegatus*), juvenile, 13-22 mm long, wet weight of 0.05-0.32 g	Nominal concentrations of 0, 6.25, 12.5, 25.0, 50.0, or 100 mg/L AC 263222 (equivalent to mean measured concentrations of 4.74, 10.4, 24.4, 47.3, or 98.7 mg/L) for 96 hours under flow-through conditions.	96-hour LC_{50} >98.7 mg/L	Barker and Skorczynski 1998 MRID 44817702

Appendix 3: Toxicity of imazapic to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Invertebrates			
Oysters, Eastern (*Crassostrea virginica*), umbo to distal valve edge length 33-49 mm, wet tissue weight 0.92-2.64 g, 20 oysters per group.	Nominal concentrations of 0, 6.25, 12.5, 25.0, 50.0, or 100 mg/L (equivalent to mean measured concentrations of 4.43, 9.70, 21.5, 47.2, or 99.2 mg/L) AC 263222 for 96 hours under flow-through conditions.	No statistical differences in new shell deposition in treated oysters compared with controls. 96-hour EC_{50} >99.2 mg/L NOEC = 99.2 mg/L	Barker and Liu 1998b MRID 44817703
Shrimp, Mysid (*Mysidopsis bahia*), post-larval, less than 24 hours old	Nominal concentrations of 0, 6.25, 12.5, 25.0, 50.0, or 100 mg/L (equivalent to mean measured concentrations of 4.63, 10.1, 21.9, 46.7, or 97.7 mg/L) AC 263222 for 96 hours under flow-through conditions.	96-hour EC_{50} >97.7 mg/L NOEC = 97.7 mg/L	Barker and Liu 1998a MRID 44817704
Water flea (*Daphnia magna*), <24 hours old, 10 per dose group	nominal concentration of 0 or 100 mg/L AC 263222 for 48 hours under static test conditions	48-hour LC_{50} >100 mg/L 48-hour NOEC = 100 mg/L	Yurk et al. 1993b MRID 42711437

Appendix 3: Toxicity of imazapic to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Aquatic Plants			
Anabaena flos-aquae, freshwater blue-green algae	Nominal concentration of 50.8 μg/L (mean measured concentration 49.9 μg/L) AC 263222 (equivalent to direct application of maximum label rate of 0.064 lbs a.i./acre to 15 cm column of water) for 5 days.	Test substance resulted in 11.9% growth inhibition, compared with controls. There were no treatment related effects on the size of shape of algal cells. EC_{50} >67.4 μg/L (mean measured concentration)	Hughes et al. 1994 MRID 43320310
Selenastrum capricomutum, algae	Nominal concentration of 50.8 μg/L (mean measured concentration 49.9 μg/L) AC 263222 (equivalent to direct application of maximum label rate of 0.064 lbs a.i./acre to 15 cm column of water) for 5 days.	Test substance resulted in 0.18% growth inhibition EC_{50} >52.3 μg/L (mean measured concentration)	Hughes et al. 1994 MRID 43320310
Skeletonema costatum, algae	Nominal concentration of 50.0 μg/L (mean measured concentration 49.9 μg/L) AC 263222 (equivalent to direct application of maximum label rate of 0.064 lbs a.i./acre to 15 cm column of water) for 5 days.	Test substance resulted in 0.777% growth stimulation. EC_{50} >45.0 μg/L (mean measured concentration)	Hughes et al. 1994 MRID 43320310
Navicula pelliculosa, algae	Nominal concentration of 50.4 μg/L (mean measured concentration 49.9 μg/L) AC 263222 (equivalent to direct application of maximum label rate of 0.064 lbs a.i./acre to 15 cm column of water) for 5 days.	Test substance resulted in 32.9% growth inhibition, if data from all 4 replicates are used. If outlier data are omitted, growth inhibition is 11.1%. EC_{50} >67.3 μg/L (mean measured concentration)	Hughes et al. 1994 MRID 43320310
Lemna gibba (Duckweed) macrophyte	Active ingredient concentrations of AC 263222 ranging from 1.27 to 20.1 μg/L (mean measure concentrations ranged from 1.22 to 12.5 μg/L) for 14 days. Static test.	Frond counts. EC_{25} = 4.23 μg/L (3.82-4.69 μg/L = 95%CL) EC_{50} = 6.10 μg/L (5.69-6.53 μg/L = 95%CL)	Hughes et al. 1994 MRID 43320310

WORKSHEETS FOR
Imazapic

NOTES on Imazapic Worksheets:
For hydraulic ground spray, Worksheet A03b, the values for the acres treated per hour are less than the typical rates of 11 to 21 acres per hour used in many herbicide exposure assessments (USDA 1989a,b,c). See section 2.3 of the risk assessment.

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GENERAL ASSUMPTIONS, VALUES, and MODELS

Worksheet A01: Constants and conversion factors used in calculations [CONST]		
Conversion	ID	Value
mg/lb	mg_lb	453,600
mL/gallon	ml_gal	3,785
lb/gallon to mg/mL	lbg_mgml	119.8
lb/acre to µg/cm^2	lbac_ugcm	11.21
lb/acre to mg/cm^2	lbac_mgcm	0.01121
gallons to liters	gal_lit	3.785

Worksheet A02: General Assumptions Used in Worker Exposure Assessments [STD]				
Parameter	ID	Value	Units	Reference
Body Weight (General)	BW	70	kg	ICRP (1975), p. 13
Surface area of hands	Hands	840	cm^2	U.S. EPA 1992
Surface area of lower legs	LLegs	2070	cm^2	U.S. EPA 1992
Weight of liquid adhering to surface of skin after a spill	Liq	0.008	mL/cm^2	Mason and Johnson 1987

Worksheet A03a: Directed Ground Sprays (includes backpack, cut surface, and streamline applications) - General Assumptions Used in Worker Exposure Assessments [BACKPACK]

Parameter/Assumption	ID	Value	Units	Reference
Hours of application per day				
Central estimate		7	hours	USDA 1989a,b,c
Lower estimate		6		
Upper estimate		8		
Acres treated per hour				
Central estimate		0.625	acres/hour	USDA 1989a,b,c
Lower estimate		0.25		
Upper estimate		1		
Acres treated per day				
Central estimate	ACREC	4.375	acres/day	N/A[1]
Lower estimate	ACREL	1.5		
Upper estimate	ACREU	8		
Absorbed dose rate (mg/day)				
Central estimate	RATEC	0.003	(mg agent/kg bw) ÷ (lbs agent handled per day)[2]	SERA 2000
Lower estimate	RATEL	0.0003		
Upper estimate	RATEU	0.01		

[1] Calculated as the product of the number of hours of application and the number of acres treated per hour for each category - i.e., central estimate, lower estimate, and upper estimate.

[2] "Agent" refers to the material being handled and may be expressed in units of a.i. or a.e. Depending on the agent under consideration, additional exposure conversions may be made in the exposure assessment and dose response assessment. For the risk assessment, the only important point is that the exposure and dose/response assessments must use the same units - that is, a.i., a.e., etc. - or the units must be converted to some equivalent form in the risk characterization.

Worksheet A03b: Hydraulic/Broadcast Ground Sprays - General Assumptions Used in Worker Exposure Assessments [HYDSPRAY]

Parameter/Assumption	ID	Value	Units	Reference
Hours of application per day				
Central estimate		7	hours	USDA 1989a,b,c
Lower estimate		6		
Upper estimate		8		
Acres treated per hour				
Central estimate		4	acres/hour	See section 2.3. These values are less than the typical rates of 11 to 21 acres per hour used in many herbicide exposure assessments (USDA 1989a,b,c).
Lower estimate		2		
Upper estimate		6		
Acres treated per day				
Central estimate	ACREC	28	acres/day	N/A[1]
Lower estimate	ACREL	12		
Upper estimate	ACREU	48		
Absorbed dose rate				
Central estimate	RATEC	0.0002	(mg agent/kg bw) ÷ (lbs agent handled per day) [2]	SERA. 2000
Lower estimate	RATEL	0.00001		
Upper estimate	RATEU	0.0009		

[1] Calculated as the product of the number of hours of application and the number of acres treated per hour for each category - i.e., central estimate, lower estimate, and upper estimate.

[2] "Agent" refers to the material being handled and may be expressed in units of a.i. or a.e. Depending on the agent under consideration, additional exposure conversions may be made in the exposure assessment and dose response assessment. For the risk assessment, the only important point is that the exposure and dose/response assessments must use the same units - that is, a.i., a.e., etc. - or the units must be converted to some equivalent form in the risk characterization.

Worksheet 03c: Aerial Broadcast Sprays (includes pilots, mixers, and loaders) - General Assumptions Used in Worker Exposure Assessments.[AERIAL]

Parameter/Assumption	Code	Value	Units	Reference
Hours of application per day				
Central estimate		7	hours	USDA 1989a,b,c
Lower estimate		6		
Upper estimate		8		
Acres treated per hour				
Central estimate		70	acres/hour	USDA 1989a,b,c
Lower estimate		40		
Upper estimate		100		
Acres treated per day				
Central estimate	ACREC	490	acres/day	N/A[1]
Lower estimate	ACREL	240		
Upper estimate	ACREU	800		
Absorbed dose rate				
Central estimate	RATEC	0.00003	(mg agent/kg bw) ÷ (lbs agent handled per day)[2]	SERA 2000
Lower estimate	RATEL	0.000001		
Upper estimate	RATEU	0.0001		

[1] Calculated as the product of the number of hours of application and the number of acres treated per hour for each category - i.e., central estimate, lower estimate, and upper estimate.

[2] "Agent" refers to the material being handled and may be expressed in units of a.i. or a.e. Depending on the agent under consideration, additional exposure conversions may be made in the exposure assessment and dose response assessment. For the risk assessment, the only important point is that the exposure and dose/response assessments must use the same units - that is, a.i., a.e., etc. - or the units must be converted to some equivalent form in the risk characterization.

Worksheet A04: General Assumptions Used in Exposure Assessments for the General Public [PUBL]

Narrative: This table contains various values used in the exposure assessments for the general public. Three general groups of individuals are considered: adult male, adult female, and a 2 year old child. Values are specified for body weight, surface areas for various parts of the body, water intake, fish consumption, and the consumption of fruits or vegetables. ***NOTE****: Not all types of value are specified for each group. The only values specified are those used in the risk assessment.*

Description	ID	Value	Units	Reference
Body Weights				
Male, Adult	BWM	70	kg	ICRP (1975), p. 13.
Female, Adult	BWF	64	kg	Burnmaster 1998; U.S. EPA 1985[1]
Child, 2-3 years old	BWC	13.3	kg	U.S. EPA, 1996b, page 7-1, Table 7-2
Body Surface Areas				
Female, feet and lower legs	SAF1	2915	cm^2	U.S. EPA, 1992, p. 8-11, Table 8-3, total for feet and lower legs
Female, exposed skin when wearing shorts and a T-shirt	SAF2	5300	cm^2	U.S. EPA, 1992, p. 8-11, Table 8-3, total for arms, hands, lower legs, and feet.
Child, male, 2-3 years old, total body surface area	SAC	6030	cm^2	U.S. EPA, 1996b, p. 6-15, Table 6-6, 50th percentile.
Water Intake				
Adult				
typical	WCAT	2	L/day	U.S. EPA, 1996b, p. 3-28, Table 3-30, midpoint of mean (1.4 L/day) and 90th percentile (2.4 L/day) rounded to one significant place.
lower range for exposure assessment	WCAL	1.4	L/day	U.S. EPA, 1996b, p. 3-28, Table 3-30, mean
upper range	WCAH	2.4	L/day	U.S. EPA, 1996b, p. 3-28, Table 3-30, 90th percentile
Child, <3 years old				
typical	WCT	1	L/day	U.S. EPA, 1996b, p. 3-28, Table 3-30, midpoint of mean (0.61L/day) and 90th percentile (1.5 L/day) rounded to one significant place.
lower range for exposure assessment	WCL	0.61	L/day	U.S. EPA, 1996b, p. 3-28, Table 3-30, mean
upper range	WCH	1.50	L/day	U.S. EPA, 1996b, p. 3-28, Table 3-30, 90th percentile

Worksheet A04: General Assumptions Used in Exposure Assessments for the General Public [PUBL]

Narrative: This table contains various values used in the exposure assessments for the general public. Three general groups of individuals are considered: adult male, adult female, and a 2 year old child. Values are specified for body weight, surface areas for various parts of the body, water intake, fish consumption, and the consumption of fruits or vegetables. ***NOTE****: Not all types of value are specified for each group. The only values specified are those used in the risk assessment.*

Description	ID	Value	Units	Reference
Fish Consumption				
Freshwater anglers, typical intake per day over a prolonged period	FAT	0.010	kg/day	U.S. EPA, 1996b, p. 10-51, average of means from four studies
Freshwater anglers, maximum consumption for a single day	FAU	0.158	kg/day	Ruffle et al. 1994
Native American subsistence populations, typical intake per day	FNT	0.081	kg/day	U.S. EPA, 1996b, p. 10-51, median value of 94 individuals
Native American subsistence populations, maximum for a single day	FNU	0.770	kg/day	U.S. EPA, 1996b, p. 10-51, highest value of 94 individuals
Consumption of Fruits or Vegetables				
Amount of food consumed per kg bw per day for longer term exposures scenarios.				
Typical	VT	0.0043	kg food/kg bw/day	U.S. EPA, 1996b, Table 9-21, p. 9-39, mean intake of vegetables
Upper	VU	0.01	kg food/kg bw/day	U.S. EPA, 1996b, Table 9-21, p. 9-39, 95th percentile for intake of vegetables
Worst-case scenario for consumption in a single day, acute exposure scenario only.	VAcute	0.454	kg food	1 lb. The approximate mid range of the above typical and upper limits based on the 64 kg body weight.
Miscellaneous				
Estimate of dislodgeable residue as a proportion of application rate shortly after application.	DisL	0.1	none	Harris and Solomon 1992, data on 2,4-D

[1]This is the average value (63.79 kg), rounded to the nearest kg for 3 different groups of women between 15-49 years old: control (62.07 kg), pregnant (65.90 kg), and lactating (63.48 kg). See Burnmaster 1998, p.218, Table III., Risk Analysis. 18(2): 215-219. This is identical to the body weight for females, 45-55 years old, 50th percentile from U.S. EPA, 1985, page 5, Table 2-2, rounded to nearest kilogram.

Worksheet A05a: Estimated concentrations of pesticides on or in various types of vegetation shortly after application at 1 lb a.e./acre [from Hoerger and Kenaga (1972), Table 9, p. 22]. [HK]

Type of Vegetation	Concentration (mg chemical/kg vegetation)			
	Typical		Upper Limit	
	ID	Value	ID	Value
Range grass	RGT	125	RGU	240
Grass	GST	92	GSU	110
Leaves and leafy crops	LVT	35	LVU	125
Forage crops	FCT	33	FCU	58
Pods containing seeds	PDT	3	PDU	12
Grain	GNT	3	GNU	10
Fruit	FRT	1.5	FRU	7

Worksheet A05b: Concentrations of chemical on spheres (berries) at the specified application rate. [FRUIT]

Diameter (cm)	Planar Surface Area (cm^2)[a]	Amount deposited (mg)[b]	Weight of sphere (kg)[c]	Concentration (mg/kg)[d]
1	0.7853981634	0.008796459	0.0005236	16.8
5	19.6349540849	0.21991148575	0.065449847	3.36
10	78.5398163397	0.87964594301	0.5235987756	1.68
	Application rate	1 lb/acre =	0.0112	mg/cm^2

a Planar surface area of a sphere = ð r^2 where r is the radius in cm.

b Amount deposited is calculated as the application rate in mg/cm^2 multiplied by the planar surface area.

c Assumes a density of 1 g/cm^3 for the fruit. The volume of a sphere is$(1\div6)\times$ ð × d^3 where d is the diameter in cm. Assuming a density of 1 g/cm^3, the weight of the sphere in kg is equal to:

$$kg= (1\div6)\times ð \times d^3 \div 1000$$

d Amount of chemical in mg divided by the weight of the sphere in kg.

Worksheet A06: Central estimates of off-site drift associated with aerial application of pesticides (from Bird 1995, Figure 2, p. 204) [OFFSITE]

Distance Down Wind (feet)	ID	Drift as a proportion of application rate
100	DRFT100	0.03
500	DRFT200	0.002
1000	DRFT300	0.0006
2500	DRFT400	0.0002

Worksheet A07a: Estimate of first-order absorption rate (k_a in hours^{-1}) and 95% confidence intervals (from SERA 2000). [KAMODEL]

Model parameters	ID	Value	
Coefficient for $k_{o/w}$	C_KOW	0.233255	
Coefficient for MW	C_MW	0.005657	
Model Constant	C	1.49615	
Number of data points	DP	29	
Degrees of Freedom (d.f.)	DF	26	
Critical value of $t_{0.025}$ with 26 d.f.[1]	CRIT	2.056	
Standard error of the estimate	SEE	16.1125	
Mean square error or model variance	MDLV	0.619712	
Standard deviation of model (s)	MSD	0.787218	$MDLV^{0.5}$
X′X, cross products matrix	0.307537	-0.00103089	0.00822769
	-0.00103089	0.000004377	-0.0000944359
	0.0082	-0.0000944359	0.0085286

[1] Mendenhall and Scheaffer, 1973, Appendix 3, 4, p. A31.

Central (maximum likelihood) estimate:

$$\log_{10} k_a = 0.233255 \log_{10}(k_{o/w}) - 0.005657\ MW - 1.49615$$

95% Confidence intervals for $\log_{10} k_a$

$$\log_{10} k_a \pm t_{0.025} \times s \times (a'X'X\,a)^{0.5}$$

where a is a column vector of {1, MW, $\log_{10}(k_{o/w})$}.

NB: Although the equation for the central estimate is presented with $k_{o/w}$ appearing before MW to be consistent with the way a similar equation is presented by EPA, MW must appear first in column vector a because of the way the statistical analysis was conducted to derive X′X .

See following page for details of calculating $a'X'X\,a$ without using matrix arithmetic.

Worksheet Worksheet A07a (continued)
Details of calculating a′X′X a

The term $\mathbf{a}'\cdot(\mathbf{X}'\mathbf{X})^{-1}\cdot\mathbf{a}$ requires matrix multiplication. While this is most easily accomplished using a program that does matrix arithmetic, the calculation can be done with a standard calculator.

Letting

$\mathbf{a}$ = {a_1, a_2, a_3}

and

$(\mathbf{X}'\mathbf{X})^{-1}$ =
{
{b_1, b_2, b_3},
{c_1, c_2, c_3},
{d_1, d_2, d_3}
},

$\mathbf{a}'\cdot(\mathbf{X}'\mathbf{X})^{-1}\cdot\mathbf{a}$ is equal to

Term 1: {a_1 ×([a_1×b_1] + [a_2×c_1] + [a_3×d_1])} +
Term 2: {a_2 ×([a_1×b_2] + [a_2×c_2] + [a_3×d_2])} +
Term 3: {a_3 ×([a_1×b_3] + [a_2×c_3] + [a_3×d_3])}.

Worksheet A07b: Estimate of dermal permeability (K_p in cm/hr) and 95% confidence intervals (data from U.S. EPA 1992). [PKMODEL]

Model parameters	ID	Value	
Coefficient for $k_{o/w}$	C_KOW	0.706648	
Coefficient for MW	C_MW	0.006151	
Model Constant	C	2.72576	
Number of data points	DP	90	
Degrees of Freedom (d.f.)	DF	87	
Critical value of $t_{0.025}$ with 87 d.f.[1]	CRIT	1.96	
Standard error of the estimate	SEE	45.9983	
Mean square error or model variance	MDLV	0.528716	
Standard deviation of model (s)	MSD	0.727129	$MDLV^{0.5}$
X′X, cross products matrix	0.0550931	-0.0000941546	-0.0103443
	-0.0000941546	0.0000005978	-0.0000222508
	-0.0103443	-0.0000222508	0.00740677

[1] Mendenhall and Scheaffer, 1973, Appendix 3, Table 4, p. A31.

NOTE: The data for this analysis is taken from U.S. EPA (1992), Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/011B, Table 5-4, pp. 5-15 through 5-19. The EPA report, however, does not provide sufficient information for the calculation of confidence intervals. The synopsis of the above analysis was conducted in STATGRAPHICS Plus for Windows, Version 3.1 (Manugistics, 1995) as well as Mathematica, Version 3.0.1.1 (Wolfram Research, 1997). Although not explicitly stated in the EPA report, 3 of the 93 data points are censored from the analysis because they are statistical outliers: [Hydrocortisone-21-yl]-hemipimelate, n-nonanol, and n-propanol. The model parameters reported above are consistent with those reported by U.S. EPA but are carried out to greater number of decimal places to reduce rounding errors when calculating the confidence intervals. See notes to Worksheet A07a for details of calculating maximum likelihood estimates and confidence intervals.

CHEMICAL SPECIFIC VALUES

Worksheet B01: Anticipated Application and Dilution Rates for imazapic [WSB01]				
Item	Code	Value	Units	Reference/Source
Typical application rate	Typ	0.0624	lb a.e./acre	Section 2.4
Lowest application rate	Low	0.03125	lb a.e./acre	Section 2.4
Highest application rate	Hi	0.0624	lb a.e./acre	Section 2.4
Typical dilution	CDil	6	gal./acre	American Cyanamid (1998c, 2000)
Lowest dilution	LDil	2	gal./acre	
Highest dilution	HDil	10	gal./acre	

Typical concentration in applied solution:

Typical application rate divided by the average of the lowest and highest dilutions, converted to mg/mL, and rounded to two significant places after the decimal.

0.0624 lb/acre ÷ 6 gal/acre] × 119.8 (mg/mL)/(lb/gal) = **1.25 mg/mL** [TypDr]

Lowest estimated concentration in applied solution:

Lowest application rate divided by the highest dilution, converted to mg/mL, and rounded to two significant places after the decimal.

0.03125 lb/acre ÷ 10 gal/acre) × 119.8 (mg/mL)/(lb/gal) = **0.37 mg/mL** [LowDr]

Highest estimated concentration in applied solution:

Highest application rate divided by the lowest dilution, converted to mg/mL, and rounded to two significant decimal places after the decimal.

0.0624 lb/acre ÷ 2 gal/acre × 119.8 (mg/mL)/(lb/gal) = **4.0 mg/mL** [HI_Dr]

Worksheet B02: Summary of central estimate and range of concentrations of imazapic in field solutions.				
Parameter	ID	Value	Units	Reference/Source
Typical	TypDR	1.25	mg/mL	See calculations above
Low	LowDR	0.37	mg/mL	
High	Hi_DR	4	mg/mL	

Worksheet B03: Summary of chemical specific values used for imazapic in exposure assessment worksheets. [WSB03]				
Parameter	ID	Value	Units	Source/Reference
Molecular weight (acid)	MW	275.31	grams/mole	Table 2-1
Water Solubility, pH 7	WS	36,000	mg/L	
$K_{o/w}$, pH 7	Kow	2.47	unitless	
Foliar half-time ($t_{½}$)	FT12	7	days	Very little information is available on foliar half times. The value of 7 days is taken from Hallman and Leonard (1999)
Halftime on vegetation, central	FrT12C	7	days	
composite of different lower	FrT12L	7	days	
types upper	FrT12U	7	days	
Dissipation coefficients on vegetation				
central	VgKC	0.09902	$days^{-1}$	ln(2)/half-time. The upper limit on half-time is used to calculate the lower limit on dissipation coefficient.
lower	VgKL	0.09902	$days^{-1}$	
upper	VgKU	0.09902	$days^{-1}$	
Bioconcentration factor, edible portion, acute exposure	BCFT	0.11	L/kg fish	Only one bioconcentration factor is used, the value in whole fish taken from Robinson (1994). Because of the very low bioconcentration factor in whole fish and the rapid time to steady state, the distinctions between acute and chronic BCFs and edible and inedible fractions is not necessary.
Bioconcentration factor, edible portion, chronic exposure	BCFCh	0.11	L/kg fish	
Bioconcentration factor, whole fish, acute	BCFWA	0.11	L/kg fish	
Bioconcentration factor, whole fish, chronic	BCFWC	0.11	L/kg fish	
EPA RfD[a]	RfDP	0.5	mg/kg bw/day	Section 3.3.3

[a] This RfD was derived by the U.S. EPA Office of Pesticides (U.S. EPA, 1996a). No RfD for this compound is listed on IRIS..

Worksheet B04: Calculation of first-order dermal absorption rate (k_a) for imazapic.							
Parameters	Value	Units					Reference
Molecular weight	275.31	g/mole					
$K_{o/w}$ at pH 7	2.47	unitless					
$\log_{10} K_{o/w}$	0.39						
Column vector ***a*** for calculating confidence intervals (see Worksheet A07a for definitions.)							
a_1	1						
a_2	275.31						
a_3	0.39						
Calculation of $\mathbf{a'} \cdot (\mathbf{X'X})^{-1} \cdot \mathbf{a}$ (see Worksheet A07a for details of calculation.)							
Term 1	0.0269206741						
Term 2	0.0378033307						
Term 3	-0.005633668						
$\mathbf{a'} \cdot (\mathbf{X'X})^{-1} \cdot \mathbf{a}$	0.0591	calculation verified in Mathematica 3.0.1.1					
$\log_{10} k_a = 0.233255 \log_{10}(\boldsymbol{k_{o/w}}) - 0.005657\ \boldsymbol{MW} - 1.49615$							WSA07a
$\log_{10}$ of first order absorption rate (k_a)							
Central estimate	-2.96198014217	±	$\boldsymbol{t}_{0.025}$	×	$\boldsymbol{s}$	×	$(\mathbf{a'} \cdot (\mathbf{X'X})^{-1} \cdot \mathbf{a})^{0.5}$
Lower limit	-3.35545036077	-	2.0560	×	0.787218	×	0.24310491562
Upper limit	-2.56850992357	+	2.0560	×	0.787218	×	0.24310491562
First order absorption rates (i.e., antilog or 10^x of above values).							
Central estimate	0.00109	$hours^{-1}$					
Lower limit	0.00044	$hours^{-1}$					
Upper limit	0.00270	$hours^{-1}$					

Worksheet B05: Calculation of dermal permeability rate (K_p) in cm/hour for imazapic.							
Parameters	Value	Units	Reference				
Molecular weight	275.31	g/mole					
$K_{o/w}$ at pH 7	2.47	unitless					
$\log_{10} K_{o/w}$	0.39269695326						
Column vector ***a*** for calculating confidence intervals (see Worksheet A07a for definitions.)							
a_1	1						
a_2	275.31						
a_3	0.39269695326						
Calculation of $\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$ - see Worksheet A07b for details of calculation.							
Term 1	0.025109222						
Term 2	0.0169832948						
Term 3	-0.00532558						
$\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$	0.0368	calculation verified in Mathematica 3.0.1.1					
$\log_{10} k_p = 0.706648 \log_{10}(k_{o/w}) - 0.006151\ MW - 2.72576$							Worksheet A07b
$\log_{10}$ of dermal permeability							
Central estimate	-4.14169329337	±	$t_{0.025}$	×	s	×	$\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}^{0.5}$
Lower limit	-4.41508884666	-	1.9600	×	0.727129	×	0.19183326093
Upper limit	-3.86829774008	+	1.9600	×	0.727129	×	0.19183326093
Dermal permeability							
Central estimate	0.0000722	cm/hour					
Lower limit	0.0000385	cm/hour					
Upper limit	0.0001354	cm/hour					

Worksheet B06: Summary of chemical specific dermal absorption values used for imazapic dermal absorption. [WSB06]

Description	Code	Value	Units	Reference/Source
Zero-order absorption (K_p)				
Central estimate	KpC	0.00007220	cm/hour	Worksheet B05, values rounded to two significant figures
Lower limit	KpL	0.00003845	cm/hour	
Upper limit	KpU	0.00013540	cm/hour	
First-order absorption rates (k_a)				
Central estimate	AbsC	0.00109	$hour^{-1}$	Worksheet B04, values rounded to two significant figures
Lower limit	AbsL	0.00044	$hour^{-1}$	
Upper limit	AbsU	0.0027	$hour^{-1}$	

Worksheet B07: Estimates of the concentration of imazapic in ambient water per lb a.e. applied per acre based on monitoring data and the resulting estimated concentrations in ambient water that are used in the chronic contaminated water exposure assessments.

Scenario	GLEAMs model runs were conducted at rainfall rates of 5 to 250 inches per year and an application rate of 1 lb/acre with a 100 acre treatment block adjacent to a 10 acre pond that is 1 meter deep.	ID	WCR (mg/L) ÷ (lb a.e./acre)
Typical	The typical rate is taken as 10 µg/L. This is about the peak concentrations that could be expected at rainfall rates of about 100 inches per year as well as the average concentration at rainfall rates of 250 inches per year.. The upper limit is approximately the peak concentration from sandy soils at rainfall rates of 250 inches per year. The lower limit is about the average concentration from clay or loam soil at an annual rainfall rate of 25 inches per year.	AWT	0.010
Low		AWL	0.001
High		AWU	0.060

Estimated Concentration in Ambient Water (WCR × Application Rate)

			Application Rate	WCR		Estimated Ambient Concentration (mg/L)
Typical			0.0624	0.01		0.00062
Low			0.03125	0.001		0.000031
High			0.0624	0.06		0.0037

WORKER EXPOSURE ASSESSMENTS

Worksheet C01a: Worker exposure estimates for directed foliar (backpack) applications of imazapic				
Parameter/Assumption	Code	Value	Units	Source/Designation
Application rates				
Central estimate	ApplC	0.0624	lbs a.e./acre	WSB01.TYP
Lower estimate	ApplL	0.03125	lbs a.e./acre	WSB01.LOW
Upper estimate	ApplU	0.0624	lbs a.e./acre	WSB01.HI
Acres treated per day				
Central estimate	ACREC	4.375	acres/day	WSA03.ACREC
Lower estimate	ACREL	1.5	acres/day	WSA03.ACREL
Upper estimate	ACREU	8	acres/day	WSA03.ACREU
Amount handled per day (product of application rate and acres treated per day)				
Central estimate	HANDLC	0.273	lb/day	
Lower estimate	HANDLL	0.046875	lb/day	
Upper estimate	HANDLU	0.4992	lb/day	
Absorbed dose rate (mg/day)				
Central estimate	RATEC	0.003	(mg agent/kg bw) ÷ (lbs agent handled per day)	Worksheet A03a
Lower estimate	RATEL	0.0003		
Upper estimate	RATEU	0.01		
Absorbed dose (product of amount handled and absorbed dose rate)				
Central estimate	DOSEC	0.0008	mg/kg bw/day	N/A
Lower estimate	DOSEL	0.000014		
Upper estimate	DOSEU	0.005		

Worksheet C01b: Worker exposure estimates for boom spray (hydraulic ground spray) applications of imazapic [WSC01]				
Parameter/Assumption	Code	Value	Units	Source/Designation
Application rates				
Central estimate	APPLC	0.0624	lbs a.e./acre	WSB01.TYP
Lower estimate	APPLL	0.03125	lbs a.e./acre	WSB01.LOW
Upper estimate	APPLU	0.0624	lbs a.e./acre	WSB01.HI
Acres treated per day				
Central estimate	ACREC	28	acres/day	WSA04.ACREC
Lower estimate	ACREL	12	acres/day	WSA04.ACREL
Upper estimate	ACREU	48	acres/day	WSA04.ACREU
Amount handled per day (product of application rate and acres treated per day)				
Central estimate	HANDLC	1.7472	lb/day	
Lower estimate	HANDLL	0.375	lb/day	
Upper estimate	HANDLU	2.9952	lb/day	
Absorbed dose rate				
Central estimate	RATEC	0.0002	(mg agent/kg bw) ÷ (lbs agent handled per day)	Worksheet A03b
Lower estimate	RATEL	0.00001		
Upper estimate	RATEU	0.0009		
Absorbed dose (product of amount handled and absorbed dose rate)				
Central estimate	DOSEC	0.00035	mg/kg bw/day	N/A
Lower estimate	DOSEL	0.000004		
Upper estimate	DOSEU	0.002696		

WS01c: Worker exposure estimates for aerial applications of imazapic [WKAREXP01]				
NOTE: The upper and lower estimates of dose are based on the typical application rate. Variability is encompassed by differences in the number of acres treated and the absorbed dose rate.				
Parameter/Assumption	Code	Value	Units	Source/Designation
Application rates				
Central estimate	WS10C	0.0624	lbs a.e./acre	APPL.TYP
Lower estimate	WS10L	0.03125	lbs a.e./acre	APPL.LOW
Upper estimate	WS10U	0.0624	lbs a.e./acre	APPL.HI
Acres treated per day				
Central estimate	ACREC	520	acres/day	AERIAL.ACREC
Lower estimate	ACREL	240	acres/day	AERIAL.ACREL
Upper estimate	ACREU	800	acres/day	AERIAL.ACREU
Amount handled per day (product of application rate and acres treated per day)				
Central estimate	HANDLC	32.448	lb/day	N/A[1]
Lower estimate	HANDLL	7.5	lb/day	
Upper estimate	HANDLU	49.92	lb/day	
Absorbed dose rate				
Central estimate	RATEC	0.00003	(mg agent/kg bw) ÷ (lbs agent handled per day)[2]	Worksheet A03c
Lower estimate	RATEL	0.000001		
Upper estimate	RATEU	0.0001		
Absorbed dose (product of amount handled and absorbed dose rate)				
Central estimate	DOSEC	0.00097	mg/kg bw	N/A
Lower estimate	DOSEL	0.0000075		
Upper estimate	DOSEU	0.004992		

[1] Calculated as the product of the number of hours of application and the number of acres treated per hour for each category - i.e., central estimate, lower estimate, and upper estimate.

[2] "Agent" refers to the material being handled and may be expressed in units of a.e. or a.e. Depending on the agent under consideration, additional exposure conversions may be made in the exposure assessment and dose response assessment. For the risk assessment, the only important point is that the exposure and dose/response assessments must use the same units - that is, a.e., a.e., etc. - or the units must be converted to some equivalent form in the risk characterization.

Worksheet C02: Workers: Accidental Dermal Exposure Assessments Using Zero-Order Absorption			
Parameter	Value	Units	Source
Body weight (*W*)	70	kg	WSA02.BW
Surface Area of hands (*S*)	840	cm^2	WSA02.Hands
Dermal permeability (K_p, cm/hour) [see Worksheet B05]			
Typical	0.0000722	cm/hour	WSB06.KpC
Lower	0.00003845	cm/hour	WSB06.KpL
Upper	0.0001354	cm/hour	WSB06.KpU
Concentration in solution (*C*) [see Worksheet B02]			
Typical	1.25	mg/mL	WSB02.TypDr
Lower	0.37	mg/mL	WSB02.LowDr
Upper	4	mg/mL	WSB02.HI_Dr

Note that 1 mL is equal to 1 cm^3 and thus mg/mL = mg/cm^3.

Details of calculations for worker zero-order dermal absorption scenarios.

Equation (U.S. EPA 1992)

$$K_p \cdot C \cdot Time(hr) \cdot S \cdot \div W = Dose(mg/kg)$$

where: C = concentration in mg/cm^3 or mg/mL, S = Surface area of skin in cm^2, W = Body weight in kg.

Immersion of Hands or Wearing Contaminated Gloves for One-Minute

Typical Value: Use typical concentration and central estimate of K_p.
0.0000722 cm/hr × 1.25 mg/cm^3 × 1/60 hr × 840 cm^2 ÷ 70 kg = 1.81e-05 mg/kg [WZHT1M]

Lower Estimate: Use lower range of estimated concentration and lower limit of K_p.
0.0000385 cm/hr × 0.37 mg/cm^3 × 1/60 hr × 840 cm^2 ÷ 70 kg = 2.85e-06 mg/kg [WZHL1M]

Upper Estimate: Use upper range of estimated concentration and upper limit of K_p.
0.0001354 cm/hr × 4 mg/cm^3 × 1/60 hr × 840 cm^2 ÷ 70 kg = 0.00010832 mg/kg [WZHU1M]

Wearing Contaminated Gloves for One-Hour

Typical Value: Use typical concentration and central estimate of K_p.
0.0000722 cm/hr × 1.25 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 0.001083 mg/kg [WZHT1H]

Lower Estimate: Use lower range of estimated concentration and lower limit of K_p.
0.0000385 cm/hr × 0.37 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 1.71e-04 mg/kg [WZHL1H]

Upper Estimate: Use upper range of estimated concentration and upper limit of K_p.
0.0001354 cm/hr × 4 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 0.0065 mg/kg [WZHU1H]

Worksheet C03: Worker Accidental Spill Based on the Assumption of First-Order Absorption			
Parameter	Value	Units	Source
Liquid adhering to skin after a spill (***L***)	0.008	mL/cm^2	WSA02.Liq
Body weight (***W***)	70	kg	WSA02.BW
Surface Areas (**A**)			
Hands	840	cm^2	WSA02.Hands
Lower legs	2070	cm^2	WSA02.LLegs
First-order dermal absorption rates (k_a)			
Central Estimate	0.00109	hour^{-1}	WSB06.ABSC
Lower limit of range	0.000440	hour^{-1}	WSB06.ABSL
Upper limit of range	0.00270	hour^{-1}	WSB06.ABSU
Concentration in solution (***C***) [see Worksheet Worksheet B01]			
Typical	1.25	mg/mL	TypDr
Lower	0.37	mg/mL	LowDr
Upper	4	mg/mL	HI_Dr

Details of calculations.

Equation (from Durkin et al. 1995)

$$Dose_{(mg/kg\ bw)} = k_{a\ (1/hours)} \times L_{(mg/cmsq)} \times C_{(mg/mL)} \times T_{(hours)} \times A_{(cm\ sq)} \div W_{(kg)}$$

where ***T*** is the duration of exposure in hours and other terms are defined as above. Note that 1 mL=1cm^3.

Lower Legs: Spill with 1 Hour (*T*) Exposure Period

Typical Value [WFLT1H],
0.0010900 h^{-1} × 0.008 mL/cm^2 × 1.25 mg/cm^3 × 1 hr × 2070 cm^2 ÷ 70 kg = 3.2e-04 mg/kg
Lower range [WFLL1H],
0.0004400 h^{-1} × 0.008 mL/cm^2 × 0.37 mg/cm^3 × 1 hr × 2070 cm^2 ÷ 70 kg = 3.9e-05 mg/kg
Upper range [WFLU1H],
0.0027000 h^{-1} × 0.008 mL/cm^2 × 4 mg/cm^3 × 1 hr × 2070 cm^2 ÷ 70 kg = 2.6e-03 mg/kg

Hands: Spill with 1 Hour (*T*) Exposure Period

Typical Value [WFHT1H],
0.0010900 h^{-1} × 0.008 mL/cm^2 × 1.25 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 1.3e-04 mg/kg
Lower range [WFHL1H],
0.0004400 h^{-1} × 0.008 mL/cm^2 × 0.37 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 1.6e-05 mg/kg
Upper range [WFHU1H],
0.0027000 h^{-1} × 0.008 mL/cm^2 × 4 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 1.0e-03 mg/kg

EXPOSURE ASSESSMENTS for the GENERAL PUBLIC

Worksheet D01: Direct spray of child.			
***Verbal Description**: A naked child is accidentally sprayed over the entire body surface with a field dilution as it is being applied. The child is effectively washed - i.e., all of the compound is removed - after 1 hour. The absorbed dose is estimated using the assumption of first-order dermal absorption.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	1	hour	N/A
Body weight (***W***)	13.3	kg	WSA04.BWC
Exposed surface area (***A***)	6030	cm^2	WSA04.SAC
Liquid adhering to skin per cm^2 of exposed skin.(***L***)	0.008	mL/cm^2	WSA02.LIQ
Concentrations in solution (***C***)			
Typical/Central	1.25	mg/mL	WSB02.TYPDR
Low	0.37	mg/mL	WSB02.LOWDR
High	4	mg/mL	WSB02.HI_DR
First-order dermal absorption rate (k_a)			
Central	0.00109	$hour^{-1}$	WSB06.AbsC
Low	0.000440	$hour^{-1}$	WSB06.AbsL
High	0.0027	$hour^{-1}$	WSB06.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	0.00494	mg/kg	SPRYC
Low	0.000590	mg/kg	SPRYL
High	0.039	mg/kg	SPRYH

Details of calculations

Equation: $L \times C \times A \times k_a \times T \div W$

Central Estimate [SPRYCC]:
0.008 mL/cm^2 × 1.25 mg/mL × 6030 cm^2 × 0.00109 h^{-1} × 1 h ÷ 13.3 kg = 0.00494 mg/kg

Lower Range of Estimate [SPRYCL]:
0.008 mL/cm^2 × 0.37 mg/mL × 6030 cm^2 × 0.00044 h^{-1} × 1 h ÷ 13.3 kg = 0.00059 mg/kg

Upper Range of Estimate [SPRYCH]:
0.008 mL/cm^2 × 4 mg/mL × 6030 cm^2 × 0.0027 h^{-1} × 1 h ÷ 13.3 kg = 0.039 mg/kg

Worksheet D02: Direct spray of woman.			
Verbal Description*: A woman is accidentally sprayed over the feet and legs with a field dilution as it is being applied. The woman washes and removes all of the compound after 1 hour. The absorbed dose is estimated using the assumption of first-order dermal absorption.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	1	hour	N/A
Body weight (***W***)	64	kg	WSA04.BWF
Exposed surface area (***A***)	2915	cm^2	WSA04.SAF1
Liquid adhering to skin per cm^2 of exposed skin.(***L***)	0.008	mL/cm^2	WSA02.LIQ
Concentrations in solution (***C***)			
Typical/Central	1.25	mg/mL	WSB02.TYPDR
Low	0.37	mg/mL	WSB02.LOWDR
High	4	mg/mL	WSB02.HI_DR
First-order dermal absorption rate (k_a)			
Central	0.00109	$hour^{-1}$	WSB06.AbsC
Low	0.000440	$hour^{-1}$	WSB06.AbsL
High	0.0027	$hour^{-1}$	WSB06.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	0.000496	mg/kg	SPRYWC
Low	0.000059	mg/kg	SPRYWL
High	0.0039	mg/kg	SPRYWH

Details of calculations

Equation: $L \times C \times S \times k_a \times T \div W$

Central Estimate [SPRYWC]:
0.008 mg/mL × 1.25 mg/mL × 2915 cm^2 × 0.00109 h^{-1} × 1 h ÷ 64 kg = 0.000496 mg/kg

Lower Range of Estimate [SPRYWL]:
0.008 mg/mL × 0.37 mg/mL × 2915 cm^2 × 0.00044 h^{-1} × 1 h ÷ 64 kg = 0.0000593 mg/kg

Upper Range of Estimate [SPRYWH]:
0.008 mg/mL × 4 mg/mL × 2915 cm^2 × 0.0027 h^{-1} × 1 h ÷ 64 kg = 0.0039 mg/kg

Worksheet D03: Dermal contact with contaminated vegetation.			
Verbal Description*: A woman wearing shorts and a short sleeved shirt is in contact with contaminated vegetation for 1 hour shortly after application of the compound - i.e. no dissipation or degradation is considered. The chemical is effectively removed from the surface of the skin - i.e., washing - after 24 hours.*			
Parameter/Assumption	Value	Units	Source/Reference
Contact time (***Tc***)	1	hour	N/A
Exposure time (***Te***)	24	hours	N/A
Body weight (***W***)	64	kg	WSA04.BWF
Exposed surface area (***A***)	5300	cm^2	WSA04.SAF2
Dislodgeable residue (***Dr***) as a proportion of application rate	0.1	none	WSA04.DisL
Application Rates(***R***)			
Typical/Central	0.0624	lb a.i/acre	WSB01.TYP
Low	0.03125	lb a.i/acre	WSB01.LOW
High	0.0624	lb a.i/acre	WSB01.HI
First-order dermal absorption rate (k_a)			
Central	0.00109	$hour^{-1}$	WSB06.AbsC
Low	0.000440	$hour^{-1}$	WSB06.AbsL
High	0.00270	$hour^{-1}$	WSB06.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations on next page.***			
Central	1.34e-04	mg/kg	VEGDWC
Low	2.54e-05	mg/kg	VEGDWL
High	3.32e-04	mg/kg	VEGDWH

Description of Calculations:

Step 1:

Use method of Durkin et al. (1995, p. 68, equation 4) to calculate the transfer rate (***Tr***) units of µg/(cm^2·hr)) based on the dislodgeable residue ***(Dr***) in units of µg/cm^2. Estimate *Dr* based on 0.1 of the application rate after converting application rate (***R***) in lb a.e./acre to units of µg/cm^2:

$x = \log(\boldsymbol{Tr}\ (\mu g/(cm^2 \cdot hr))) = (1.09 \times \log_{10}(\boldsymbol{R} \times \text{WSA01.lbac\_ugcm} \times 0.1)) + 0.05$

$\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr)) = 10^x$

Step 2:

Convert ***Tr*** from units of µg/(cm^2·hr)) to units of mg/(cm^2·hr)) by dividing by 1000:

$\boldsymbol{Tr}(mg/(cm^2 \cdot hr)) = \boldsymbol{Tr}(\mu g/(cm^2 \cdot hr))/1000$

Step 3:

Estimate amount (*Amnt*) transferred to a specified surface are of skin (***A***) in mg during the exposure period (contact time or ***Tc***):

$\boldsymbol{Amnt}(mg) = \boldsymbol{Tr}(mg/(cm^2 \cdot hr)) \times \boldsymbol{Tc}\ (hours) \times \boldsymbol{A}\ (cm^2)$

Step 4:

Estimate the absorbed dose ($\boldsymbol{D}_{\boldsymbol{Abs}}$) in mg/kg bw as the product of the amount on the skin , the first-order absorption rate, and the duration of exposure (***Te***) divided by the body weight:

$\boldsymbol{D}_{\boldsymbol{Abs}} = \boldsymbol{Amnt}(mg) \times \mathbf{k_a}\ (hours^{-1}) \times \boldsymbol{Te}\ (hours) \div \boldsymbol{W}\ (kg)$

See next page for details of calculations.

Worksheet D03 Details of calculations: *Dermal Exposure to Contaminated Vegetation*

Central Estimate:

Step 1:

$x = \log_{10}(\boldsymbol{Tr}\ (\mu g/(cm^2 \cdot hr))) = (1.09 \times \log_{10}(0.0624 \times 11.21 \times 0.1)) + 0.05 =$ -1.21e+00 µg/(cm²·hr)

$\boldsymbol{Tr}\ (\mu g/(cm^2 \cdot hr)) = 10^{-1.21e+00} =$ 6.18e-02 µg/(cm²·hr)

Step 2:

$\boldsymbol{Tr}$ (mg/(cm²·hr)) = 6.18e-02 µg/(cm²·hr) ÷ 1000 µg/mg = 6.18e-05 mg/(cm²·hr)

Step 3:

Amnt(mg) = 6.18e-05 mg/(cm²·hr) × 1 hr × 5300 cm² = 3.27e-01 mg

Step 4:

$\boldsymbol{D_{Abs}}$ (mg/kg bw) = 3.27e-01 mg × 0.00109 hr^{-1} × 24 hours ÷ 64 kg = 1.34e-04 `[VEGDWC]`

Lower Range of Estimate:

Step 1:

$x = \log_{10}(\boldsymbol{Tr}\ (\mu g/(cm^2 \cdot hr))) = (1.09 \times \log_{10}(0.03125 \times 11.21 \times 0.1)) + 0.05 =$ -1.54e+00µg/(cm²·hr)

$\boldsymbol{Tr}\ (\mu g/(cm^2 \cdot hr)) = 10^{-1.54e+00} =$ 2.91e-02 µg/(cm²·hr)

Step 2:

$\boldsymbol{Tr}$ (mg/(cm²·hr)) = 2.91e-02 µg/(cm²·hr) ÷ 1000 µg/mg = 2.91e-05 mg/(cm²·hr)

Step 3:

Amnt(mg) = 2.91e-05 mg/(cm²·hr) × 1 hr × 5300 cm² =1.54e-01 mg

Step 4:

$\boldsymbol{D_{Abs}}$ (mg/kg bw) = 1.54e-01 mg × 0.00044 hr^{-1} × 24 hours ÷ 64 kg = 2.54e-05 `[VEGDWL]`

Upper Range of Estimate:

Step 1:

$x = \log_{10}(\boldsymbol{Tr}\ (\mu g/(cm^2 \cdot hr))) = (1.09 \times \log_{10}(0.0624 \times 11.21 \times 0.1)) + 0.05 =$ -1.21e+00 µg/(cm²·hr)

$\boldsymbol{Tr}\ (\mu g/(cm^2 \cdot hr)) = 10^{-1.21e+00} =$ 6.18e-02 µg/(cm²·hr)

Step 2:

$\boldsymbol{Tr}$ (mg/(cm²·hr)) = 6.18e-02 µg/(cm²·hr) ÷ 1000 µg/mg = 6.18e-05 mg/(cm²·hr)

Step 3:

Amnt(mg) = 6.18e-05 mg/(cm²·hr) × 1 hr × 5300 cm² = 3.27e-01 mg

Step 4:

$\boldsymbol{D_{Abs}}$ (mg/kg bw) = 3.27e-01 mg × 0.0027 hr^{-1} × 24 hours ÷ 64 kg = 3.32e-04 `[VEGDWH]`

Worksheet D04: Consumption of contaminated fruit, acute exposure scenario.			
Verbal Description*: A woman consumes 1 lb (0.4536 kg) of contaminated fruit shortly after application of the chemical - i.e. no dissipation or degradation is considered. Residue estimates based on relationships from Hoerger and Kenaga (1972) summarized in WSA07.*			
Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	64	kg	`WSA04.BWF`
Amount of fruit consumed (***A***)	0.454	kg	`N/A`
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	`WSB01.Typ`
Lower	0.03125	lb a.e./acre	`WSB01.Low`
Upper	0.0624	lb a.e./acre	`WSB01.Hi`
Residue rates (***rr***)			
Typical	1.5	RUD[1]	`WSA05a.FRT`
Upper	7	RUD[1]	`WSA05a.FRU`
Dose estimates (***D***) - **see details of calculations below**			
Typical	0.0007	mg/kg bw	`VEGCWAT`
Lower	0.00033	mg/kg bw	`VEGCWAL`
Upper	0.003	mg/kg bw	`VEGCWAU`
[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.e./acre applied.			

Equation (terms defined in above table):

D (mg/kg bw) = ***A***(kg) × ***R***(lb a.e./acre) × ***rr***(mg/kg÷lb a.e./acre) ÷***W***(kg bw)

Details of Calculations

Typical: Use typical application rate and typical RUD.

D = 0.454 kg × 0.0624 lb a.e./acre × 1.5 mg/kg÷lb a.e./acre ÷ 64 kg = 0.0007 mg/kg bw

Lower: Use lowest estimated application rate. Use typical RUD because no lower estimate of the RUD is available.

D = 0.454 kg × 0.03125 lb a.e./acre × 1.5 mg/kg÷lb a.e./acre ÷ 64 kg = 0.00033 mg/kg bw

Upper: Use highest estimated application rate and highest RUD.

D = 0.454 kg × 0.0624 lb a.e./acre × 7 mg/kg÷lb a.e./acre ÷ 64 kg = 0.003 mg/kg bw

Worksheet D05: Consumption of contaminated fruit, chronic exposure scenario.			
***Verbal Description**: A woman consumes contaminated fruit for a 90 day period starting shortly after application of the chemical. Initial residue estimates are based on relationships from Hoerger and Kenaga (1972) summarized in Worksheet A05a. The foliar half-time is used to estimate the concentration on vegetation after 90 days. The geometric mean of the initial and 90 day concentrations is used as a central/typical dose.*			
Parameters/Assumptions	Value	Units	Source/Reference
Halftime on vegetation (***t***$_{½}$) central	7	days	`WSB03.FrT12C`
lower	7	days	`WSB03.FrT12L`
upper	7	days	`WSB03.FrT12U`
Duration of exposure (***t***)	90	days	`N/A`
Body weight (***W***)	64	kg	`WSA04.BWF`
Amount of vegetation consumed per unit body weight(***A***)			
Typical	0.0043	kg veg./kg bw	`WSA04.VT`
Upper	0.01	kg veg./kg bw	`WSA04.VU`
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	`WSB01.Typ`
Lower	0.03125	lb a.e./acre	`WSB01.Low`
Upper	0.0624	lb a.e./acre	`WSB01.Hi`
Residue rates (***rr***)			
Typical	1.5	RUD[1]	`WSA05a.FRT`
Upper	7	RUD[1]	`WSA05aFRU`
Dose estimates (***D***) - **see details of calculations on next page**			
Typical	4.68e-06	mg/kg bw/day	`VEGCWCT`
Lower	2.34e-06	mg/kg bw/day	`VEGCWCL`
Upper	5.08e-05	mg/kg bw/day	`VEGCWCU`
[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on fruit (mg chemical per kg of vegetation) for each l lb a.e./acre applied.			

Details of calculations on next page

Subchronic consumption of vegetation: Details of calculations

Equations (terms defined below or in table on previous page):

Step 1: Calculate $C_{0,}$ concentration in vegetation on Day 0 - i.e., day of application- as the product of the application rate (***R***) and the residue rate (***rr***):

C_0 (mg/kg/(lb a.e./acre)) = ***R***(lb a.e./acre) × ***rr***(mg/kg÷lb a.e./acre)

Step 2: Calculate $C_{90,}$ concentration in vegetation on Day 90 (t=90 days) based on dissipation coefficient (k) derived from foliar half-life ($t_{½}$).

k ($days^{-1}$) = ln(2) ÷ $t_{½}$ (days)

C_{90} (mg/kg/(lb a.e./acre)) = C_0 (mg/kg) × e^{-tk}

Step 3: Use the geometric mean of C_0 and C_{90} to get a central estimate of concentration in vegetation (mg/kg veg.) and multiply this value by the vegetation consumption (kg veg/kg bw) to calculate the daily dose (mg/kg bw) over the exposure period.

D (mg/kg bw) = $(C_0 \times C_{90})^{0.5}$ (mg/kg veg.) × ***A*** kg veg./kg bw × ***W*** kg bw ÷ ***B***(kg bw)

= $(C_0 \times C_{90})^{0.5}$ (mg/kg veg.) × ***A*** kg veg./kg bw

Central Estimate:

Use the typical application rate, the typical vegetation consumption rate, and the typical residue rate along with the central estimate of half-time on vegetation.

Step 1:

C_0 = 0.0624 lb a.e./acre × 1.5 mg/kg veg. = 0.0936 mg/kg veg.

Step 2:

k = ln(2) ÷7 $days^{-1}$ = 0.099

C_{90} = 0.0936 mg/kg × $e^{-0.099 \times 90}$ = 1.26e-05 mg/kg veg.

Step 3:

D (mg/kg bw/day) = $(0.0936 \times 1.26e\text{-}05)^{0.5}$ (mg/kg veg.) × 0.0043 kg veg/kg bw = 4.68e-06 mg/kg bw

Lower Estimate:

Use the lowest anticipated application rate along with the lower limit of the half-time of vegetation. Also the typical vegetation consumption rate and the typical residue rate because lower limits on these estimates are not available.

Step 1:

C_0 = 0.03125 lb a.e./acre × 1.5 mg/kg veg. = 0.046875 mg/kg veg.

Step 2:

k = ln(2) ÷7 $days^{-1}$ = 0.099

C_{90} = 0.046875 mg/kg × $e^{-0.099 \times 90}$ = 6.33e-06 mg/kg veg.

Step 3:

D $_{(mg/kg\ bw)}$ = $(0.046875 \times 6.33e\text{-}06)^{0.5}$ $_{(mg/kg\ veg.)}$ × 0.0043 $_{(kg\ veg/kg\ bw)}$ = 2.34e-06 $_{(mg/kg\ bw)}$

Upper Estimate:

Use the highest anticipated application rate, the upper range of the vegetation consumption rate and the upper range of the residue rate along with the upper limit of the half-time on vegetation.

Step 1:

C_0 = 0.0624 lb a.e./acre × 7 mg/kg veg. = 0.4368 mg/kg veg.

Step 2:

k = ln(2) ÷7 $days^{-1}$ = 0.099

C_{90} = 0.4368 mg/kg × $e^{-0.099 \times 90}$ = 5.90e-05 mg/kg veg.

Step 3:

D $_{(mg/kg\ bw)}$ = $(0.4368 \times 5.90e\text{-}05)^{0.5}$ $_{(mg/kg\ veg.)}$ × 0.01 $_{(kg\ veg/kg\ bw)}$ = 5.08e-05 $_{(mg/kg\ bw)}$

Worksheet D06: Consumption of contaminated water, acute exposure scenario.			
***Verbal Description**: A young child (2-3 years old) consumes 1 liter of contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre . No dissipation or degradation is considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Surface area of pond [SA]	1000	m^2	N/A
Average depth [DPTH]	1	m	N/A
Volume of pond in cubic meters [VM]	1000	m^3	N/A
Volume of pond in Liters [VL]	1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]	200	gallons	N/A
	757	liters	1 gallon = 3.785 Liters
Concentrations in field solution (***C*** $_{(mg/L)}$)			
Central	1250	mg/L	WSB02.TypDR
Low	370	mg/L	WSB02.LowDR
High	4000	mg/L	WSB02.Hi_DR
Concentrations in ambient water ***C*** × VS(liters) ÷ LV)			
Central	0.94625	mg/L	
Low	0.28009	mg/L	
High	3.028	mg/L	
Body weight (***W***)	13.3	kg	WSA04.BWC
Amount of water consumed (***A***)			
Typical	1	L/day	WSA04.WCT
Lower	0.61	L/day	WSA04.WCL
Upper	1.5	L/day	WSA04.WCH
Dose estimates (***D***) - **see details of calculations on next page.**			
Typical	0.071	mg/kg bw	WATCCAT
Lower	0.013	mg/kg bw	WATCCAL
Upper	0.34	mg/kg bw	WATCCAU

Details of calculations on next page

Acute Consumption of Contaminated Water from an Accidental Spill Details of calculations

Equations (terms defined below or in table on previous page)

Step 1: Calculate the concentration in the pond based on the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing.

$$Conc._{(mg/L)} = VS_{(gal.)} \times 3.785_{L/gal} \times C_{(mg/L)} \div VL_{(liters)}$$

Step 2: Calculate the dose based on the concentration in the water, the amount of water consumed, and the body weight.

$$D_{(mg/kg\ bw)} = Conc._{(mg/L)} \times A_{(L)} \div W_{(kg)}$$

Calculations

Central Estimate:

Use the typical field dilution, and the typical water consumption.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 1250.00_{(mg/L)} \div 1000000_{(liters)} = 0.9463_{(mg/L)}$$

Step 2:

$$D_{(mg/kg\ bw)} = 0.94625_{(mg/L)} \times 1_{(L)} \div 13.3_{(kg)} = 0.071_{(mg/kg\ bw)}$$ [WATCCAT]

Lower Estimate:

Use the lowest estimated field dilution and the lower range of water consumption.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 370_{(mg/L)} \div 1000000_{(liters)} = 0.28_{(mg/L)}$$

Step 2:

$$D_{(mg/kg\ bw)} = 0.28_{(mg/L)} \times 0.61_{(L)} \div 13.3_{(kg)} = 0.013_{(mg/kg\ bw)}$$ [WATCCAL]

Upper Estimate:

Use the highest estimated field concentration and the upper range of water consumption.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 4000_{(mg/L)} \div 1000000_{(liters)} = 3.03_{(mg/L)}$$

Step 2:

$$D_{(mg/kg\ bw)} = 3.03_{(mg/L)} \times 1.5_{(L)} \div 13.3_{(kg)} = 0.34_{(mg/kg\ bw)}$$ [WATCCAU]

Worksheet D07: Consumption of contaminated water, chronic exposure scenario.			
Verbal Description*: An adult (70 kg male) consumes contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Application Rates (***R*** $_{(\text{lb a.e./acre})}$)			
Central	0.0624	lb a.e./gal	WSB01.Typ
Low	0.03125		WSB01.Low
High	0.0624		WSB01.Hi
Water Contamination Rate (WCR)(***C*** $_{(\text{mg/L})}$÷***R*** $_{(\text{lb a.e./gal})}$)			
Central	1.00e-02	mg/L/lb a.e./acre	WSB07.AWT
Low	1.00e-03		WSB07.AWL
High	6.00e-02		WSB07.AWU
Body weight (***W***)	70	kg	WSA046.BWM
Amount of water consumed (***A*** $_{(\text{L/day})}$)			
Typical	2	L/day	WSA04.WCAT
Lower	1.4	L/day	WSA04.WCAL
Upper	2.4	L/day	WSA04.WCAH
Dose estimates (***D***) - **see details of calculations on next page.**			
Typical	1.78e-05	mg/kg bw/day	WATCMCT
Lower	6.25e-07	mg/kg bw/day	WATCMCL
Upper	1.28e-04	mg/kg bw/day	WATCMCU

Details of calculations on next page

Chronic Consumption of Contaminated Ambient Water
Details of calculations

Equations (terms defined in table on previous page)

Verbal Description: Multiply the application rate ($\boldsymbol{R}_{\text{(lb a.e./acre)}}$) by the water contamination rate ($\boldsymbol{WCR}_{\text{((mg/L)×(lb a.e./gal))}}$) to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day ($\boldsymbol{A}_{\text{(L/day)}}$) and then divided by the body weight ($\boldsymbol{W}_{\text{(kg)}}$)to get the estimate of the absorbed dose ($\boldsymbol{D}_{\text{(mg/kg bw)}}$).

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = \boldsymbol{R}_{\text{(lb a.e./acre)}} \times \boldsymbol{WCR}_{\text{((mg/L)×(lb a.e./gal))}} \times \boldsymbol{A}_{\text{(L/day)}} \div \boldsymbol{W}_{\text{(kg)}}$$

Central Estimate:

Use the typical application rate, typical contamination rate (WCR), and the typical water consumption.

$\boldsymbol{D}_{\text{(mg/kg bw)}}$ = 0.0624 $_{\text{(lb a.e./acre)}}$ × 1.00e-02 $_{\text{((mg/L)×(lb a.e./gal))}}$ × 2 $_{\text{(L/day)}}$ ÷ 70 $_{\text{(kg bw)}}$ = 1.78e-05 $_{\text{(mg/kg bw)}}$ [WATCMCT]

Lower Range of Estimate:

Use the lowest anticipated application rate, the low end of the range of the water contamination rate (WCR), and the low end of the range for water consumption.

$\boldsymbol{D}_{\text{(mg/kg bw)}}$ = 0.03125 $_{\text{(lb a.e./acre)}}$ × 1.00e-03 $_{\text{((mg/L)×(lb a.e./gal))}}$ × 1.4 $_{\text{(L/day)}}$ ÷ 70 $_{\text{(kg bw)}}$ = 6.25e-07 $_{\text{(mg/kg bw)}}$ [WATCMCL]

Upper range of Estimate:

Use the lowest anticipated application rate, the low end of the range of the water contamination rate (WCR), and the low end of the range for water consumption.

$\boldsymbol{D}_{\text{(mg/kg bw)}}$ = 0.0624 $_{\text{(lb a.e./acre)}}$ × 6.00e-02 $_{\text{((mg/L)×(lb a.e./gal))}}$ × 2.4 $_{\text{(L/day)}}$ ÷ 70 $_{\text{(kg bw)}}$ = 1.28e-04 $_{\text{(mg/kg bw)}}$ [WATCMCU]

Worksheet D08: Consumption of contaminated fish, acute exposure scenario.

Verbal Description*: An adult angler consumes fish taken from contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre . No dissipation or degradation is considered. Because of the available and well documented information and substantial differences in the amount of caught fish consumed by the general public and native American subsistence populations, separate exposure estimates are made for these two groups.*

Parameters/Assumptions	Value	Units	Source/Reference
Surface area of pond [SA]	1000	m^2	N/A
Average depth [DPTH]	1	m	N/A
Volume of pond in cubic meters [VM]	1000	m^3	N/A
Volume of pond in Liters [VL]	1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]	200	gallons	N/A
Concentrations in spilled solution (***C*** $_{(mg/L)}$)			
Central	1250	mg/L	WSB02.TYPDR×1000
Low	370	mg/L	WSB02.LOWDR×1000
High	4000	mg/L	WSB02.HI_DR×1000
Body weight (***W***)	70	kg	WSA04.BWM
Amount of fish consumed (***A***)			
General Population, typical	0.01	kg/day	WSA04.FAU
upper range	0.158		
Subsistence populations, typical	0.081	kg/day	WSA04.FNU
upper range	0.77		
Bioconcentration factor (***BCF***$_{(L/kg\ fish)}$)	0.11	L/kg fish	WSB03.BCFE
Dose estimates (***D***) - **see details of calculations on next page.**			
General Population			
Typical	1.49e-05	mg/kg bw	FISHAMGPT
Lower	4.40e-06	mg/kg bw	FISHAMGPL
Upper	7.52e-04	mg/kg bw	FISHAMGPU
Native American subsistence populations			
Typical	1.21e-04	mg/kg bw	FISHAMNAT
Lower	3.56e-05	mg/kg bw	FISHAMNAL
Upper	3.67e-03	mg/kg bw	FISHAMNAU

Details of calculations on next page

Acute Consumption of Contaminated Fish after an Accidental Spill Details of calculations

Equations (terms defined below or in table on previous page)

Step 1: As in the acute drinking water scenario, calculate the concentration in the pond based on the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing.

$$\textit{Conc.}_{(mg/L)} = \textit{VS}_{(gal.)} \times 3.785_{L/gal} \times \textit{C}_{(mg/L)} \div \textit{VL}_{(liters)}$$

Step 2: Calculate the dose based on the concentration in the water, the bioconcentration factor, the amount of fish consumed, and the body weight.

$$\textit{D}_{(mg/kg\ bw)} = \textit{Conc.}_{(mg/L)} \times \textit{BCF}_{(L/kg\ fish)} \times \textit{A}_{(kg\ fish)} \div \textit{W}_{(kg\ bw)}$$

General Public

Central Estimate:

Use the typical field dilution as well as the experimental BCF and typical daily fish consumption for the general public.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 1250_{(mg/L)} \div 1000000_{(liters)} = 0.95_{(mg/L)}$$

Step 2:

$$\text{D}_{(mg/kg\ bw)} = 0.95_{(mg/L)} \times 0.11_{(L/kg)} \times 0.01_{(kg\ fish)} \div 70_{(kg)} = 1.49\text{e-}05_{(mg/kg\ bw)}$$ `[FISHAMGPT]`

Lower End of Range for the Estimate:

Use the lower field dilution as well as the experimental BCF and daily fish consumption for the general public.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 370_{(mg/L)} \div 1000000_{(liters)} = 0.28_{(mg/L)}$$

Step 2:

$$\text{D}_{(mg/kg\ bw)} = 0.28_{(mg/L)} \times 0.11_{(L/kg)} \times 0.01_{(kg\ fish)} \div 70_{(kg)} = 4.40\text{e-}06_{(mg/kg\ bw)}$$ `[FISHAMGPL]`

Upper End of Range for the Estimate:

Use the upper field dilution as well as the experimental BCF and upper range of daily fish consumption for the general public.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 4000_{(mg/L)} \div 1000000_{(liters)} = 3.03_{(mg/L)}$$

Step 2:

$$\text{D}_{(mg/kg\ bw)} = 3.03_{(mg/L)} \times 0.11_{(L/kg)} \times 0.158_{(kg\ fish)} \div 70_{(kg)} = 7.52\text{e-}04_{(mg/kg\ bw)}$$ `[FISHAMGPU]`

(continued on next page)

Acute Consumption of Contaminated Fish after an Accidental Spill Details of calculations (continued)

Native American Subsistence Populations

Central Estimate:

Use the typical field dilution as well as the experimental BCF and typical daily fish consumption for the native American subsistence populations.

Step 1:

Conc. $_{(mg/L)}$ = 200 $_{(gal.)}$ × 3.785 $_{L/gal}$ × 1250 $_{(mg/L)}$ ÷ 1000000 $_{(liters)}$ = 0.95 $_{(mg/L)}$

Step 2:

D $_{(mg/kg\ bw)}$ = 0.95 $_{(mg/L)}$ × 0.11 $_{(L/kg)}$ × 0.081 $_{(kg\ fish)}$ ÷ 70 $_{(kg)}$ = 1.21e-04 $_{(mg/kg\ bw)}$ [FISHAMNAT]

Estimate of Lower End of Range:

Use the lower field dilution as well as the experimental BCF and typical daily fish consumption for the native American subsistence populations.

Step 1:

Conc. $_{(mg/L)}$ = 200 $_{(gal.)}$ × 3.785 $_{L/gal}$ × 370 $_{(mg/L)}$ ÷ 1000000 $_{(liters)}$ = 0.280 $_{(mg/L)}$

Step 2:

D $_{(mg/kg\ bw)}$ = 0.28 $_{(mg/L)}$ × 0.11 $_{(L/kg)}$ × 0.081 $_{(kg\ fish)}$ ÷ 70 $_{(kg)}$ = 3.56e-05 $_{(mg/kg\ bw)}$ [FISHAMNAL]

Estimate of Upper End of Range:

Use the upper field dilution as well as the experimental BCF and upper range of daily fish consumption for the native American subsistence populations.

Step 1:

Conc. $_{(mg/L)}$ = 200 $_{(gal.)}$ × 3.785 $_{L/gal}$ × 4000 $_{(mg/L)}$ ÷ 1000000 $_{(liters)}$ = 3.030 $_{(mg/L)}$

Step 2:

D $_{(mg/kg\ bw)}$ = 3.03 $_{(mg/L)}$ × 0.11 $_{(L/kg)}$ × 0.77 $_{(kg\ fish)}$ ÷ 70 $_{(kg)}$ = 3.67e-03 $_{(mg/kg\ bw)}$ [FISHAMNAU]

Worksheet D09: Consumption of contaminated fish, chronic exposure scenario.			
Verbal Description*: An adult (70 kg male) consumes fish taken from contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Application Rates (***R*** $_{(\text{lb a.e./acre})}$)			
Central	0.0624	lb a.e./acre	WSB01.Typ
Low	0.03125		WSB01.Low
High	0.0624		WSB01.Hi
Water Contamination Rate (WCR)(***C*** $_{(\text{mg/L})}$÷***R*** $_{(\text{lb a.e./gal})}$)			
Central	1.00e-02	mg/L/lb a.e./acre	WSB07.AWT
Low	1.00e-03		WSB07.AWL
High	6.00e-02		WSB07.AWU
Bioconcentration factor (***BCF*** $_{(\text{L/kg fish})}$)	0.11	L/kg fish	WSB03.BCFCh
Body weight (***W***)	70	kg	WSA04.BWM
Amount of fish consumed (***A***)			
General Population typical	0.01	kg/day	WSA04.FAT
upper limit	0.158	kg/day	WSA04.FAU
Native American subsistence populations typical	0.081	kg/day	WSA04.FNT
upper limit	0.77	kg/day	WSA04.FNU
Dose estimates (***D***) - **see details of calculations on next page.**			
General Public			
Typical	9.81e-09	mg/kg bw/day	FISHMCT
Lower	4.91e-10	mg/kg bw/day	FISHMCL
Upper	9.30e-07	mg/kg bw/day	FISHMCU
Native American Subsistence Population			
Typical	7.94e-08	mg/kg bw/day	FISHNMCT
Lower	3.98e-09	mg/kg bw/day	FISHNMCL
Upper	4.53e-06	mg/kg bw/day	FISHNMCU

Details of calculations on next page

Chronic Consumption of Contaminated Fish, Details of calculations

Equations (terms defined below or in table on previous page)

Verbal Description: Multiply the application rate ($\boldsymbol{R}_{\text{(lb a.e./acre)}}$) by the water contamination rate ($\boldsymbol{WCR}_{\text{((mg/L)×(lb a.e./gal))}}$) to get the concentration in ambient water. This product is in turn multiplied by the bioconcentration factor ($\boldsymbol{BCF}_{\text{(L/kg fish)}}$) and the amount of fish consumed per day ($\boldsymbol{A}_{\text{(kg fish/day)}}$) and then divided by the body weight ($\boldsymbol{W}_{\text{(kg bw)}}$) to get the estimate of the absorbed dose ($\boldsymbol{D}_{\text{(mg/kg bw)}}$).

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = \boldsymbol{R}_{\text{(lb a.e./acre)}} \times \boldsymbol{WCR}_{\text{((mg/L)/(lb a.e./gal))}} \times \boldsymbol{A}_{\text{(kg/day)}} \times \boldsymbol{BCF}_{\text{(L/kg fish)}} \div \boldsymbol{W}_{\text{(kg)}}$$

General Public

Central Estimate:

Use the typical application rate, typical contamination rate (WCR), the typical fish consumption, the measured bioconcentration factor, and standard body weight.

$\boldsymbol{D}_{\text{(mg/kg bw)}}$ = 0.0624 $_{\text{(lb a.e./acre)}}$ × 1.00e-02 $_{\text{((mg/L)/(lb a.e./gal))}}$ × 0.11 $_{\text{(L/kg fish)}}$ × 0.01 $_{\text{(kg fush/day)}}$ ÷ 70 $_{\text{(kg bw)}}$ = 9.81e-09 $_{\text{(mg/kg bw)}}$ [FISHMCT]

Lower Range of Estimate:

Use the lowest anticipated application rate, lower range of contamination rate (WCR), the typical fish consumption, the measured bioconcentration factor, and standard body weight. Typical fish consumption is used because there is no published lower estimate.

$\boldsymbol{D}_{\text{(mg/kg bw)}}$ = 0.03125 $_{\text{(lb a.e./acre)}}$ × 1.00e-03 $_{\text{((mg/L)/(lb a.e./gal))}}$ × 0.11 $_{\text{(L/kg fish)}}$ × 0.01 $_{\text{(kg fush/day)}}$ ÷ 70 $_{\text{(kg bw)}}$ = 4.91e-10 $_{\text{(mg/kg bw)}}$ [FISHMCL]

Upper Range of Estimate:

Use the highest labeled application rate, upper range of contamination rate (WCR), the maximum l fish consumption, the measured bioconcentration factor, and standard body weight.

$\boldsymbol{D}_{\text{(mg/kg bw)}}$ = 0.0624 $_{\text{(lb a.e./acre)}}$ × 6.00e-02 $_{\text{((mg/L)/(lb a.e./gal))}}$ × 0.11 $_{\text{(L/kg fish)}}$ × 0.158 $_{\text{(kg fush/day)}}$ ÷ 70 $_{\text{(kg bw)}}$ = 9.30e-07 $_{\text{(mg/kg bw)}}$ [FISHMCU]

Chronic Consumption of Contaminated Fish
Details of calculations (continued)

Native American Subsistence Populations

Central Estimate:

Use the typical application rate, typical contamination rate (WCR), the typical fish consumption for native American subsistence populations, the measured bioconcentration factor, and standard body weight.

$$\boldsymbol{D}_{(\text{mg/kg bw})} = 0.0624_{\text{(lb a.e./acre)}} \times 1.00\text{e-}02_{\text{((mg/L)/(lb a.e./gal))}} \times 0.11_{\text{(L/kg fish)}} \times 0.081_{\text{(kg fush/day)}} \div 70_{\text{(kg bw)}} = 7.94\text{e-}08_{\text{(mg/kg bw)}}$$ [FISHNMCT]

Lower Range of Estimate:

Use the lowest anticipated application rate, lower range of contamination rate (WCR), the typical fish consumption for native American subsistence populations, the measured bioconcentration factor, and standard body weight. Typical fish consumption is used because there is no published lower estimate.

$$\boldsymbol{D}_{(\text{mg/kg bw})} = 0.03125_{\text{(lb a.e./acre)}} \times 1.00\text{e-}03_{\text{((mg/L)/(lb a.e./gal))}} \times 0.11_{\text{(L/kg fish)}} \times 0.081_{\text{(kg fush/day)}} \div 70_{\text{(kg bw)}} = 3.98\text{e-}09_{\text{(mg/kg bw)}}$$ [FISHNMCL]

Upper Range of Estimate:

Use the highest labeled application rate, upper range of contamination rate (WCR), the maximum l fish consumption for native American subsistence populations, the measured bioconcentration factor, and standard body weight.

$$\boldsymbol{D}_{(\text{mg/kg bw})} = 0.0624_{\text{(lb a.e./acre)}} \times 6.00\text{e-}02_{\text{((mg/L)/(lb a.e./gal))}} \times 0.11_{\text{(L/kg fish)}} \times 0.77_{\text{(kg fush/day)}} \div 70_{\text{(kg bw)}} = 4.53\text{e-}06_{\text{(mg/kg bw)}}$$ [FISHNMCU]

SUMMARY TABLES FOR HUMAN HEALTH RISK ASSESSMENT

Worksheet E01: Summary of Worker Exposure Scenarios

Scenario	Dose (mg/kg/day or event)			Exposure Assessment Worksheet
	Typical	Lower	Upper	
General Exposures (dose in mg/kg/day)				
Directed ground spray (Backpack)	8.00e-04	1.41e-05	4.99e-03	WSC01a
Broadcast ground spray (Boom spray)	3.49e-04	3.75e-06	2.70e-03	WSC01b
Aerial applications	9.73e-04	7.50e-06	4.99e-03	WSC01c
Accidental/Incidental Exposures (dose in mg/kg/event)				
Immersion of Hands, 1 minute	1.81e-05	2.85e-06	1.08e-04	WSC02
Contaminated Gloves, 1 hour	1.08e-03	1.71e-04	6.50e-03	WSC02
Spill on hands, 1 hour	1.31e-04	1.56e-05	1.04e-03	WSC03
Spill on lower legs, 1 hour	3.22e-04	3.85e-05	2.56e-03	WSC03

Worksheet E02: Summary of risk characterization for workers[1]

RfD	0.5	mg/kg/day	Sect. 3.3.3.	
Scenario	Hazard Quotient			Exposure Assessment Worksheet
	Typical	Lower	Upper	
General Exposures				
Directed ground spray (Backpack)	1.6e-03	2.8e-05	1.0e-02	WSC01a
Broadcast ground spray (Boom spray)	7.0e-04	7.5e-06	5.4e-03	WSC01b
Aerial applications	1.9e-03	1.5e-05	1.0e-02	WSC01c
Accidental/Incidental Exposures				
Immersion of Hands, 1 minute	3.6e-05	5.7e-06	2.2e-04	WSC02
Contaminated Gloves, 1 hour	2.2e-03	3.4e-04	1.3e-02	WSC02
Spill on hands, 1 hour	2.6e-04	3.1e-05	2.1e-03	WSC03
Spill on lower legs, 1 hour	6.4e-04	7.7e-05	5.1e-03	WSC03

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Worksheet E01 for summary of exposure assessment.

Worksheet E03: Summary of Exposure Scenarios for the General Public

Scenario	Target	Dose (mg/kg/day)			Worksheet
		Typical	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	0.00494	0.00059	0.039	WSD01
Direct spray, lower legs	Woman	0.000496	0.0000593	0.0039	WSD02
Dermal, contaminated vegetation	Woman	0.000134	0.000025	0.000332	WSD03
Contaminated fruit, acute exposure	Woman	0.0007	0.00033	0.003	WSD04
Contaminated water, acute exposure	Child	0.071	0.013	0.34	WSD06
Consumption of fish, general public	Man	0.00001	4.40e-06	0.000752	WSD08
Consumption of fish, subsistence populations	Man	0.000121	0.00004	0.0036663	WSD08
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	4.68e-06	2.34e-06	5.08e-05	WSD05
Consumption of water	Man	1.78e-05	6.25e-07	1.28e-04	WSD07
Consumption of fish, general public	Man	9.81e-09	4.91e-10	9.30e-07	WSD09
Consumption of fish, subsistence populations	Man	7.94e-08	3.98e-09	4.53e-06	WSD09

Worksheet E04: Summary of risk characterization for the general public [1] .

Chronic RfD	0.5	mg/kg/day	Sect. 3.3.3.	
Acute RfD	0.5	mg/kg/day	Sect. 3.3.3.	

Scenario	Target	Hazard Quotient			Worksheet
		Typical	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	9.9e-03	1.2e-03	7.8e-02	WSD01
Direct spray, lower legs	Woman	9.9e-04	1.2e-04	7.8e-03	WSD02
Dermal, contaminated vegetation	Woman	2.7e-04	5.1e-05	6.6e-04	WSD03
Contaminated fruit, acute exposure	Woman	1.4e-03	6.6e-04	6.0e-03	WSD04
Contaminated water, acute exposure	Child	1.4e-01	2.6e-02	6.8e-01	WSD06
Consumption of fish, general public	Man	3.0e-05	8.8e-06	1.5e-03	WSD08
Consumption of fish, subsistence populations	Man	2.4e-04	7.1e-05	7.3e-03	WSD08
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	9.4e-06	4.7e-06	1.0e-04	WSD05
Consumption of water	Man	3.6e-05	1.3e-06	2.6e-04	WSD07
Consumption of fish, general public	Man	2.0e-08	9.8e-10	1.9e-06	WSD09
Consumption of fish, subsistence populations	Man	1.6e-07	8.0e-09	9.1e-06	WSD09

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Worksheet E02 for summary of exposure assessments.

EXPOSURE ASSESSMENTS for Terrestrial Species

Worksheet F01: Direct spray of small mammal assuming first order absorption kinetics.			
Verbal Description*: A 20 g mammal is directly sprayed over one half of the body surface as the chemical is being applied. The absorbed dose over the first day - i.e., a 24 hour period) is estimated using the assumption of first-order dermal absorption. In the absence of any data on dermal absorption in a small mammal, the estimated absorption rate for humans is used. An empirical relationship between body weight and surface area (Boxenbaum and D'Souza 1990) is used to estimate the surface area of the animal.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	24	hour	N/A
Body weight (***W***)	0.020	kg	Section 4.2.1.
Exposed surface area (***A***)	$cm^2=1110\times BW(kg)^{0.65}$		Boxenbaum and D'Souza 1990
	87	cm^2	
Application rate (***R***)			
Typical/Central	0.0624	lb a.e. /acre	WSB01.TYP
Low	0.03125		WSB01.LOW
High	0.0624		WSB01.HI
Conversion Factor (***F***) for lb/acre to mg/cm^2	0.01121		WSA01.LBAC_MGCM
First-order dermal absorption rate (k_a)			
Central	0.00109	$hour^{-1}$	WSB06.AbsC
Low	0.000440	$hour^{-1}$	WSB06.AbsL
High	0.00270	$hour^{-1}$	WSB06.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	0.039	mg/kg	SMDSDC
Low	0.008	mg/kg	SMDSDL
High	0.1	mg/kg	SMDSDH

Details of calculations on next page.

Direct Spray of Small Mammal, first-order absorption, Details of calculations

Equation: $0.5 \times F \times R \times A \times 1^{-ka \times T} \div W$

Verbal Description: *Multiply by 0.5 because only one half of the body surface is assumed to be sprayed. Calculate the amount deposited on the animal as the product of the application rate converted to mg/cm^2 and the surface area of the animal in cm^2. Get the proportion of the amount that is absorbed using the assumption of first order absorption kinetics. Divide by the body weight.*

Central Estimate: Use the central estimate of the application rate and dermal absorption rate,
0.5 × 0.01121 (mg/cm^2÷lb/acre) × 0.0624 lb/acre × 87 cm^2
× 1-e$^{-0.00109/h \times 24h}$ ÷ 0.02 kg = 0.039 mg/kg [SMDSDC]

Lower Range of Estimate: Use the lowest anticipated application rate and lower 95% limit of the estimated dermal absorption rate,
0.5 × 0.01121 (mg/cm^2÷lb/acre) × 0.03125 lb/acre × 87 cm^2
× 1-e$^{-0.00044/h \times 24 h}$ ÷ 0.02 kg = 0.008 mg/kg [CMDSDL]

Upper Range of Estimate: Use the highest anticipated application rate and upper 95% limit of the estimated dermal absorption rate,
0.5 × 0.01121 (mg/cm^2÷lb/acre) × 0.0624 lb/acre × 87 cm^2
× 1-e$^{-0.0027/h \times 24 h}$ ÷ 0.02 kg = 0.1 mg/kg [DMDSDH]

Worksheet F02: Direct spray of small mammal assuming 100% absorption over the first 24 hour period.			
Verbal Description*: A 20 g mammal is directly sprayed over one half of the body surface as the chemical is being applied. The deposited dose is assumed to be completely absorbed during the first day. An empirical relationship between body weight and surface area (Boxenbaum and D'Souza 1990) is used to estimate the surface area of the animal.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	24	hour	N/A
Body weight (***W***)	0.020	kg	Section 4.2.1.
Exposed surface area (***A***)	$cm^2=1110\times BW(kg)^{0.65}$		Boxenbaum and D'Souza 1990
	87	cm^2	
Application rate (***R***)			
Typical/Central	0.0624	lb a.e. /acre	WSB01.TYP
Low	0.03125		WSB01.LOW
High	0.0624		WSB01.HI
Conversion Factor (***F***) for lb/acre to mg/cm^2	0.01121		WSA01.LBAC_MGCM
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	1.5	mg/kg	SMDS2DC
Low	0.76	mg/kg	SMDS2DL
High	1.5	mg/kg	SMDS2DH

Direct Spray of Small Mammal, Complete absorption, Details of calculations

Equation: $0.5 \times F \times R \times A \div W$

Verbal Description: *Multiply by 0.5 because only one half of the body surface is assumed to be sprayed. Calculate the amount deposited on the animal as the product of the application rate converted to mg/cm^2 and the surface area of the animal in cm^2. Divide by the body weight.*

Central Estimate: Use the central estimate of the application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.0624 lb/acre $\times$ 87 $cm^2 \div$ 0.02 kg = 1.5 mg/kg [SMDS2DC]

Lower Range of Estimate [WSE042DL]: Use the lowest anticipated application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.03125 lb/acre $\times$ 87 $cm^2 \div$ 0.02 kg = 0.76 mg/kg [SMDS2DL]

Upper Range of Estimate [WSE042DH]: Use the highest anticipated application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.0624 lb/acre $\times$ 87 $cm^2 \div$ 0.02 kg = 1.5 mg/kg [SMDS2DU]

Worksheet F03: Direct spray of bee assuming 100% absorption over the first 24 hour period.			
Verbal Description*: A 0.093 g bee is directly sprayed over one half of the body surface as the chemical is being applied. The deposited dose is assumed to be completely absorbed during the first day. An empirical relationship between body weight and surface area (Boxenbaum and D'Souza 1990) is used to estimate the surface area of the animal.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	24	hour	N/A
Body weight (***W***)	0.000093	kg	Section 4.2.1.
Exposed surface area (***A***)	$cm^2=1110\times BW(kg)^{0.65}$		Boxenbaum and D'Souza 1990
	2.7	cm^2	
Application rate (***R***)			
Typical/Central	0.0624	lb a.e. /acre	WSB01.TYP
Low	0.03125		WSB01.LOW
High	0.0624		WSB01.HI
Conversion Factor (***F***) for lb/acre to mg/cm^2	0.01121		WSA01.LBAC_MGCM
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	10	mg/kg	BEEDS2DC
Low	5.1	mg/kg	BEEDS2DL
High	10	mg/kg	BEEDS2DH

Direct Spray of Bee, Complete absorption, Details of calculations

Equation: $0.5 \times F \times R \times A \div W$

Verbal Description: *Multiply by 0.5 because only one half of the body surface is assumed to be sprayed. Calculate the amount deposited on the animal as the product of the application rate converted to mg/cm^2 and the surface area of the animal in cm^2. Divide by the body weight.*

Central Estimate: Use the central estimate of the application rate,
0.5 × 0.01121 ($mg/cm^2 \div$ lb/acre) × 0.0624 lb/acre × 2.7 cm^2 ÷ 0.000093 kg = 10 mg/kg [BEEDS2DC]

Lower Range of Estimate: Use the lowest anticipated application rate,
0.5 × 0.01121 ($mg/cm^2 \div$ lb/acre) × 0.03125 lb/acre × 2.7 cm^2 ÷ 0.000093 kg = 5.1 mg/kg [BEEDS2DL]

Upper Range of Estimate: Use the highest anticipated application rate,
0.5 × 0.01121 ($mg/cm^2 \div$ lb/acre) × 0.0624 lb/acre × 2.7 cm^2 ÷ 0.000093 kg = 10 mg/kg [BEEDS2DH]

Worksheet F04: Consumption of contaminated vegetation by a small mammal, acute exposure scenario.

Verbal Description*: A 20 g mammal consumes vegetation shortly after application of the chemical - i.e. no dissipation or degradation is considered. The contaminated vegetation accounts for 100% of the diet. Residue estimates based on relationships for leaves and leafy vegetables from Hoerger and Kenaga (1972) summarized in Worksheet A05a.*

Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	0.020	kg	N/A
Food consumed per day (***A***)	0.003	kg	U.S. EPA 1989
Duration of exposure (***D***)	1	day	N/A
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	WSB01.Typ
Lower	0.03125	lb a.e./acre	WSB01.Low
Upper	0.0624	lb a.e./acre	WSB01.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WSA05a.LVT
Upper	125	RUD[1]	WSA05a.LVU
Dose estimates (***D***) - **see details of calculations below**			
Typical	0.33	mg/kg bw	VGCSMAC
Lower	0.16	mg/kg bw	VGCSMAL
Upper	1.2	mg/kg bw	VGCSMAU

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.e./acre applied.

Equation (terms defined in above table):

D (mg/kg bw) = ***A***(kg) × ***R***(lb a.e./acre) × ***rr***(mg/kg veg.÷lb a.e./acre) ÷ ***W***(kg bw)

Details of Calculations

Typical: Use typical application rate and typical RUD.

D = 0.003 kg × 0.0624 lb a.e./acre × 35 mg/kg÷lb a.e./acre ÷ 0.02 kg = 0.33 mg/kg bw [VGCSMAC]

Lower: Use lowest estimated application rate. Use typical RUD because no lower estimate of the RUD is available.

D = 0.003 kg × 0.03125 lb a.e./acre × 35 mg/kg÷lb a.e./acre ÷ 0.02 kg = 0.16 mg/kg bw [VGCSMAL]

Upper: Use highest estimated application rate and highest RUD.

D = 0.003 kg × 0.0624 lb a.e./acre × 125 mg/kg÷lb a.e./acre ÷ 0.02 kg = 1.2 mg/kg bw [VGCSMAU]

Worksheet F05: Consumption of contaminated vegetation by a small mammal, chronic exposure scenario.

Verbal Description*: A 20 g mammal consumes contaminated vegetation for a 90 day period starting shortly after application of the chemical. It is assumed that 100% of the diet is contaminated. Initial residue estimates are based on relationships for leaves and leafy vegetables from Hoerger and Kenaga (1972) summarized in Worksheet A05a. The foliar half-time is used to estimate the concentration on vegetation after 90 days. The geometric mean of the initial and 90 day concentrations is used as the estimate of the dose.*

Parameters/Assumptions	Value	Units	Source/Reference
Duration of exposure (***D***)	90	days	N/A
Body weight (***W***)	0.02	kg	N/A
Food consumed per day (***A***)	0.003	kg	U.S. EPA 1989
kg food consumed per kg bw	0.15	Unitless	0.003/0.02
Foliar halftimes ($t_{½}$) Central	7	$days^{-1}$	Worksheet B03
Low	7	$days^{-1}$	
High	7	$days^{-1}$	
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	WSB01.Typ
Lower	0.03125	lb a.e./acre	WSB01.Low
Upper	0.0624	lb a.e./acre	WSB01.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WSA05a.LVT
Upper	125	RUD[1]	WSA05a.LVU
Dose estimates (***D***) - **see details of calculations on next page**			
Typical	4.00e-04	mg/kg bw	VGCSMCT
Lower	1.70e-06	mg/kg bw	VGCSMCL
Upper	6.79e-06	mg/kg bw	VGCSMCU

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on fruit (mg chemical per kg of vegetation) for each l lb a.e./acre applied.

Equations (terms defined below or in above table):

Step 1: Calculate $C_{0,}$ concentration in vegetation on Day 0 - i..e., day of application.

C_0 (mg/kg) = ***R***(lb a.e./acre) × ***rr***(mg/kg÷lb a.e./acre)

Step 2: Calculate $C_{90,}$ concentration in vegetation on Day 90 (t=90 days) based on dissipation coefficient (k) derived from foliar half-life ($t_{½}$).

k ($days^{-1}$) = ln(2) ÷ $t_{½}$ (days)

C_{90} (mg/kg) = C_0 (mg/kg) × e^{-tk}

Step 3: Use the geometric mean of C_0 and C_{90} to get a central estimate of concentration in vegetation (mg/kg veg.) and multiply this value by the vegetation consumption (kg veg/kg bw) to calculate the daily dose (mg/kg bw) over the exposure period.

D (mg/kg bw) = $(C_0 \times C_{90})^{0.5}$ (mg/kg veg.) × ***A*** kg veg./kg bw

Details of calculations on next page

Subchronic consumption of vegetation by a small mammal:
Details of calculations

Central Estimate:

Use the typical application rate, the typical vegetation consumption rate, and the typical residue rate along with the central estimate of half-time on vegetation.

Step 1:

C_0 = 7 lb a.e./acre × 0.03125 mg/kg veg. = 0.21875 mg/kg veg.

Step 2:

k = ln(2) ÷ 7 $days^{-1}$ = 0.099

C_{90} = 0.21875 mg/kg × $e^{-0.099 \times 90}$ = 0.0000295 mg/kg veg.

Step 3:

D (mg/kg bw/day) = $(0.21875 \times 0.0000295)^{0.5}$ (mg/kg veg.) × 0.15 kg veg/kg bw = 0.0004 mg/kg bw [VGCSMCT]

Lower Estimate:

Use the lowest anticipated application rate along with the upper estimate of the half-time on vegetation. Also the typical vegetation consumption rate and the typical residue rate because lower limits on these estimates are not available.

Step 1:

C_0 = 0.03125 lb a.e./acre × 0.03125 mg/kg veg. = 0.00097656 mg/kg veg.

Step 2:

k = ln(2) ÷7 $days^{-1}$ = 0.099

C_{90} = 0.00097656 mg/kg × $e^{-0.099 \times 90}$ = 1.32e-07 mg/kg veg.

Step 3:

$D_{(mg/kg\ bw)} = (0.00097656 \times 1.32e\text{-}07)^{0.5}{}_{(mg/kg\ veg.)} \times 0.15_{(kg\ veg/kg\ bw)} = 1.70e\text{-}06_{(mg/kg\ bw)}$ [VGCSMCL]

Upper Estimate:

Use the highest anticipated application rate, the upper range of the vegetation consumption rate and the upper range of the residue rate along with the lower range of the estimated of half-time on vegetation.

Step 1:

C_0 = 0.0624 lb a.e./acre × 0.0624 mg/kg veg. = 0.00389376 mg/kg veg.

Step 2:

k = ln(2) ÷7 $days^{-1}$ = 0.099

C_{90} = 0.00389376 mg/kg × $e^{-0.099 \times 90}$ = 0 mg/kg veg.

Step 3:

$D_{(mg/kg\ bw)} = (0.00389376 \times 0)^{0.5}{}_{(mg/kg\ veg.)} \times 0.15_{(kg\ veg/kg\ bw)} = 6.79e\text{-}06_{(mg/kg\ bw)}$ [VGCSMCU]

Worksheet F06: Consumption of contaminated water by a small mammal, acute exposure scenario.			
Verbal Description*: A small (20g) mammal consumes contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre . No dissipation or degradation is considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Surface area of pond [SA]	1000	m^2	N/A
Average depth [DPTH]	1	m	N/A
Volume of pond in cubic meters [VM]	1000	m^3	N/A
Volume of pond in Liters [VL]	1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]	200	gallons	N/A
Concentrations in solution ($C_{(mg/L)}$)			
Central	1250	mg/L	WSB02.TYPDR×1000
Low	370	mg/L	WSB02.LOWDR×1000
High	4000	mg/L	WSB02.HI_DR×1000
Body weight (***W***)	0.02	kg	N/A
Amount of water consumed (***A***)	0.005	L/day	U.S. EPA 1989
Dose estimates (***D***) - **see details of calculations below.**			
Typical	0.238	mg/kg bw	WTCSMAT
Lower	0.0700	mg/kg bw	WTCSMAL
Upper	0.76	mg/kg bw	WTCSMAU

Equations (terms defined below or in table)

Step 1: Calculate the concentration in the pond based on the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing.

$$\text{Conc.}_{(mg/L)} = VS_{(gal.)} \times 3.785_{L/gal} \times C_{(mg/L)} \div VL_{(liters)}$$

Step 2: Calculate the dose based on the concentration in the water, the amount of water consumed, and the body weight.

$$D_{(mg/kg\ bw)} = \text{Conc.}_{(mg/L)} \times A_{(L)} \div W_{(kg)}$$

Central Estimate: Use the typical field dilution,

Step 1: $\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 1250_{(mg/L)} \div 1000000_{(liters)} = 0.95_{(mg/L)}$

Step 2: $D_{(mg/kg\ bw)} = 0.95_{(mg/L)} \times 0.005_{(L)} \div 0.02_{(kg)} = 0.238_{(mg/kg\ bw)}$ [WTCSMAT]

Lower Estimate: Use the lowest estimated field dilution,

Step 1: $\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 370_{(mg/L)} \div 1000000_{(liters)} = 0.28_{(mg/L)}$

Step 2: $D_{(mg/kg\ bw)} = 0.28_{(mg/L)} \times 0.005_{(L)} \div 0.02_{(kg)} = 0.07_{(mg/kg\ bw)}$ [WTCSMAL]

Upper Estimate: Use the highest estimated field concentration,

Step 1: $\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 4000_{(mg/L)} \div 1000000_{(liters)} = 3.03_{(mg/L)}$

Step 2: $D_{(mg/kg\ bw)} = 3.03_{(mg/L)} \times 0.005_{(L)} \div 0.02_{(kg)} = 0.76_{(mg/kg\ bw)}$ [WTCSMAU]

Worksheet F07: Consumption of contaminated water by a small mammal, chronic exposure scenario.			
Verbal Description*: A small (20 g) mammal consumes contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Application Rates (***R*** $_{\text{(lb a.e./acre)}}$)			
Central	0.0624	lb a.e./acre	WSB01.Typ
Low	0.03125		WSB01.Low
High	0.0624		WSB01.Hi
Water Contamination Rate (WCR)(***C*** $_{\text{(mg/L)}}$÷***R*** $_{\text{(lb a.e./acre)}}$)			
Central	0.01	mg/L/lb a.e./acre	WSB07.AWT
Low	0.001		WSB07.AWL
High	0.06		WSB07.AWU
Body weight (***W***)	0.02	kg	U.S. EPA 1989
Amount of water consumed (***A*** $_{\text{(L/day)}}$)	0.005	L/day	U.S. EPA 1989
Dose estimates (***D***) - **see details of calculations on next page.**			
Typical	0.0002	mg/kg bw	WTCSMCT
Lower	0.000008	mg/kg bw	WTCSMCL
Upper	0.001	mg/kg bw	WTCSMCU

Equations (terms defined in table)

Verbal Description: Multiply the application rate (***R*** $_{\text{(lb a.e./acre)}}$) by the water contamination rate (***WCR*** $_{\text{((mg/L)×(lb a.e./gal))}}$) to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day (***A*** $_{\text{(L/day)}}$) and then divided by the body weight (***W*** $_{\text{(kg)}}$)to get the estimate of the absorbed dose (***D*** $_{\text{(mg/kg bw)}}$).

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = \boldsymbol{R}_{\text{(lb a.e./acre)}} \times \boldsymbol{WCR}_{\text{((mg/L)/(lb a.e./gal))}} \times \boldsymbol{A}_{\text{(L/day)}} \div \boldsymbol{W}_{\text{(kg)}}$$

Central Estimate: Use the typical application rate and typical water contamination rate (WCR)

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = 0.0624_{\text{(lb a.e./acre)}} \times 0.01_{\text{((mg/L)/(lb a.e./gal))}} \times 0.005_{\text{(L/day)}} \div 0.02_{\text{(kg bw)}} = 0.0002_{\text{(mg/kg bw)}}$$ [WTCSMCT]

Lower Range of Estimate: Use the lowest anticipated application rate and the low end of the range of the water contamination rate (WCR)

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = 0.03125_{\text{(lb a.e./acre)}} \times 0.001_{\text{((mg/L)/(lb a.e./gal))}} \times 0.005_{\text{(L/day)}} \div 0.02_{\text{(kg bw)}} = 0.000008_{\text{(mg/kg bw)}}$$ [WTCSMCL]

Upper range of Estimate: Use the lowest anticipated application rate and the low end of the range of the water contamination rate (WCR)

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = 0.0624_{\text{(lb a.e./acre)}} \times 0.06_{\text{((mg/L)/(lb a.e./gal))}} \times 0.005_{\text{(L/day)}} \div 0.02_{\text{(kg bw)}} = 0.001_{\text{(mg/kg bw)}}$$ [WTCSMCU]

Worksheet F08: Consumption of contaminated fish by predatory bird, acute exposure scenario. *[FISHBIRDACUTE]*

***Verbal Description**: A predatory bird consumes fish taken from contaminated water after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre . No dissipation or degradation is considered. The assumption is made that bioconcentration will reach equilibrium. This probably will overestimate exposure and subsequent risk.*

Parameters/Assumptions	Value	Units	Source/Reference
Surface area of pond [SA]	1000	m^2	N/A
Average depth [DPTH]	1	m	N/A
Volume of pond in cubic meters [VM]	1000	m^3	N/A
Volume of pond in Liters [VL]	1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]	200	gallons	N/A
	757	liters	1 gallon = 3.785 liters
Concentrations in field solution (***FC*** $_{(mg/L)}$)			
Central	1250	mg/L	WSB02.TypDR
Low	370	mg/L	WSB02.LowDR
High	4000	mg/L	WSB02.Hi_DR
Concentrations in ambient water (WC) (***FC* × *VS*** $_{(liters)}$ ***/VL***)			
Central	0.94625	mg/L	
Low	0.28009	mg/L	
High	3.028	mg/L	
Bioconcentration factor (***BCF***$_{(L/kg\ fish)}$)	0.11	L/kg fish	WSB03.BCFWA
Concentrations in fish (FC) (***WC*** × ***BCF***) (mg/kg)			
Central	0.1040875	mg/kg fish	
Low	0.0308099		
High	0.33308		
Fish consumed as a proportion of body weight (P_F)			
typical	0.1	g fish/g bw	Various species based on values from U.S. EPA (1993).
lower	0.05		
upper limit	0.15		
Dose estimates (D) (**FC × P_F**)			
Typical	0.0104	mg/kg bw/day	
Lower	0.0015	mg/kg bw/day	
Upper	0.0500	mg/kg bw/day	
Reproductive NOAEL	113	mg/kg/day	Section 4.1.2.2.
Hazard Quotient (HQ) ***(D÷NOAEL)***			
Typical	9.21e-05	mg/kg bw/day	
Lower	1.36e-05	mg/kg bw/day	
Upper	4.42e-04	mg/kg bw/day	

Worksheet F09: Consumption of contaminated fish by predatory bird, chronic exposure scenario. *[FISHBIRDCHRONIC]*			
Verbal Description*: An predatory bird consumes fish taken from contaminated ambient water for a lifetime. The levels in water are estimated from monitoring and modeling data and dissipation, degradation and other environmental processes are considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Application Rates (***R*** $_{(\text{lb a.e./acre})}$)			
Central	0.0624	lb a.e./gal	WSB01.Typ
Low	0.03125		WSB01.Low
High	0.0624		WSB01.Hi
Water Contamination Rate (WCR)(***C*** $_{(\text{mg/L})}$÷***R*** $_{(\text{lb a.e./gal})}$)			
Central	0.01	mg/L/lb a.e./acre	WSB07.AWT
Low	0.001		WSB07.AWL
High	0.06		WSB07.AWU
Water Concentrations (WC) (***WCR*** × ***R***) (mg/L)			
Central	0.000624	mg/L/lb a.e./acre	
Low	0.0000313		
High	0.003744		
Bioconcentration factor (***BCF*** $_{(\text{L/kg fish})}$)	0.11	L/kg fish	WSB03.BCFWhl
Concentrations in fish (FC) (***WC*** × ***BCP***) (mg/kg)			
Central	0.0000686	mg/L/lb a.e./acre	
Low	0.000003		
High	0.00041184		
Fish consumed as a proportion of body weight (P_F)			
typical	0.1	g fish/g bw	Various species based on values from U.S. EPA (1993).
lower	0.05		
upper limit	0.15		
Dose estimates (D)			
Typical	6.86e-06	mg/kg bw/day	
Lower	1.72e-07	mg/kg bw/day	
Upper	6.18e-05	mg/kg bw/day	
Reproductive NOAEL	113	mg/kg/day	Section 4.1.2.2.
Risk Quotient (RQ) ***(D÷NOAEL)***			
Typical	6.07e-08	mg/kg bw/day	
Lower	1.52e-09	mg/kg bw/day	
Upper	5.47e-07	mg/kg bw/day	

Worksheet F10: Consumption of contaminated vegetation by a large mammal, acute exposure scenario. *[VGCLMA]*

***Verbal Description**: A 70 kg herbivore, such as a deer, consumes range grass shortly after application of the chemical - i.e. no dissipation or degradation is considered. The contaminated vegetation accounts for 100% of the diet. Residue estimates based on relationships for range grass from Hoerger and Kenaga (1972) summarized in Worksheet A05a. Caloric requirements are used to estimate food consumption from U.S. EPA (1993).*

Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	70	kg	N/A
Caloric requirement (***KR***)	5226	kcal/day	U.S. EPA (1993, p. 3-6)
above based on following equation: ***kcal/day = 1.518 × W(g)$^{0.73}$***			
Caloric content of vegetation (dry weight, ***KCD***)	2.46	kcal/g	U.S. EPA (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)	0.85	unitless	U.S. EPA (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)	0.37	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)	14	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***D***)	1	day	N/A
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	WSB01.Typ
Lower	0.03125	lb a.e./acre	WSB01.Low
Upper	0.0624	lb a.e./acre	WSB01.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WSA05a.LVT
Upper	125	RUD[1]	WSA05a.LVU
Conc. in Vegetation (***C***) [***R***×***rr***]			
Typical	2.184	mg/kg	Note: lower value based on typical ***rr*** and lower ***R***.
Lower	1.09375	mg/kg	
Upper	7.8	mg/kg	
Dose estimates (***D***) ***[C × A ÷W]***			
Typical	0.4	mg/kg bw	VGCSMAC
Lower	0.2	mg/kg bw	VGCSMAL
Upper	1.6	mg/kg bw	VGCSMAU
NOAEL for Assessing Hazard (***NOAEL***)	50	mg/kg/day	Section 3.3.3. ***This is estimated rather than experimental***.
Hazard Quotient (***HQ***) [***D ÷ NOAEL***]			
Typical	8.84e-03	unitless	
Lower	4.43e-03	unitless	
Upper	3.16e-02	unitless	

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.e./acre applied.

Worksheet F11: Consumption of contaminated vegetation by a large mammal, chronic exposure scenario. *[VGCLMC]*

***Verbal Description**: A 70 kg herbivore, such as a deer, consumes range grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 10 to 100% of the diet. Residue estimates based on relationships for range grass from Hoerger and Kenaga (1972) summarized in Worksheet A05a.* Caloric requirements are used to estimate food consumption from U.S. EPA (1993). *Dissipation is considered using the foliar halftime and taking the geometric mean of the initial and day-90 residues as the measure of dose.*

Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	70	kg	N/A
Caloric requirement (***KR***)	5226	kcal/day	U.S. EPA (1993, p. 3-6)
above based on following equation: $kcal/day = 1.518 \times W(g)^{0.73}$			
Caloric content of vegetation (dry weight, ***KCD***)	2.46	kcal/g	U.S. EPA (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)	0.85	unitless	U.S. EPA (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)	0.37	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)	14	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***D***)	1	day	N/A
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	WSB01.Typ
Lower	0.03125	lb a.e./acre	WSB01.Low
Upper	0.0624	lb a.e./acre	WSB01.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WSA05a.LVT
Upper	125	RUD[1]	WSA05a.LVU
Day 0 Conc. in Vegetation (C_0) [***R***×***rr***]			
Typical	2.184	mg/kg	Note: lower value based on typical ***rr*** and lower ***R***.
Lower	1.09375	mg/kg	
Upper	7.8	mg/kg	
Foliar dissipation coefficient (***k***)			
Typical	0.099021	$days^{-1}$	Worksheet B02
Lower	0.099021	$days^{-1}$	
Upper	0.099021	$days^{-1}$	
Day 90 Conc. in Vegetation (C_{90}) [$C_0 \times e^{-k \times 90\ days}$]			
Typical	0.0003	mg/kg	
Lower	0.0001	mg/kg	
Upper	0.00105	mg/kg	
Central Estimate of Conc. in Vegetation (C_{Ave}) [$(C_0 \times C_{90})^{0.5}$]			
Typical	0.025355	mg/kg	
Lower	0.012698	mg/kg	
Upper	0.09	mg/kg	

Worksheet F11 *(continued)*: Consumption of contaminated vegetation by a large mammal, chronic exposure scenario			
Proportion of diet contaminated (***P_D***)			
Typical	0.3	Unitless	See section 4.2.2.3.
Lower	0.1	Unitless	
Upper	1.0	Unitless	
Dose estimates (***D***) ***[C_{Ave} × A ÷W***]			
Typical	0.0015	mg/kg bw	
Lower	0.00025692	mg/kg bw	
Upper	0.02	mg/kg bw	
Systemic Toxicity NOAEL (***$NOAEL_T$***)	50	mg/kg/day	Section 3.3.3.
Toxicity Hazard Quotient (***HQ***) [***D ÷ $NOAEL_T$***]			
Typical	3.08e-05	unitless	
Lower	5.14e-06	unitless	
Upper	3.66e-04	unitless	
Repro. NOAEL (***$NOAEL_R$***)	1200	mg/kg/day	Section 3.3.3.
Repro. Hazard Quotient (***rHQ***) [***D ÷ $NOAEL_R$***]			
Typical	1.28e-06	unitless	
Lower	2.14e-07	unitless	
Upper	1.53e-05	unitless	

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.e./acre applied.

Worksheet F12: Consumption of contaminated vegetation by a large bird, acute exposure scenario. *[VGCLBA]*

Verbal Description*: A 4 kg herbivorous bird, such as a Canada Goose, consumes range grass shortly after application of the chemical - i.e. no dissipation or degradation is considered. The contaminated vegetation accounts for 100% of the diet. Residue estimates based on relationships for range grass from Hoerger and Kenaga (1972) summarized in Worksheet A05a.* from U.S. EPA (1993).

Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	4	kg	N/A
Caloric requirement (***KR***)	471	kcal/day	U.S. EPA (1993, Eq. 3-35, p. 3-22)
above based on following equation: ***kcal/day = 3.12 × W(g)$^{0.604}$***			
Caloric content of vegetation (dry weight, ***KCD***)	2.46	kcal/g	U.S. EPA (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)	0.85	unitless	U.S. EPA (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)	0.37	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)	1.28	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***D***)	1	day	N/A
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	WSB01.Typ
Lower	0.03125	lb a.e./acre	WSB01.Low
Upper	0.0624	lb a.e./acre	WSB01.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WSA05a.LVT
Upper	125	RUD[1]	WSA05a.LVU
Conc. in Vegetation (***C***) [***R***×***rr***]			
Typical	2.184	mg/kg	Note: lower value based on typical ***rr*** and lower ***R***.
Lower	1.09375	mg/kg	
Upper	7.8	mg/kg	
Dose estimates (***D***) ***[C × A ÷W]***			
Typical	0.7	mg/kg bw	VGCSMAC
Lower	0.3	mg/kg bw	VGCSMAL
Upper	2.5	mg/kg bw	VGCSMAU
Reproductive NOAEL (***NOAEL***)	113	mg/kg/day	Section 3.3.3.
Hazard Quotient (***HQ***) [***D ÷ NOAEL***]			
Typical	0.01	unitless	
Lower	0.003	unitless	
Upper	0.0	unitless	

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.e./acre applied.

Worksheet F13: Consumption of contaminated vegetation by a large bird, chronic exposure scenario. *[VGCLBC]*

Verbal Description*: A 4 kg herbivorous bird, such as a Canada Goose, consumes range grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 10 to 100% of the diet. Residue estimates based on relationships for range grass from Hoerger and Kenaga (1972) summarized in Worksheet A05a.* Caloric requirements are used to estimate food consumption from U.S. EPA (1993). *Dissipation is considered using the foliar halftime and taking the geometric mean of the initial and day-90 residues as the measure of dose.*

Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	4	kg	N/A
Caloric requirement (***KR***)	471	kcal/day	U.S. EPA (1993, p. 3-6)
above based on following equation: $kcal/day = 3.12 \times W(g)^{0.604}$			
Caloric content of vegetation (dry weight, ***KCD***)	2.46	kcal/g	U.S. EPA (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)	0.85	unitless	U.S. EPA (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)	0.37	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)	1.3	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***D***)	90	days	N/A
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	WSB01.Typ
Lower	0.03125	lb a.e./acre	WSB01.Low
Upper	0.0624	lb a.e./acre	WSB01.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WSA05a.LVT
Upper	125	RUD[1]	WSA05a.LVU
Day 0 Conc. in Vegetation (C_0) [***R***×***rr***]			
Typical	2.184	mg/kg	Note: lower value based on typical ***rr*** and lower ***R***.
Lower	1.09375	mg/kg	
Upper	7.8	mg/kg	
Foliar dissipation coefficient (***k***)			
Typical	0.099021	$days^{-1}$	Worksheet B02
Lower	0.099021	$days^{-1}$	
Upper	0.099021	$days^{-1}$	
Day 90 Conc. in Vegetation (C_{90}) [$C_0 \times e^{-k \times 90\ days}$]			
Typical	0.0003	mg/kg	
Lower	0.0001	mg/kg	
Upper	0.00105	mg/kg	
Central Estimate of Conc. in Vegetation (C_{Ave}) [$(C_0 \times C_{90})^{0.5}$]			
Typical	0.025355	mg/kg	
Lower	0.012698	mg/kg	
Upper	0.09	mg/kg	

Worksheet F13 *(continued)*: Consumption of contaminated vegetation by a large bird, chronic exposure scenario			
Proportion of diet contaminated (***P_D***)			
Typical	0.3	Unitless	See section 4.2.2.3.
Lower	0.1	Unitless	
Upper	1.0	Unitless	
Dose estimates (***D***) ***[C_{Ave} × A ÷W***]			
Typical	0.0024	mg/kg bw	
Lower	0.0004055	mg/kg bw	
Upper	0.03	mg/kg bw	
Repro. NOAEL (***$NOAEL_R$***)	113	mg/kg/day	Section 3.3.3.
Repro. Hazard Quotient (***HQ***) [***D ÷ $NOAEL_R$***]			
Typical	2.15e-05	unitless	
Lower	3.59e-06	unitless	
Upper	2.56e-04	unitless	

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.e./acre applied.

Worksheet F14: Consumption of contaminated insects by a small bird, acute exposure scenario. *[VGCSBA]*

***Verbal Description**: A small insectivorous bird (10g) bird consumes insects shortly after application of the chemical - i.e. no dissipation or degradation is considered. The contaminated food accounts for 100% of the diet. Residue estimates in insects are based on relationships for seed containing pods and forage crops from Hoerger and Kenaga (1972) summarized in Worksheet A05a.*

Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	0.01	kg	N/A
Caloric requirement (***KR***)	13	kcal/day	U.S. EPA (1993, Eq. 3-35, p. 3-22)
above based on following equation: ***kcal/day = 3.12 × W(g)$^{0.604}$***			
Caloric content of insects (dry weight, ***KCD***)	4.3	kcal/g	U.S. EPA (1993, p. 3-5)
Water content of insects (proportion, ***PW***)[2]	0.65	unitless	U.S. EPA (1993, p. 4-13)
Caloric content of vegetation (wet weight, ***KCW***)	1.51	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)	0.01	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***D***)	1	day	N/A
Application rates (***R***)			
Typical	0.0624	lb a.e./acre	WSB01.Typ
Lower	0.03125	lb a.e./acre	WSB01.Low
Upper	0.0624	lb a.e./acre	WSB01.Hi
Residue rates (***rr***)			
Typical	33	RUD[1]	WSA05a.FCT
Lower	3	RUD[1]	WSA05a.PDT
Upper	58	RUD[1]	WSA05a.FCU
Conc. in Vegetation (***C***) [***R***×***rr***]			
Typical	2.0592	mg/kg	Note: lower value based on typical ***rr*** for pods. Lower ranges not provided in Hoerger and Kenaga (1972)
Lower	0.09375	mg/kg	
Upper	3.6192	mg/kg	
Dose estimates (***D***) ***[C × A ÷W***]			
Typical	1.72	mg/kg bw	
Lower	0.078	mg/kg bw	
Upper	3.0	mg/kg bw	
Reproductive NOAEL (***NOAEL***)	113	mg/kg/day	Section 3.3.3.
Hazard Quotient (***HQ***) [***D ÷ NOAEL***]			
Typical	0.02	unitless	
Lower	0.001	unitless	
Upper	0.0	unitless	

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.e./acre applied.
[2] Average of beetles (61%) and grasshoppers (69%) from U.S. EPA (1993, Table 4-1, p. 4-13)

Worksheet G01: Summary of Exposure Scenarios for Terrestrial Animals.

Scenario	Dose (mg/kg/day)			Worksheet
	Typical	Lower	Upper	
Acute/Accidental Exposures				
Direct spray				
small mammal, first-order absorption	0.039	0.008	0.1	WSF01
small animal, 100% absorption	2	1	2	WSF02
bee, 100% absorption	10	5	10	WSF03
Contaminated vegetation				
small mammal	0.3	0.2	1	WSF04
large mammal	0.4	0.2	2	WSF10
large bird	0.7	0.3	2	WSF12
Contaminated water				
small mammal	0.2	0.07	0.8	WSF06
Contaminated insects				
small bird	1.7	0.1	3.0	WSF14
Contaminated fish				
predatory bird	0.010	0.0015	0.050	WSF08
Longer-term Exposures				
Contaminated vegetation				
small mammal	4.00e-04	1.70e-06	6.79e-06	WSF05
large mammal	1.54e-03	2.57e-04	1.83e-02	WSF10
large bird	2.43e-03	4.06e-04	2.89e-02	WSF13
Contaminated water				
small mammal	2.00e-04	8.00e-06	1.00e-03	WSF07
Contaminated fish				
predatory bird	6.86e-06	1.72e-07	6.18e-05	WSF09

Worksheet G02: Summary of quantitative risk characterization for terrestrial animals[1]

Scenario	Hazard Quotient[2] Typical	Lower	Upper
Acute/Accidental Exposures			
Direct spray			
small mammal, first-order absorption	8e-04	2e-04	2e-03
small animal, 100% absorption	3e-02	2e-02	3e-02
bee, 100% absorption	1e-02	5e-03	1e-02
Contaminated vegetation			
small mammal, toxicity	7e-03	3e-03	2e-02
small mammal, reproduction	3e-04	1e-04	1e-03
large mammal, toxicity	9e-03	4e-03	3e-02
large mammal, reproduction	4e-04	2e-04	1e-03
large bird, reproduction	6e-03	3e-03	2e-02
Contaminated water			
small mammal, toxicity	5e-03	1e-03	2e-02
small mammal, reproduction	2e-04	6e-05	6e-04
Contaminated insects			
small bird, reproduction	2e-02	7e-04	3e-02
Contaminated fish			
predatory bird, reproduction	2e-02	7e-04	4e-04
Longer-term Exposures			
Contaminated vegetation			
small mammal, toxicity	8e-06	3e-08	1e-07
small mammal, reproduction	3e-07	1e-09	6e-09
large mammal, toxicity	3e-05	5e-06	4e-04
large mammal, reproduction	1e-06	2e-07	2e-05
large bird, reproduction	2e-05	4e-06	1e-02
Contaminated water			
small mammal	4e-06	2e-07	1e-03
Contaminated fish			
predatory bird	6e-08	2e-09	6e-02

Toxicity Indices [3]		
General toxicity value for mammal - NOAEL	50	mg/kg/day
Reproductive toxicity value for mammal - NOAEL	1200	mg/kg/day
Reproductive toxicity value for bird - NOAEL	113	mg/kg/day
Toxicity value for bee - $<LD_{50}$	1075	mg/kg

[1] See Worksheet G01 (Table 4-1 in text) for summary of exposure assessment.
[2]Estimated dose ÷ toxicity index
[3] See Section 4.3 for a discussion of the toxicity indices.
[4] Calculated as a LD_{50} >0.1 mg/ 0.000093 kg bee. At this exposure level, 25% mortality was observed (Section 4.1.2.3).

Worksheet G03: Quantitative Risk Characterization for Aquatic Species.

Risk Quotients	**Central**	**Lower**	**Upper**	**Endpoint**
Fish				
Acute	9e-03	3e-03	3e-02	Mortality
Chronic	7e-06	3e-07	4e-05	LOAEL
Aquatic Invertebrates				
Acute	9e-03	3e-03	3e-02	Mortality
Chronic	6e-06	3e-07	4e-05	NOAEL
Aquatic Plants				
Acute (spill)	**237**	**70**	**757**	NOEC
Chronic (ambient)	0.2	0.008	0.9	NOEC

Exposures (mg/L)	Central	Lower	Upper	Worksheet
Acute	0.95	0.28	3.0	F08/D03[1]
Longer-term	0.00062	0.000031	0.0037	F09

Toxicity values (mg/L)

	Value (mg/L)	Endpoint	Section
Fish, acute	100	Mortality	4.3.3.2.
Fish, chronic	96	Growth and development	4.3.3.2.
Aquatic Invertebrates, acute	100	Mortality	4.3.3.3
Aquatic Invertebrates, chronic	100	No data found. Acute value used.	4.3.3.3
Aquatic plants	0.004	Frond counts EC_{25}	4.3.3.4.

Worksheet G04: Summary of Exposure Assessment and Risk Characterization for Terrestrial Plants from Runoff.

Application rate	0.0624	lb a.e./acre	Highest FS rate, Section 2.4.
NOEC for survival, preemergence	0.016	lb a.e./acre	Section 4.3.2.4.

Annual Rainfall	Clay	Loam	Sand
	Proportion lost in Runoff		
5	0.00000	0.00000	0.00000
10	0.00000	0.00000	0.00000
15	0.00551	0.01319	0.01366
20	0.02576	0.07170	0.07517
25	0.04053	0.09959	0.08775
50	0.10529	0.20095	0.13196
100	0.19801	0.31878	0.19635
150	0.26065	0.38431	0.24578
200	0.30658	0.42460	0.28619
250	0.34139	0.45270	0.32010
	Functional Off-site Application Rate[1]		
5	0.00000	0.00000	0.00000
10	0.00000	0.00000	0.00000
15	0.00034	0.00082	0.00085
20	0.00161	0.00447	0.00469
25	0.00253	0.00621	0.00548
50	0.00657	0.01254	0.00823
100	0.01236	0.01989	0.01225
150	0.01626	0.02398	0.01534
200	0.01913	0.02650	0.01786
250	0.02130	0.02825	0.01997
	Hazard Quotient[2]		
5	0.00	0.00	0.00
10	0.00	0.00	0.00
15	0.02	0.05	0.05
20	0.10	0.28	0.29
25	0.16	0.39	0.34
50	0.41	0.78	0.51
100	0.77	1.24	0.77
150	1.02	1.50	0.96
200	1.20	1.66	1.12
250	1.33	1.77	1.25

[1] The functional off-site application rate is calculated as the nominal application rate specified on line two multiplied by the proportion lost in runoff.

[2] The hazard quotient is calculated as the function off-site application rate divided by the NOEC specified on line three.

Worksheet G05: Summary of Exposure Assessment and Risk Characterization for Terrestrial Plants from Drift and Wind Erosion.

	Most Sensitive Plant	Least Sensitive Plant	
Post-emergence NOEC for visual injury, lb a.i./acre	0.001	0.0320	Section 3.2.4.
Application Rate, lb a.e./acre	0.0624	Highest FS use.	Section 2.4
Estimates of the proportion of offsite drift			
Drift	Aerial[1]	Ground[1]	See section 4.2.3.2 for basis of drift estimates.
100 ft.	0.03	0.00069	
500 ft.	0.002	0.000046	
1000 ft.	0.0006	0.0000138	
2000 ft.	0.0002	0.000005	
Estimates of functional offsite application rate			
100 ft.	0.001872	0.0000431	Calculated as the product of the application rate and the estimated proportion of offsite drift.
500 ft.	0.0001248	0.0000029	
1000 ft.	0.0000374	0.0000009	
2000 ft.	0.0000125	0.0000003	
Hazard Quotient - Sensitive Species			
100 ft.	**1.9e+00**	4.3e-02	Calculated as the offsite application rate divided by the NOEC for the most sensitive species.
500 ft.	1.2e-01	2.9e-03	
1000 ft.	3.7e-02	8.6e-04	
2000 ft.	1.2e-02	2.9e-04	
Hazard Quotient - Tolerant Species			
100 ft.	5.9e-02	1.3e-03	Calculated as the offsite application rate divided by the NOEC for the least sensitive species.
500 ft.	3.9e-03	9.0e-05	
1000 ft.	1.2e-03	2.7e-05	
2000 ft.	3.9e-04	9.0e-06	