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104PP

REREGISTRATION ELIGIBILITY DECISION

ENVIRONMENTAL RISK ASSESSMENT

BENSULIDE

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U.S. EPA
Office of Pesticide Programs
Environmental Fate and Effects Division
(7507C)

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REREGISTRATION ELIGIBILITY DECISION

ENVIRONMENTAL RISK ASSESSMENT
for
BENSULIDE

Office of Pesticide Programs
Environmental Fate and Effects Division
Environmental Risk Branch II

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EXECUTIVE SUMMARY

Adequacy of Data:

The quality of the risk assessment for bensulide was significantly compromised by the lack of important data. No adequate field dissipation data have been provided to the Agency, making it impossible to know if the degradation rates measured in the laboratory accurately reflect those that occur under field conditions. Risk to nontarget plants could not be assessed because data have been submitted for neither terrestrial nor aquatic plants. Furthermore, the risk of chronic effects to aquatic organisms are unknown because chronic toxicity studies have not been submitted. Finally, the data submitted acute toxicity to freshwater invertebrates were inadequate, which decreased the certainty of the risk assessment. These data gaps must be filled, and the environmental risk of bensulide needs to be reassessed as these data become available.

Toxicity Summary:

The available acute toxicity data on the TGAI indicate that bensulide is practically nontoxic to slightly toxic to birds (LD_{50} = 1386 mg/kg; LC_{50} > 5620 ppm), and moderately toxic to small mammals (LD_{50} = 312 mg/kg, rat). Bensulide causes eggshell thinning in birds at a dietary concentration of 25 ppm, with the NOAEL established at 2.5 ppm. Bensulide is highly toxic to bees (LD_{50} = 1.6 μg/bee). Bensulide is moderately to highly toxic to freshwater fish (LC_{50} = 0.72-1.1 ppm) and (based on supplemental data) moderately toxic to freshwater invertebrates (LC_{50} = 1.4-3.3 ppm). Bensulide is highly toxic to estuarine/marine fish (LC_{50} = 320-560 ppb) and moderately to very highly toxic to estuarine/marine invertebrates (LC_{50} = 62 to >1000 ppb). Data on the toxicity of bensulide to plants are not available.

Risk Assessment:

<u>Birds</u>: Use of the emulsifiable concentrate (EC) products of bensulide are not expected to pose a high **acute** risk to birds. The restricted use and endangered species LOCs are exceeded when the maximum application rate is equal to or greater than 6.0 and 3.0 lb ai/A, respectively. For granular products used on turf and ornamentals, the risk quotients indicate high acute risk. The high acute LOC is exceeded for small birds when the maximum application rate is 7.5 lb ai/A or greater, and for medium birds when the maximum application rate is 12.5 lb ai/A. However, acute risk would be substantially reduced, possibly to a minimal level, if the user incorporates the pesticide into the soil through irrigating immediately after application, as the labels directs. Chronic risk quotients for EC products exceed the LOC for chronic risk. Use of both EC and granular products on all use sites is predicted to pose a high risk of causing egg shell thinning and other reproductive impairments in birds.

Mammals: Risk quotients for all uses of EC products fall in the range of high acute risk for some herbivorous and insectivorous mammals. For vegetable uses, little dietary exposure is expected for herbivorous mammals because bensulide is applied to bare fields. The high risk for registered uses on vegetables (maximum application rate of 3 to 6 lb ai/A) is limited to the more vulnerable insectivorous species (i.e., smaller species that feed on small insects). No use of EC products pose a high risk to granivorous species. The high risk for registered EC uses on turf (12.5 lb ai/A) covers a wide range of herbivorous and insectivorous species. For uses of granular products on turf, risk quotients for all uses (maximum application rates 7.5-12.5 lb ai/A) exceed the high acute LOC for small and medium sized mammals. Acute risk for both EC and granular products would be substantially reduced if the user incorporates the pesticide into the soil through irrigating immediately after application, as the labels directs. Although this would likely eliminate acute hazard to mammals for the vegetable uses, it may not be enough to eliminate the acute hazard to mammals for turf uses. Chronic risk quotients for EC products exceed the LOC for chronic risk. Use of both EC and granular products on all use sites is predicted to pose a high risk of chronic effects in mammals. Risk associated with bensulide use on ornamentals is considered insignificant.

Aquatic organisms: Uses of granular bensulide on turf generally poses a high acute risk to freshwater fish. Use of EC formulations on turf, ornamentals, and vegetables do not pose a high risk to freshwater fish; however, unincorporated broadcast applications of EC formulations at 6 lb ai/A or greater pose a risk that may warrant restricted use classification. Risks are reduced when the following application methods are applied: (1) using lower application rates, (2) limiting the number of applications to one per year, (3) incorporating applications in the soil (vegetable uses only), and (4) using banded applications (vegetable uses only). Risk associated with bensulide use on ornamentals is considered insignificant.

All uses of bensulide on turf in coastal areas generally pose a high acute risk to marine and estuarine fish. Note that this conclusions apply only to use in areas where bensulide may be transported from the use site to marine and estuarine areas. Uses on vegetables will not pose a high risk to freshwater fish, but most uses on vegetables pose a risk that may warrant restricted use classification. Exceptions that do not warrant restricted use are once per year applications at 6 lb ai/A that are both banded and soil incorporated, and applications at 3 lb ai/A that are banded application and/or soil incorporation.

Use of bensulide on turf generally poses a high acute risk to both freshwater and marine/estuarine invertebrates. Vegetable uses with a maximum rate of 6 lb ai/A generally pose a high risk to marine/estuarine invertebrates, although this high risk can be avoided by applying one application per year that is both banded and soil incorporated. All types of applications to vegetables pose a risk to marine/estuarine invertebrates that may warrant restricted use classification. Uses of bensulide on vegetables does not pose a high risk to freshwater invertebrates, but in some cases pose a risk that may warrant restricted use classification.

Vegetable fields in Arizona and California that are irrigated by the Colorado River are generally very flat and surrounded by a berm. Use of bensulide on vegetable fields of this type will poses minimal risk to all aquatic organisms because there would be insignificant transport of pesticides from such fields into aquatic habitats. Twice-per-year applications generally occur only in this region of the United States. Therefore, they are not expected to pose high risk, even though the RQs exceed the LOC for high risk.

Chronic risk to fish and invertebrates could not be assessed because chronic toxicity data were not available. Since bensulide is highly persistent, chronic risk to these organisms must be assumed in the absence of data.

Plants: Risk to plants could not be assessed because no acceptable data were available on the toxicity of bensulide to nontarget terrestrial and aquatic plants. Since bensulide is an herbicide, risk to nontarget plants must be assumed in the absence of data. Efficacy data suggest that while bensulide would likely effect seed germination and seedling emergence, it would likely not effect nontarget plants that are already emerged.

.**Environmental Fate and Transport:**

Although the environmental fate data base for bensulide is not complete, information from acceptable laboratory studies indicates bensulide is persistent. Neither abiotic hydrolysis nor photolysis are major degradation processes in water or on soil surfaces. The main route of dissipation of bensulide appears to be aerobic soil metabolism with a reported half-life of 1 year. Under aerobic conditions it appears that mineralization of bensulide to CO_2 and immobilization as unextractable residues are the major mechanisms of dissipation in the soil. Under anaerobic soil conditions bensulide did not degrade. Based on the lack of degradation under laboratory conditions, it is predicted that bensulide will be extremely persistent in anaerobic terrestrial ecosystems.

Information from acceptable laboratory studies indicates that bensulide is not mobile in the four soils tested (K_{oc}'s ranged from 1,433 to 4,326 ml/g); however, the degradates bensulide oxon (N-[(2-(diisopropoxyphosphinoylthio)-1-ethyl]- benzenesulfonamide) and benzenesulphonamide ranged from mobile to highly mobile in the same four test soils. Bensulide has the potential to be transported dissolved in water and on suspended sediment in runoff to surface waters where, based on laboratory data, it is expected to persist. Bensulide has the persistence characteristics of chemicals found capable of leaching to ground water; however, based on other environmental fate characteristics (i.e., high sorption capacity) and supporting groundwater modeling, bensulide is not expected to leach to ground water.

The environmental fate assessment developed from the results of the laboratory studies has not been confirmed by acceptable field dissipation information. In 8 unacceptable field dissipation studies using bensulide at 6 and 12.5 lb ai/A, the half-life of bensulide was reported to range from 8-34 days in studies conducted in California and from 91-210 days in studies conducted in Mississippi. However, in none of the studies was a consistent decline of parent compound observed. None of the studies is acceptable because the application rate could not be confirmed and bare ground plots were not used for confirmation of application. The study plots had been planted to turf, and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch. In a currently unacceptable but upgradeable field dissipation study, calculated first-order half-lives for bensulide in the top 6 inches of soil were 106.8 days (registrant-calculated) and 80.4 days (reviewer-calculated). Bensulide and its degradate bensulide oxon were found only in the top 6 inches of the soil.

Bensulide does not appear to have a large potential to bioaccumulate in fish with a reported whole body bioconcentration factor of 550X and a whole body elimination of 98% after 14 days depuration.

1. Use Characterization

Bensulide is used for preemergent control of annual grasses and broadleaf weeds in agricultural crops (vegetables), dichondra and grass lawns. Registered use sites include leafy vegetables (mostly head lettuce), golf greens, dry bulb vegetables (onions), cucurbits (mostly melons), cole crops (cauliflower, cabbage, broccoli), peppers, carrots, and lawn care (professional and homeowner applications) (Gowan, 1997a, Gowan, 1997b, Meister, 1995).

There are currently 11 registered products containing bensulide in the U.S.; at least 63 bensulide products have been previously registered. The majority of bensulide products for both agricultural and turf uses are formulated as an emulsified concentrate (EC). A small amount of bensulide is made into granular products for turf and homeowner uses. There is one liquid "ready-to-use" formulation registered, however it is not currently manufactured or sold in the U.S. and is not considered in this evaluation for reregistration (Gowan, 1997a).

Bensulide is applied using ground spray equipment (preplant and preemergence) and in chemigation (preemergence), and is not aerially applied. Bensulide is manufactured into two agricultural products which contain 4 and 6 pounds of active ingredient per gallon (lbs ai/gal). The majority of the agricultural uses involve the 4 lbs ai/gal EC formulation. The 6 lbs ai/gal product was introduced in 1996 and is being used on a trial basis. A 9 lbs ai/gal use has been proposed for cucurbits; however, it is not registered at this time. Technical bensulide is sold to several companies which manufacture bensulide products for turf and ornamental uses. Turf and ornamental uses may use the EC or granular formulations (Gowan, 1997a, Gowan, 1997b).

The principal uses of bensulide are on lettuce, golf greens, onions and melons. Lettuce production in Southwest deserts accounts for one-third of the bensulide use in the U.S. Bensulide use on golf greens in the central U.S. also accounts for about one-third of the use. Onion production accounts for about 15% of the bensulide use and occurs in the Rio Grande

Valley of Texas, northeast Colorado, and probably Idaho. There is no use on onions in California or Florida. Melon production in the Central Valley of California and the Rio Grande Valley of Texas accounts for approximately 10 percent of bensulide use. Use on melon and cauliflower crops in Southwest deserts may account for as much as 10% of bensulide use. Specific characterizations of the use areas are given in Appendix A (Gowan, 1997a; Gowan 1997b).

Bensulide is a preplant or preemergent herbicide which affects meristematic root tissues and is usually applied very early in the spring to bare ground before any vegetation is present. The agricultural use rate is typically 5-6 lbs ai/acre, and the 6 lb rate is often used. An exception to this occurs in Southwest deserts, where it is usually applied in the fall and again to a second crop (usually lettuce) about 120 days later. Up to 6 lbs ai/acre can be applied for each crop for a maximum of 12 lbs ai/acre/year. Sprinkler and chemigation systems are used in Southwest deserts to deliver bensulide and often use rates as low as 4 lb ai/acre per application. A 9 lbs ai/gal use has been proposed for cucurbits; however, it has not been registered at this time (Gowan, 1997a, Gowan, 1997b).

Bensulide is applied to turf in the late winter to early spring and must be watered-in to be effective. Typical application rates are 7.5 to 12.5 lbs ai/acre per application, with a maximum application of 25 lbs ai/year. There is minor use of bensulide on commercial turf sod farms, but no reported use in greenhouses (Gowan, 1997a, Gowan, 1997b).

2. Exposure Characterization

a. Environmental Fate Assessment

Although the environmental fate data base for bensulide is not complete, information from acceptable laboratory studies indicate that bensulide is persistent. Information from acceptable laboratory adsorption/desorption studies indicates that bensulide is not mobile in four soils; however, the degradates bensulide oxon and benzenesulphonamide ranged from being mobile to highly mobile in the same four test soils. This environmental fate assessment concentrates on bensulide because it is persistent and the two degradates' concentrations are expected to be low. In an aerobic soil metabolism study, bensulide oxon reached a maximum concentration of 13.8% of the applied at 270 days posttreatment and decreased to 10.1% at 360 days, and benzenesulfonamide reached a maximum level of 0.52% at 360 days. The toxicity of the degradates is unknown.

The main route of dissipation of bensulide appears to be aerobic soil metabolism with a reported half-life of 1 year (363 days). Under aerobic conditions it appears that mineralization of bensulide to CO_2 and immobilization as unextractable residues are the major mechanisms of degradation in the soil. Additional minor degradation pathways include oxidative desulfurization of the phosphorodithioate moiety to form bensulide oxon and cleavage of the C-N bond to form benzenesulfonamide. Under anaerobic soil conditions bensulide did not degrade. Based on the lack of degradation under laboratory conditions, it is likely that bensulide will be persistent in aerobic and anaerobic terrestrial ecosystems. Photolysis is not a major route of dissipation of bensulide in water or on soil surfaces. Abiotic hydrolysis is not a major route of dissipation.

The environmental fate assessment developed from the results of the laboratory studies has not been confirmed by acceptable field dissipation information. In six unacceptable terrestrial field dissipation studies using bensulide at 6 and 12.5 lbs ai/A, the reported half-life of bensulide ranged from 8-34 days in studies conducted in California and from 91-210 days in studies conducted in Mississippi. However, the information provided by these studies is marginal because substantial residues of bensulide were recovered at all sampling depths immediately following application (indicating contamination during sampling). In addition, because substantial residues of bensulide were recovered at all sampling depths at the time of application, the depth of leaching could not be determined.

Two unacceptable studies were conducted on established turf in California with sampling to 39.5 inches. In one study, both bensulide and the degradate bensulide oxon were detected to 27.5 inches, but in the other study, they were detected only in the surface layer. No consistent decline of parent compound was apparent in either study. However, the information provided by these studies is marginal because the application rate could not be confirmed and bare-ground plots were not used for confirmation of application. The study plots had been planted to turf several weeks prior to the first application, and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch.

Supplemental information from an unacceptable but upgradeable study showed that bensulide, when applied at 10 lb ai/A to a Norfolk soil in NC subsequently planted to cabbage, dissipated with a observed half-life in the top 6 inches of soil of greater than 90 but less than 180 days. Calculated first-order half-lives for bensulide in the top 6 inches of soil were 106.8 days (registrant-calculated) and 80.4 days (reviewer-calculated). The maximum concentration of bensulide found was 5.46 ppm (immediately posttreatment) and mean concentrations ranged from 3.37 to 4.24 ppm between 0 and 90 days posttreatment (range of concentrations 1.56-5.46 ppm). Mean concentrations decreased sharply between the 90- and 182-day sampling interval and decreased to below the Limit of Quantitation (0.05 ppm) by 546 days posttreatment. The degradate bensulide oxon was never present at greater than 0.56 ppm (maximum at 90 days posttreatment) and decreased to the Limit of Quantitation (0.05 ppm) by 182 days posttreatment. Bensulide and its degradate bensulide oxon were found only in the top 6 inches of the soil; rainfall plus irrigation was at least 118% of the 27 year average during the first 5 months of the study. The observed dissipation of extractable bensulide residues in his study was possibly due to microbial metabolism and/or binding to soil. Data indicate that leaching was not an important route of dissipation for bensulide in this study; the significance of plant uptake is unknown because plant material was not analyzed in this study.

Bensulide does not appear to bioaccumulate in fish in laboratory studies, with a reported whole body bioconcentration factor of 550X and a whole body elimination of 98% after 14 days depuration.

Bensulide has the potential to be transported dissolved in water and on suspended sediment in runoff to surface waters where, based on characteristics determined from the laboratory data, it is expected to persist. Bensulide has some of the characteristics of chemicals detected in ground water (persistence); however, because the behavior of bensulide in the field have not been determined (no acceptable field dissipation data), the ground water assessment is tentative. There were no detections of bensulide reported in the Pesticide Ground Water Database.

b. Environmental Fate and Transport Data

i. Degradation

a. Abiotic Hydrolysis

Bensulide does not hydrolyze quickly at pH 5, 7, and 9 (25°C) with reported half-lives of 230, 220 and 220 days, respectively. These half-lives were extrapolated from a 30-day study. Reported half-lives for pH 5, 7 and 9 at 40°C were 27.7, 27.0 and 26.9 days, respectively, indicating that while hydrolysis rates increased with increasing temperature, there were no changes in the relative rates of hydrolysis at the different pHs. Bensulide hydrolysis products in pH 9 solutions held at 40°C for 40 days included: O-isopropyl S-[2[(phenylsulfonyl) amino]ethyl]phosphorodithioic acid (59.4% of the applied); bis[2-[(phenylsulfonyl)amino]ethyl) disulfide (2.0%); N-(2-hydroxylethyl)benzenesulfonamide (1.4%); benzenesulfonamide (0.2%). Other identified degradates were isopropanol and O,O-diisopropyl phosphorthioic acid. The study is acceptable and satisfies the data requirement for abiotic hydrolysis (GLN 161-1; 00160074).

b. Photodegradation in Water

Bensulide is stable to photolysis in sterile aqueous buffer solutions. Bensulide degraded in aqueous pH 9 solutions irradiated with black light (spectral distribution of the black light and sunlight at wavelengths of interest [285 - 450 nm] were comparable) with a calculated half-life of 200 days (corrected for dark controls). The major degradate was desisopropyl bensulide reaching a maximum of 13.0 - 13.6% by day 40. Bensulide oxon was first detected after 21 days of irradiation and reached a maximum concentration of 4.8% at Day 40. Since desisopropyl bensulide was produced in the dark-control study (10.3% of the applied after 40 days irradiation), it was estimated that only 3% of the desisopropyl bensulide present after 28 days of continuous radiation was due to photolysis. The study is acceptable and satisfies the data requirement for photodegradation in water (GLN 161-2; 40513401).

c. Photolysis on Soil

Bensulide was stable to photolysis on Sorento loam soil in the laboratory. The photolysis half-life of bensulide when applied to thin layers of dried soil slurries that were then exposed to a xenon light source was calculated to be 90 days (rate constant of 7.6×10^{-3} day^{-1}) which was estimated to be equivalent to 220 days of solar irradiation; bensulide did not degrade in the dark controls. After 11.5 days of xenon irradiation (equivalent of 28 days solar irradiation), 89.6% of the radioactivity of the irradiated samples remained as parent bensulide. Bensulide oxon accounted for 4.6% of the radioactivity in the irradiated samples after 11.5 days of xenon irradiation. Three trace components (none exceeding 2% of initial radioactivity) were observed but not identified. No significant amount of CO_2 ($\leq$0.6% of applied radioactivity) was formed during the course of the study. Soil bound residues ranged from 0.9-2.6% of the applied radioactivity. The study is acceptable and satisfies the data requirement for photodegradation on soil (GLN 161-3; 42162001).

d. Photodegradation in Air

Based on the vapor pressure of bensulide (Pure active: 1.1×10^{-4} Pa; 8.2×10^{-7} mm Hg/Torr [41532001]) and the calculated Henry's constant (7.7×10^{-8} atm-mole/m^3), bensulide is not predicted to volatilize from either soil or water. Therefore it is not expected that there will be sufficient residues of bensulide in air for photodegradation to be a significant route of dissipation for bensulide.

e. Aerobic Soil Metabolism

Bensulide was persistent under aerobic conditions in soil in the laboratory. Bensulide degraded with a reported half-life of 363 days in Sorrento loam soil that was incubated in the laboratory under static aerobic conditions in the dark at approximately 25°C. Mineralization to CO_2 appears to be the major mechanism of bensulide degradation under aerobic conditions in soil, with 21% of ^{14}C-bensulide mineralized after 360 days. The major nonvolatile metabolite was bensulide oxon (maximum of 13.80% of the applied at 270 days posttreatment, decreasing to 10.10% at 360 days), which is formed by the oxidative desulfurization of the phosphorodithioate moiety. Another identified minor metabolite, benzenesulfonamide, reached a maximum of 0.52% at 360 days; it is formed by the cleavage of the carbon-nitrogen bond. Another unidentified compound was present at a maximum of 2.37% at 360 days and, although this metabolite could not be conclusively identified, the molecular weight was determined to be 263 g/mol. Unextractable soil-bound residues increased to a maximum of 18% of the applied radioactivity by 360 days posttreatment. The study is acceptable and satisfies the data requirement for aerobic soil metabolism (GLN 162-1; 40460301).

f. Anaerobic Soil Metabolism

Bensulide was persistent under anaerobic conditions in soil in the laboratory. Following a 30 day aerobic soil incubation period in Sorrento loam soil, followed by 60 days of anaerobic incubation [flooding plus N_2 atmosphere]), soil-extractable residues contained parent bensulide at 91.15% of the applied; identified degradates were bensulide oxon and benzenesulfonamide (both < 2% of the applied). Unextractable ^{14}C-residues were 8.22%, evolved CO_2 was 0.40 %, and less than 2% of the applied radioactivity was present in the flood water. The degradate profile after 30 days aerobic incubation was comparable to that in the aerobic soil metabolism study (40460301). Because similar degradates were identified in both the aerobic and anaerobic phase of the experiment, the actual processes controlling bensulide degradation under anaerobic conditions are unknown. Since less than 10% of parent bensulide degraded during the study, an anaerobic soil metabolism half-life for bensulide was not estimated. The study is acceptable and satisfies the data requirement for anaerobic soil metabolism (GLN 162-2; 40460302)

ii. Mobility

a. Batch equilibrium studies

Using batch equilibrium studies, both linear and Freundlich adsorption and desorption coefficients were determined for parent bensulide in each of four soil types. The reported adsorption values for bensulide are listed in Table 1.

Table 1. Adsorption coefficients for bensulide (42826701)

Soil	pH	CEC (meq/100g)	% clay	% Organic matter	Linear isotherm K_{ads}		Freundlich K_{ads}		
					K	K_{oc}	K	1/n	r^2
Sand	7.8	1.63	1.6	0.54	9 - 15	2973 - 4688	10.965	1.050	0.986
Sorrento sandy loam	6.8	17.3	21.0	3.9	29 - 38	1245 - 1672	30.549	1.093	0.999
Clay loam 1	7.3	19.72	33.6	7.17	77 - 116	1822 - 2753	96.828	1.075	0.986
Clay loam 2	8.1	14.13	31.6	1.34	26 - 45	3247 - 5688	34.041	0.925	0.980

The reported desorption values for bensulide in each of the same four soil types are listed in Table 2.

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Table 2. Desorption coefficients for bensulide (42826701)									
Soil	pH	CEC (meq/100g)	% clay	% Organic matter	Linear isotherm K_{des}		Freundlich K_{des}		
					K	K_{oc}	K	1/n	r^2
Sand	7.8	1.63	1.6	0.54	16 - 25	5104 - 7721	17.620	1.098	0.989
Sorrento sandy loam	6.8	17.3	21.0	3.9	54 - 71	2366 - 3075	61.802	0.953	0.995
Clay loam 1	7.3	19.72	33.6	7.17	268 - 294	6359 - 6698	277.971	0.996	0.999
Clay loam 2	8.1	14.13	31.6	1.34	76 - 109	9595 -13773	87.902	1.046	0.990

Based on the reported K_{ads} and K_{des} values, it appears that bensulide will be immobile in soils. It also appears that bensulide is more resistant to desorption once it is adsorbed. This study is acceptable and satisfies the data requirement for mobility of **unaged** bensulide (GLN 163-1; 42826701).

Degradates:

Using batch equilibrium studies, both linear and Freundlich adsorption coefficients were determined for bensulide oxon in each of four soil types (the same soils tested with the parent in 42826701). The reported adsorption values for bensulide oxon are listed in Table 3.

Table 3. Adsorption coefficients for bensulide oxon (43180701)									
Soil	pH	CEC (meq/100g)	% clay	% Organic matter	Linear isotherm K_{ads}		Freundlich K_{ads}		
					K	K_{oc}	K	1/n	r^2
Sand	7.8	1.63	1.6	0.54	0.38 - 0.86	119 - 270	1.963	0.827	0.981
Sorrento sandy loam	6.8	17.3	21.0	3.9	2.57 - 3.55	112 - 155	4.227	0.947	0.996
Clay loam 1	7.3	19.72	33.6	7.17	9.24 - 14.92	219 - 354	26.485	0.864	0.999
Clay loam 2	8.1	14.13	31.6	1.34	2.22 - 3.19	282 - 405	6.053	0.873	0.997

The reported desorption values (Freundlich K_{des} only) for bensulide oxon in each of the same four soil types are listed in Table 4 .

Table 4. Desorption values for bensulide oxon (43180701)							
Soil	pH	CEC (meq/100g)	% clay	% Organic matter	Freundlich K_{des}		
					K	1/n	r^2
Sand	7.8	1.63	1.6	0.54	2.089	0.967	0.937
Sorrento sandy loam	6.8	17.3	21.0	3.9	14.928	0.837	0.832
Clay loam 1	7.3	19.72	33.6	7.17	25.235	0.969	0.989
Clay loam 2	8.1	14.13	31.6	1.34	14.859	0.851	0.894

Based on the reported K_{ads} and K_{des} values, it appears that bensulide oxon will be mobile in soils. It also appears that bensulide oxon is more resistant to desorption once it is adsorbed. It can be concluded that the degradate bensulide oxon is more mobile than parent bensulide is in the same four soils tested.

Using batch equilibrium studies, both linear and Freundlich adsorption coefficients were determined for the bensulide degradate benzenesulphonamide in each of four soil types (the same soils tested with the parent in 42826701). The reported adsorption values for benzenesulphonamide are listed in Table 5.

Table 5. Adsorption values for benzenesulphonamide (43180702)									
Soil	pH	CEC (meq/100g)	% clay	% Organic matter	Linear isotherm K_{ads}		Freundlich K_{ads}		
					K	K_{oc}	K	1/n	r^2
Sand	7.8	1.63	1.6	0.54	0.074 - 0.13	23 - 41	0.079	1.273	1.000
Sorrento sandy loam	6.8	17.3	21.0	3.9	0.269 -0.456	12 - 20	0.343	1.134	0.985
Clay loam 1	7.3	19.72	33.6	7.17	0.707 - 0.903	17 - 21	0.797	1.020	0.996
Clay loam 2	8.1	14.13	31.6	1.34	0.04 - 0.222	5 - 28	0.088	1.446	0.912

The reported desorption values (Freundlich K_{des} only) for benzenesulphonamide each of the same four soil types are listed in Table 6.

Table 6. Desorption values for benzenesulphonamide (43180702)							
Soil	pH	CEC (meq/100g)	% clay	% Organic matter	Freundlich K_{des}		
					K	1/n	r^2
Sand	7.8	1.63	1.6	0.54	1.718	1.440	1.000
Sorrento sandy loam	6.8	17.3	21.0	3.9	0.802	1.175	0816
Clay loam 1	7.3	19.72	33.6	7.17	1.117	1.148	0.969
Clay loam 2	8.1	14.13	31.6	1.34	1.136	1.421	1.000

Based on the reported K_{ads} and K_{des} values, it appears that the bensulide degradate benzenesulfonamide will be mobile in soils. Benzenesulfonamide is more resistant to desorption once it is adsorbed. The results indicate that the degradate benzenesulphonamide is more mobile than parent bensulide in the same four soils tested.

The adsorption/desorption studies for the degradates bensulide oxon (43180701) and benzenesulphonamide (43180702) are acceptable and satisfy the data requirement for mobility of **aged** bensulide residues. Together, MRIDs 42826701, 43180701, and 43180702 satisfy the mobility data requirements for bensulide (GLN 163-1).

b. Soil TLC

The mobility of bensulide and its degradates was assessed using soil thin-layer chromatography (TLC) in four soils (00162706). Soil thin-layer chromatography is no longer considered an acceptable technique for assessing the potential of a pesticide and its degradates to leach through the soil profile. In addition, there were not enough degradates present to adequately assess their mobility (aged material was prepared by preincubating treated soil in the greenhouse for only two weeks). However, this study does provide supplemental information on the parent compound in that it was clear that parent bensulide did not migrate in the thin layers of any of the four soils tested .

c. Volatility

Based on the vapor pressure of bensulide (Pure active: 1.1 x 10^{-4} Pa; 8.2 x 10^{-7} mm Hg/Torr [41532001]) and its calculated Henry's constant (7.7 x 10^{-8} atm mole /m^3), bensulide is not predicted to volatilize from either soil or water. Therefore it is not expected that volatilization will be a significant route of dissipation for bensulide.

iii. Bioaccumulation in Fish

After 28 days of continuous exposure at 0.022 mg/L, bensulide bioaccumulated in bluegill sunfish (*Lepomis macrochirus*) to tissue residue levels of 12 mg/kg for fillet and whole fish (BCF = 550X), and 14 mg/kg for viscera (BCF = 640X). The uptake rate constant was 240 ± 27 mg/kg fish/mg/L water/day; a steady state plateau was reached within 7 days in whole fish. When bensulide exposure was discontinued, the elimination half-life for the whole body was 1.5 ± 0.19 days; by day 14 of the depuration period 99%, 98%, and 98% of the radioactive residue was eliminated from fillet, whole fish, and viscera, respectively. During the uptake phase on day 21 and 28 the major metabolites recovered from the fillet and viscera consisted of N-(2-methylsulfinylethyl)benzenesulfon-amide, N-(2-methylsulfonylethyl)benzenesulfonamide, and N-(2-methylthioethyl)benzene-sulfonamide. Minor metabolites consisted of benzenesulfonamide, bensulide oxon, N-(2-methylthioethyl)benzenesulfonamide, and an unknown (suggested by mass spectra to be a ring hydroxylated oxon with molecular ion (M^+) of 398). This study is acceptable and satisfies the data requirement for a fish bioaccumulation study (GLN 165-4; 41931001).

iv. Terrestrial Field Dissipation

There is no acceptable terrestrial field dissipation information to confirm the environmental fate assessment. However, there are numerous unacceptable studies that provide limited information on the dissipation of bensulide.

Bensulide, when applied at 10 lb ai/A to a Norfolk soil in NC subsequently planted to cabbage dissipated with a observed half-life in the top 6 inches of soil of greater than 90 but less than 180 days. Calculated half-lives for bensulide in the top 6 inches of soil (assuming first-order reaction kinetics) were 106.8 days (registrant-calculated, correlation coefficient 0.95, r^2 0.9025) and 80.4 days (reviewer-calculated, correlation coefficient 0.93, r^2 0.86). The maximum concentration of bensulide found was 5.46 ppm (immediately posttreatment) and mean concentrations ranged from 3.37 to 4.24 ppm between 0 and 90 days posttreatment (range of concentrations 1.56-5.46 ppm). Mean concentrations decreased sharply between the 90- and 182-day sampling interval (from 3.37 to 0.25 ppm) and decreased to below the Limit of Quantitation (0.05 ppm) by 546 days posttreatment. The degradate bensulide oxon was never present at greater than 0.56 ppm (maximum at 90 days posttreatment) and decreased to the Limit of Quantitation (0.05 ppm) by 182 days posttreatment. Bensulide and its degradate bensulide oxon were found only in the top 6 inches of the soil; rainfall plus irrigation was at least 118% of the 27 year average during the first 5 months of the study. The observed dissipation of extractable bensulide residues in his study was possibly due to microbial metabolism and/or binding to soil. Data indicate that leaching was not an important route of dissipation for bensulide in this study; the significance of plant uptake is unknown because plant material was not analyzed in this study. This study is not acceptable at this time because no acceptable frozen storage stability data were provided for bensulide and its degradate bensulide oxon in the soil from the study site (the study samples were stored for up to five years before analysis) and soil characterization data were incompletely identified. This study can be upgraded to acceptable with submission of acceptable frozen storage stability data on the parent and its degradate bensulide oxon and adequate identification of the soil characterization data. The data requirement has not been fulfilled (GLN 164-1; MRID 44297001).

Two unacceptable studies (MRIDs 41694201 and 41694202) were conducted on established turf in California with sampling to 39.5 inches. In one study, both bensulide and the degradate bensulide oxon were detected to 27.5 inches, but in the other study, they were detected only in the surface layer. No consistent decline of parent compound was apparent in either study. The studies are acceptable and cannot be upgraded because the application rate could not be confirmed and bare-ground plots were not used for confirmation of application. The study plots had been planted to turf several weeks prior to the first application, and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch. In an open literature study (Niemczyk and Krause, 1994) bensulide residues were persistent in the thatch. Therefore, the lack of residue data for the thatch is a critical deficiency of these studies.

In six other unacceptable terrestrial field dissipation studies involved bensulide applications at 6 and 12.5 lbs ai/A (MRIDs 40534901, 40534902, 40534903, 40534904, 40534905, and 40534906). The reported half-life of bensulide ranged from 8 to 34 days in studies conducted in California and from 91 to 210 days in studies conducted in Mississippi. However, these reported half-lives are suspect because substantial residues of bensulide were recovered at all sampling depths immediately following application (indicating contamination during sampling). In addition, because substantial residues of bensulide were recovered at all sampling depths at the time of application, the depth of leaching could not be determined. Because of the apparent contamination of samples, these six field dissipation studies are unacceptable and cannot be upgraded to fulfill environmental fate data requirements.

Individual summaries of the unacceptable field dissipation studies are provided in Appendix B.

The following studies are in the open literature and do not meet Subdivision N guidelines. However, they do provide supplemental information on the dissipation of bensulide in turf use sites.

In 1988-89, Niemczky and Krause (1994) conducted a field study using turfgrass preemergent herbicides in Wooster, OH on a silt loam soil with established Kentucky bluegrass that was previously treated with bensulide. Most of a single yearly application of bensulide remained in the thatch layer, with some transport into the surface soil. In plots without thatch, bensulide generally stayed in the top 5 cm of the soil. Bensulide persisted in the thatch layer and in the surface soil between yearly applications. Limited movement to depths of 10 cm was attributed to above average rainfall.

In a study conducted on golf courses on volcanic ash soils in Japan (Odanaka, et al., 1994), only surface runoff and leaching water were analyzed for residues of bensulide; soil samples were not analyzed. In a lysimeter study, bensulide did not leach after application (equivalent to 15 kg/ha) to a simulated putting green. In a field study, two fairways were compared. At the first fairway, surface water had a long distance of overland travel to the point of sampling (20 m), and the area of pesticide treatment was small compared to the total area drained. At the second fairway, surface water had a short distance of overland travel to the point of sampling (1 m), and the treatment area overlay the portions of the subsurface drainage which were closest to the sampling point. After treatment of both fairways with 15 kg/ha bensulide, concentrations of bensulide in both surface water and leaching water were measured following watering at 3, 10, and 38 days posttreatment. Initial samples from the first runoff event from the first fairway contained very little pesticide. There were no differences between the fairways in concentrations in samples after a second runoff event. Concentrations were highest in the earliest runoff events and decreased in the later ones. There was apparently no leaching of bensulide from the first fairway; however, there were bensulide residues in the leachate of the second fairway. The study authors explained this by the proximity of the area of pesticide treatment to the sampling point. Concentrations found in the leaching water were approximately one-tenth those found in runoff water (maximum of 282 μg/L compared to 2840 μg/L in the runoff; Odanaka, et al., 1994).

v. Spray Drift

No bensulide spray drift-specific studies were reviewed. Although there are no means of application of bensulide products which require spray drift studies, droplet size spectrum (201-1) and drift field evaluation (202-1) studies were required due to the concern for potential risk to nontarget aquatic organisms. However, to satisfy these requirements the registrant in conjunction with other registrants of other pesticide active ingredients formed the Spray Drift Task Force (SDTF). The SDTF has completed and submitted to the Agency its series of studies which are intended to characterize spray droplet drift potential due to various factors, including application methods, application equipment, meteorological conditions, crop geometry, and droplet characteristics. EPA is in the process of evaluating these studies. In the interim and for this assessment of bensulide, the Agency is relying on previously submitted spray drift data and the open literature for off-target drift rates. After its review of the new studies the Agency will determine whether a reassessment is warranted of the potential risks from the application of bensulide to nontarget organisms.

c. Water Resource Assessment

i. Summary

Bensulide has a long aerobic soil half-life (363 days) in the laboratory and will probably be very persistent in the environment. Bensulide also has a strong binding affinity (K_{oc} range of 1433-4326 ml/g), and will bind to organic matter, and should not be mobile in the soil. Based on its environmental fate characteristics and supporting modeling, bensulide is not expected to leach to ground water. Estimated maximum concentrations in ground water to be used for exposure and risk assessment purposes should be 0.9 μg/L

The "1 in 10 year" maximum acute and chronic surface water concentrations were estimated from PRZM2.3-EXAMS2.94 modeling for various crop-soil-climate treatment scenarios (Table 9). For surface water resources, the maximum acute estimated environmental concentration (EEC) was 979 μg/L and the maximum chronic EEC was 947 μg/L when bensulide was modeled at 12.5 lbs ai/A (total of 25 lbs ai/A from two 120-day interval treatments) to New York turf sites using an unincorporated granular formulation.

Water resource monitoring data for bensulide are very limited. The STORET database did not report any detections of bensulide in surface waters. The current ground water monitoring information is considered very limited because the majority of the wells sampled were not located in bensulide use areas. In this assessment, three sets of monitoring data were reviewed. Detections in two wells from Alabama were reported to be from wells installed to monitor injection wells. EFED concluded that these detections resulted from point sources and were not appropriate for estimating groundwater concentrations from non-point sources such as agricultural use of bensulide. Data from samples in California also were not considered useful because of the high limit of detection (5 μg/L) and the small number of samples. In a study conducted in Texas, the majority of the wells sampled were not in a bensulide use area. Only eight wells in Hidalgo County were considered important since they were within a bensulide use area, are likely to be near crops treated with bensulide, , and the areas appear to be highly vulnerable to ground water contamination. No bensulide residues were detected in these well samples; however, samples were analyzed only with a general screening method with an unknown detection limit.

ii. Ground Water Assessment

Based on environmental fate data, bensulide is very persistent ($t_{1/2}$=363 d) but not mobile in the soil (mean Koc=2943). The environmental fate characteristics of bensulide and results from ground water modeling support the conclusion that bensulide is not expected to leach to ground water. Estimated maximum concentrations in ground water to be used for exposure and risk assessment purposes should be 0.9 μg/L.

Bensulide is not currently regulated under the Safe Drinking Water Act (SWDA). EPA's Office of Water has not established a Maximum Contaminant Level (MCL) or Health Advisories (HA's) for bensulide residues in drinking water. The reference dose (RfD) for a 70-kg adult was established at 0.005 mg/kg/day.

<u>Estimated Concentrations in Ground Water</u>

The SCI-GROW model (Screening Concentrations in Ground Water) is a screening model used to estimate concentrations of pesticides in ground water under "worst case" conditions. The SCI-GROW model is based on scaled ground water concentration from ground water monitoring studies, environmental fate properties (aerobic soil metabolism half-lives and sorption coefficients) and application rates. SCI-GROW provides an estimate of ground water concentrations for a pesticide applied at the maximum allowed label rate in areas with ground water vulnerable to contamination. In most cases, a majority of the use area will have ground water that is less vulnerable to contamination than the areas used to derive the SCI-GROW estimate (Barrett, 1997).

Results from the SCI-GROW screening model predict that the maximum chronic concentration of bensulide in shallow ground water is not expected to exceed 0.9 μg/L for the majority of the use sites. The "upper bound" of "worst case" application rate of 25 lb ai/acre/season to turf was used in the model. Estimated concentrations in ground water will be proportionally lower if lower amounts are applied. Modeling of bensulide use on vegetables for the Yuma and Imperial Valleys (maximum of 12 lb/ai/season) results in a predicted concentration of 0.46 μg/L. Bensulide use on vegetables in other areas (maximum of 6 lb ai/season) results in a predicted concentration of 0.2 μg/L.

Typical use rates of bensulide for turf and vegetables are significantly less than these amounts; therefore, any bensulide residues reaching ground water should be much less than predicted for the higher application rates.

Uncertainties in the SCI-GROW model include the followings: (1) site specific factors regarding hydrology, soil properties, climatic conditions, and agronomic practices are not considered; (2) volatilization is not accounted for, and (3) predicted ground water concentrations are linearly extrapolated from the application rates.

The SCI-GROW model is based on results from small-scale ground water monitoring studies conducted on highly vulnerable sandy soils with shallow ground water (10-30 ft in depth). These types of soils would be classified as belonging to Hydrologic Soil Group A soils. Highly vulnerable Hydrologic Soil Group A soils generally do not occur in the bensulide use area. Soils in the bensulide use area are predominately Hydrologic Soil Group B soils with limited areas of Group C and D soils. Soils belonging to these groups have less potential for leaching and a greater potential for surface water runoff.

Comparative Leaching Assessment

The PATRIOT model was used to perform a comparative leaching assessment for bensulide which uses the program PRZM (Pesticide Root Zone Model). PRZM is a one-dimensional, dynamic, compartmental model that can be used to simulate pesticide movement in unsaturated soil systems within and immediately below the plant root zone.

PATRIOT modeling for bensulide was conducted on representative soils in the Yuma and Imperial Valley's of Arizona and California, in the Rio Grande Valley of Texas, and in

Ohio for turf. Each of these scenarios used, the maximum labeled application rate, the maximum number of applications allowed per year, irrigation, and very shallow ground water (3-6 ft in depth) to simulate "worst-case" conditions.

Complete cropping information was not available for many of the vegetables. The meteorological and soils databases appeared to be complete for the areas modeled. Site specific corrections for general irrigation and evaporation were included in the modeling. Although the PATRIOT model adjusted for general irrigation, it did not account for use of micro-jet/sprinkler irrigation which is now commonly used in the desert areas of the Imperial and Yuma Valleys. These systems use significantly less water that traditional irrigation methods. When bensulide is used with microjet irrigation it is applied as chemigation and applied with the irrigation water that is delivered to the plants. Lower application rates are often used with chemigation, and rates as low as 4 lbs/ai may be used. The use of less irrigation water and lower application rates should decrease the potential for leaching of bensulide in these areas.

The PATRIOT modeling predicted that bensulide would not leach to shallow ground water. Minor leaching (<0.1% of applied) was predicted to occur on a Brennan soil (fine-loamy, mixed, hyperthermic Aridic Haplustalfs) in the Rio Grande Valley of Texas. This leaching was considered insignificant and no bensulide was predicted to reach the shallow ground water. The Brennan soil has a high sand content (55-80%), low organic matter (0-1%) and is classified as a Hydrologic Group B soil.

The PATRIOT modeling supports the qualitative assessment for bensulide. Bensulide is not predicted to leach because its high soil sorption affinity (mean K_{oc} = 2943) indicates it will bind to soil organic matter. Additional model input information is available in the Appendix C.

Results of both the PATRIOT and SCI-GROW screening models should be considered over estimations, i.e., overly conservative for predicting the leaching potential of bensulide to ground water. Bensulide is not expected to leach to ground water.

Ground Water Monitoring Data

No information on the occurrence of bensulide in ground water was available from the US Geological Survey NAWQA studies. The STORET database reports three wells sampled for bensulide in ground water. High detections of bensulide in ground water were reported for two wells in the Mobile Bay, Alabama area in 1987. These detections were reported from wells installed to monitor injection wells. These wells were reported to be 75 and 590 feet deep. Two samples with 7400 μg/L bensulide were reported for one well. Five samples with bensulide concentrations ranging from 5-7400 μg/L were reported for the second well. The detection limit is believed to be 5 μg/L. EFED concluded that these detections were "point sources" and were not appropriate for estimating groundwater concentrations from "non-point source" agricultural use of bensulide.

STORET indicated that a municipal drinking water supply well in Tulare County, California was sampled for bensulide residues in 1985. Three samples were reported from this well with bensulide <5.0 μg/L. This is believed to be the detection limit for these samples so it is not known if bensulide was present in the samples at concentrations below 5 μg/L.

EPA's Pesticide in Ground Water Database (PGWDB) indicates that three wells were sampled for bensulide in California and 188 wells were sampled in Texas and (Hoheisel, et al., 1992).

California: EPA's PGWDB and the California Department of Food and Agriculture (CDFA) report that three wells were sampled for bensulide in Tulare County, California in 1985. EFED reported these samples as containing "0" μg/L bensulide however further investigation found the limit of detection to be 5 μg/L. This appears to be the same data as reported in STORET; however, the PGWDB provides information on one sample from three different wells while STORET provides information on three samples from one well. Both reports provide information on municipal drinking water supply well(s) in Tulare County, California in February, 1985 and both appear to have a detection limit of 5 μg/L.

EPA's PGWDB and CDFA's data did not provide detailed information on these samples; however, the STORET database provided the geographic location, well number, date of sampling and other parameters. EFED concluded that only one well was sampled and the three samples all originated from the same well. Because of the small number of samples and the high limit of detection, this information was not considered useful for this evaluation.

Texas: The Texas Department of Agriculture conducted a study to determine the impact of agricultural chemical use on rural water quality (Aurelius, 1989). Sampling occurred from 1987-1988 in areas considered to be sensitive to ground water contamination. For most counties sampled, well selection was based on the following characteristics: the well was a domestic water supply, it was near agricultural fields with a history of pesticide use, there was shallow ground water (<50 ft), and the soils were conducive to leaching.

Eleven counties in Texas were selected for ground water sampling. Eight counties sampled were located in central and north-central Texas, one in western Texas and one in southern Texas. Three hundred ninety two (392) ground water samples were collected representing 188 wells. A multi-residue method was used to screen for over 200 pesticides, including bensulide. The limit of detection is not known.

This evaluation focuses on Hidalgo County in southern Texas since this county has both vegetable production and bensulide use. None of the other counties sampled are known to have any use of bensulide. The selection of wells in Hidalgo County was not based on the general criteria listed above but were "preselected" by the Texas Water Development Board. Sixteen ground water samples from eight wells were sampled. The wells were located near a wide variety of sites including a citrus grove, a nursery, a melon field, orchards, gas wells, and a sewage sludge storage area. Three of the wells were located on farms, one in a subdivision, and two at rural houses. Five of the eight wells sampled were not used for drinking water purposes, however two of these were used for household purposes (laundry, pools, etc.). Soils at seven of the eight sites were reported to be sand to sandy loams; soil at the eighth site was reportedly a loam.

Bensulide was not detected in any of the wells sampled in the Texas study. No pesticides were detected in any of the wells in Hildago County; however, nitrates and arsenic were detected in most of them. These results support our conclusion that bensulide has a low potential to leach to groundwater.

iii. Surface Water Assessment

GENEEC Model

EFED calculates Tier 1 EECs using the GENeric Expected Environmental Concentration Program (GENEEC). The EECs are used for assessing acute and chronic risks to aquatic organisms. Acute risk assessments are performed using peak EEC values for single and multiple applications. Chronic risk assessments are performed using the 21-day EECs for invertebrates and 56-day EECs for fish.

The GENEEC program uses basic environmental fate data and information on application methods to estimate the aquatic EECs following application of a pesticide to a. The model calculates EECs of the pesticide transported from a 10-ha treatment area to a 1-ha, 2-m deep pond. The model estimates loading from agricultural runoff, taking into account adsorption to soil, soil incorporation, and degradation in soil while the pesticide is in the field (i.e., before the first runoff event), as well as adsorption to sediments and aquatic degradation once it reaches the pond. The model also accounts for direct deposition of spray drift into the pond. Spray drift deposition is assumed to be 1% and 5% of the application rate for ground and aerial applications, respectively. For this pesticide, aerobic aquatic metabolism was not taken into account because no data were available to estimate the half-life. This model was run to represent one application and two applications with a 120-d application interval. The environmental fate parameters used in the GENEEC model were:

mean soil K_{oc}:	2943
solubility:	5.6 mg/L
aerobic soil metabolism half-life:	363 days
aerobic aquatic half-life:	None available (input = 0)
hydrolysis (@pH 7):	220 days
aquatic photolysis (@ pH 7):	200 days

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(All product chemistry data taken from MRIDs 41532001 and 00157314)

EECs were calculated for both one and two applications per year. Bensulide is typically applied on vegetables once per crop cycle. In southwestern states, however, there may be two crop cycles of vegetables in one year, resulting in two applications within a year. Bensulide may also be applied to turf and ornamentals twice within a year. For both of these uses, the typical application interval is approximately 120 days. The results of the GENEEC model are reported in Table 7.

Table 7. Estimated Environmental Concentrations (EECs) for Broadcast Applications

Use Site	Application Method	Application Rate (lbs ai/A)	Number of Applications (Time Between Applications)	Initial (Peak) EEC (ppb)	21-day average EEC (ppb)	56-day average EEC (ppb)
Garlic and onions	Unincorporated ground spray and chemigation[1]	3	1	18	12	8.2
	Incorporated ground spray[2]	3	1	9.7	6.4	4.3
Vegetables	Unincorporated ground spray or chemigation[1]	6	1	36	24	16
	Unincorporated ground spray or chemigation[1]	6	2 (120 days)	65	43	29
	Incorporated ground spray[2]	6	1	19	13	8.7
	Incorporated ground spray[2]	6	2 (120 days)	35	23	16
Turf and ornamentals	Unincorporated granular broadcast[3]	7.5	1	42	28	19
	Unincorporated granular broadcast[3]	7.5	2 (120 days)	75	50	34
	Unincorporated granular broadcast[3]	10	1	56	37	25
	Unincorporated granular broadcast[3]	10	2 (120 days)	100	67	45
	Unincorporated ground spray[1]	12.5	1	76	50	34
	Unincorporated ground spray[1]	12.5	2 (120 days)	140	90	61
	Unincorporated granular broadcast[3]	12.5	1	70	47	32
	Unincorporated granular broadcast[3]	12.5	2 (120 days)	130	83	57

1 Spray drift is assumed to be 1% of the application rate. Ground spray applications are assumed to be immediately followed by irrigation.
2 Spray drift is assumed to be 1% of the application rate. Soil incorporation assumed to be to 2 inches.
3 No drifting is assumed. Granular applications are assumed to be immediately followed by irrigation.

Bensulide is often applied to vegetables as band treatments in which only the beds are treated. The application on the bed is made at the normal rate, but since not all of the field is treated, the rate of application over the entire field is reduced. The reduction in this rate depends on the proportion of the width of the bands to the width of the space between rows. For the GENEEC modeling, a proportion of 0.75 was chosen because it provides a high exposure case. (Based on additional information, this proportion was later revised to 0.5 when tier 2 modeling was conducted.) Since EECs are assumed to be directly proportional to the pounds applied per acre, banding was assumed to reduce the EECs by 25%. EECs for banded applications are presented in Table 8.

Table 8. Estimated Environmental Concentrations (EECs) for Banded Applications

Use Site	Application Method	Application Rate (lbs ai/A)	Number of Applications (Time Between Applications)	Initial (Peak) EEC (ppb)	21-day average EEC (ppb)	56-day average EEC (ppb)
Garlic and onions	Unincorporated banded spray[1]	3	1	14	9.1	6.1
	Incorporated banded spray[2]	3	1	7.3	4.8	3.2
Vegetables	Unincorporated banded spray[1]	6	1	27	18	12
	Unincorporated banded spray[1]	6	2 (120 days)	49	32	22
	Incorporated banded spray[2]	6	1	15	9.7	6.5
	Incorporated banded spray[2]	6	2 (120 days)	26	17	12

1 Spray drift is assumed to be 1% of the application rate. Ground spray applications are assumed to be immediately followed by irrigation.
2 Spray drift is assumed to be 1% of the application rate. Soil incorporation assumed to be to 2 inches.

On the basis of the EECs determined using GENEEC, HED requested a more refined assessment.

Tier 2 - PRZM/EXAMS Surface Water Modeling

Tier 2 modeling was conducted for bensulide to generate refined estimates of human exposure through drinking water. These refined EECs were also used in the ecological risk assessment for aquatic organisms.

Model Inputs

Input values for Tier 2 Surface Water Modeling were obtained from acceptable laboratory studies conducted to support the reregistration of bensulide. The molecular weight of bensulide is 397.52 g/mole and the solubility in water is 5.6 mg/L at 25° C. The reported vapor pressure is 8.2×10^{-7} mm Hg (1.1×10^{-4} Pa) and the estimated Henry's Law constant is 7.7×10^{-8} atm-m^3/mol. The "mean" K_{oc} value of 2,943 ml/g was used to estimate partitioning between soil organic carbon and water. Based on an aerobic soil metabolism half-life of 363 days, the "lumped" degradation rate constant was estimated to be 1.91×10^{-3} days^{-1} (PRZM input) or 7.95×10^{-5} hrs^{-1} (EXAMS input). Although only a single value for aerobic soil metabolism was reported, the 363 day half-life was not multiplied by a factor of 3 (as described in current OPP modeling input guidance, dated June 1995) because the approximately 1-year half-life value indicates limited degradation occurs via aerobic metabolic processes. No acceptable field dissipation study was available at the time this RED was written. An acceptable field dissipation study would be used in the reevaluation of our assessment.

Maximum application rates were derived from product labels (Prefar 6-E emulsifiable liquid concentrate; Pre-San Granular 12.5G). Application timing was obtained from county agricultural extension service information or estimated from label information (e.g., 120-day interval for second treatment). Band applications were assumed to cover at most 50% of the agricultural field (according to the registrant, Gowan), thus the appropriate application rates were decreased by 50%.

Two crop-soil-climate scenarios were modeled. The first scenario was for vegetable crops to estimate EECs from bensulide applied to cole crops (i.e., cabbage, broccoli, etc.) and lettuce in the Sacramento and San Quaquin Valleys of southern California (Major Land Resource Area C-17). The soil was the Lerdo clay loam (fine-loamy, mixed (calcareous), thermic Typic Torrifluvents) and the meteorological file was MET17.MET. The second scenario estimated surface water concentrations for surface water transport of bensulide generated from turf sites. The scenario was based in Columbia County, New York (MLRA R-144B) and the soil was the Sharkey clay (Hydrologic Soil Group D; very-fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts). The meteorological file was MET144B.MET. Both modeling scenarios used 36 years of weather data from 1948 to 1983.

<u>Model Results and Interpretations</u>

The results of the Tier 2 Surface Water Modeling are reported in Table 9. For vegetable crops, single applications of bensulide using unincorporated ground spray produced maximum EECs ranging from 42 to 93 μg/L. For two applications, maximum EECs ranged from 74 to 165 μg/L. The lower limits for each range were associated with banded applications (50% reduction in application rate). EECs for a single application with soil incorporation to the 4-cm depth ranged from 30 to 60 μg/L (approximately a 33% reduction). With two applications with soil incorporation, EECs ranged from 59 to 118 μg/L. For turf use, the granular formulations displayed the highest maximum EECs (range of 445-979 μg/L) which were approximately 2.6 to 2.8 times larger than comparable spray treatments.

The results in Table 9 indicate limited dissipation of bensulide in surface waters following transport by surface runoff . For 1 in 10-year EECs, comparisons of the maximum EECs with 56-day or annual mean EECs show little difference (e.g., at 6 lbs ai/A, maximum of 93 μg/L compared to annual mean of 87 μg/L). This finding suggests dissipation from surface waters does not occur rapidly and may occur principally by binding to suspended and bottom sediments. The Tier 2 modeling also shows an approximate doubling of EECs for modeled results when two applications occurred at 120-day intervals. These results are consistent with the observed persistence shown in the aerobic soil metabolism study (half-life of 363 days).

Table 9. EECs for Bensulide Using Tier 2 PRZM2.3/EXAMS2.94 Modeling

Use Site	Application Method	Application Rate (lbs ai/A)	Number of Applications (Time Between Applications)	Maximum EEC (µg/L)	21-day Average EEC (µg/L)	56-day Average EEC (µg/L)	Annual Mean EEC (µg/L)
Broadcast Applications							
Vegetables	Unincorporated ground spray	6	1	93	90	88	87
	Unincorporated ground spray	6	2 (120 day interval)	165	161	160	158
	Incorporated ground spray	6	1	60	56	55	54
	Incorporated ground spray	6	2 (120 day interval)	118	115	113	112
Turf	Unincorporated ground spray	12.5	1	171	168	167	165
	Unincorporated ground spray	12.5	2 (120 day interval)	353	350	349	344
	Unincorporated granular	12.5	1	445	440	438	431
	Unincorporated granular	12.5	2 (120 day interval)	979	966	963	947
Banded Applications							
Vegetables	Unincorporated ground spray	6	1	42	40	40	39
	Unincorporated ground spray	6	2 (120 day interval)	74	72	72	71
	Incorporated ground spray	6	1	30	28	28	27
	Incorporated ground spray	6	2 (120 day interval)	59	58	57	56
NOTE: Spray drift from ground spray application was assumed to be 1% of the application rate. Spray drift from granular application was set to "Off". Soil incorporation was assumed to be 4 cm.							

Assumptions, Limitations, and Uncertainties

The Tier 2 modeling assumes a single 10-hectare field generates runoff which is collected in a 1-hectare pond with no outlet. Pesticide application is assumed to be made on the entire field during a single day. The "closed system" (pond with no outlet) is a limitation for estimating surface water concentrations for drinking water sources. Other surface water bodies used as drinking water sources may exhibit considerable flow-through (rivers, streams) or turnover (reservoirs, lakes).

The Tier 2 modeling used an aerobic soil metabolism half-life of 363 days, which was based on a single acceptable laboratory study. This result is uncertain because this was the only value available to estimate the degradation rate constant.

Comparison of the results from Tier 1 and Tier 2 modeling indicated higher EECs for the Tier 2. Some possible reasons for this observed increase are: the persistence of bensulide (based on the laboratory aerobic soil metabolism study); the assumptions in the modeling, such as independence in applications between years, and multiple years of weather in PRZM-EXAMS versus the single year simulated in GENEEC.

The results of the Tier 2 modeling indicated that bensulide was approximately 70% in the dissolved phase [Bill E will think about this]

Surface Water Monitoring Data

Search of the STORET database did not report any detections of bensulide in surface waters.

iv. Drinking Water Assessment

Bensulide is not currently regulated under the Safe Drinking Water Act (SWDA). EPA's Office of Water has not established a Maximum Contaminant Level (MCL) or Health Advisories (HA's) for bensulide residues in drinking water.

The drinking water assessment discusses the modeling results and monitoring data in both surface water and ground water media for bensulide. Table 10 presents the "1 in 10 year" maximum acute and chronic surface water concentrations estimated from PRZM2.3-EXAMS2.94 modeling for various crop-soil-climate treatment scenarios. For surface water resources, the maximum acute estimated environmental concentration (EEC) was 979 μg/L and the maximum chronic EEC was 947 μg/L when bensulide was modeled at 12.5 lbs ai/A (total of 25 lbs ai/A from two 120-day interval treatments) to New York turf sites using an unincorporated granular formulation. Based on its environmental fate characteristics and supporting modeling, bensulide is not expected to leach to ground water. SCI-GROW modeling estimated the maximum concentration in ground water to be 0.9 μg/L.

Water resource monitoring data for bensulide are very limited. The STORET database did not include any reported detections of bensulide in surface waters. Two detections of bensulide in ground water were reported in the STORET database, however, they are believed to be "point sources" resulting from injection wells. The current monitoring data is considered very limited because the majority of the wells sampled were not located in bensulide use areas. In this assessment, three sets of monitoring data were reviewed. Detections in two wells from Alabama that were listed in STORET as injection well are point sources and are not considered appropriate for estimating groundwater levels from non-point sources such as agricultural use of bensulide. There were only a small number of samples from California and they had a high limit of detection (5 μg/L) and a small number of samples; therefore, these data were also not considered useful. In a study conducted in Texas, the majority of the wells sampled were not in the bensulide use area. However, eight wells in Hidalgo County were considered important since they were within a bensulide use area and were in an area that appeared to be highly vulnerable to ground water contamination. No bensulide residues were detected in these wells; however, the samples were only analyzed using a general screening method with an unknown detection limit.

Based on environmental fate data, bensulide is very persistent but not mobile in soil. Bensulide has a strong binding affinity (K_{oc}'s range from 1,433 to 4,326 ml/g) and will bind to organic matter in soil. Results from the SCI-GROW screening model predicted that the maximum chronic concentration of bensulide in shallow ground water is not expected to exceed 0.9 μg/L for the majority of the use sites. This is considered to be a "worst case" or "upper bound" for residues of bensulide in ground water. Bensulide was modeled using a 25 lb ai/acre/season application to turf. Typical use rates of bensulide for turf and vegetables are significantly less than this amount; therefore, any bensulide residues reaching ground water should be much less than predicted by the model. Additional modeling of bensulide use on California vegetables for the Yuma and Imperial Valleys (maximum of 12 lb/ai/season) resulted in a predicted groundwater concentration of 0.46 μg/L. Bensulide use on vegetables for other use areas (maximum of 6 lb ai/season) resulted in a predicted groundwater concentration of 0.2 μg/L.

Table 10. Acute and Chronic Estimated Environmental Concentrations for Bensulide in Surface Water Using PRZM2.3-EXAMS2.94

Use Site	Application Method	Application Rate (lbs ai/A)	Number of Applications (Time Between Applications)	Maximum EEC (μg/L)	Annual Mean EEC (μg/L)
Broadcast Applications					
Vegetables (cole crops)	Unincorporated ground spray	6	1	93	87
	Unincorporated ground spray	6	2 (120 day interval)	165	158
	Incorporated ground spray	6	1	60	54
	Incorporated ground spray	6	2 (120 day interval)	118	112

Use Site	Application Method	Application Rate (lbs ai/A)	Number of Applications (Time Between Applications)	Maximum EEC (μg/L)	Annual Mean EEC (μg/L)
Turf	Unincorporated ground spray	12.5	1	171	165
	Unincorporated ground spray	12.5	2 (120 day interval)	353	344
	Unincorporated granular	12.5	1	445	431
	Unincorporated granular	12.5	2 (120 day interval)	979	947
Banded Applications					
Vegetables (cole crops)	Unincorporated ground spray	6	1	42	39
	Unincorporated ground spray	6	2 (120 day interval)	74	71
	Incorporated ground spray	6	1	30	27
	Incorporated ground spray	6	2 (120 day interval)	59	56
NOTE: Spray drift from ground spray application was assumed to be 1% of the application rate. Spray drift from granular application was set to "Off". Soil incorporation was assumed to be 4 cm.					

3. Ecological Toxicity Data

a. Toxicity to Terrestrial Animals

i. Birds, Acute and Subacute

An acute oral toxicity study using the technical grade of the active ingredient (TGAI) is required to establish the toxicity of bensulide to birds. The preferred test species is either mallard duck (a waterfowl) or bobwhite quail (an upland gamebird). A single dose oral test with the bobwhite quail found the LD_{50} of bensulide (92.9% purity) was 1386 mg ai/kg. This classifies bensulide as slightly toxic on an acute oral basis. This study is classified as core and fulfills guideline 71-1. (Grimes 1986, MRID 158455)

Two subacute dietary studies using the TGAI are required to establish the toxicity of bensulide to birds. The preferred test species are mallard duck and bobwhite quail. Results of these tests are tabulated below.

Avian Subacute Dietary Toxicity

Species	% ai	5-Day LC50 (ppm)[1]	Toxicity Category	MRID No. Author/Year	Study Classification
Northern bobwhite quail *(Colinus virginianus)*	92.9	> 5620	Practically nontoxic	158456 Grimes 1986	Core
Mallard duck *(Anas platyrhynchos)*	92.9	> 5620	Practically nontoxic	158457 Grimes 1986	Core

[1] Test organisms observed an additional three days while on untreated feed.

In both subacute dietary tests, there was no mortality or overt signs of toxicity at the highest test concentration of 5620 ppm. Since the LC_{50} is greater than 5000 ppm, bensulide is practically nontoxic to birds on a subacute dietary basis. The guideline (71-2) is fulfilled (MRIDs 158456 and 158457).

ii. Birds, Chronic

Avian reproduction studies using the TGAI are required for bensulide because the following conditions are met: (1) birds may be subject to repeated or continuous exposure to the pesticide, especially preceding or during the breeding season, (2) the pesticide is stable in the environment to the extent that potentially toxic amounts may persist in animal feed, (3) the pesticide is stored or accumulated in plant or animal tissues, and/or, (4) information derived from mammalian reproduction studies indicates reproduction in terrestrial vertebrates may be adversely affected by the anticipated use of the product. The preferred test species are mallard duck and bobwhite quail. Results of these tests are tabulated below.

Avian Reproduction Toxicity

Species	% ai	NOAEL (ppm ai)	LOAEL (ppm ai)	LOAEL Endpoints	MRID No. Author/Year	Study Classification
Mallard *(Anas platyrhynchos)*	92.3	2.5	25	Eggshell thickness	44486901 Mansell and Cameron 1998	Core
Northern bobwhite *(Colinus virginianus)*	92.4	250	600	Several endpoints concerning the hatching and survival of chicks	43616001 Beavers et al. 1995	Core
Mallard *(Anas platyrhynchos)*	92.4	Not determined (< 250)	250	Eggshell thickness, percent of eggs laid that are cracked, percent of hatchlings that survived to 14 days	43616002 Beavers et al. 1995	Supplemental
Japanese quail *(Coturnix coturnix japonica)*	97.0	100	1000	Hatchability	Shellenberger et al. 1965	Supplemental[1]

1 Unreviewed report from the open literature.

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These studies show that bensulide can impair avian reproduction at relatively low dietary concentrations. The most serious effect appears to be a reduction of eggshell thickness, which begins to occur at dietary concentrations between 2.5 and 25 ppm ai. At 250 ppm ai, the reduction in eggshell thickness was severe (11% reduction in MRID 44486901 and 15% in MRID 43616002) which resulted in a significant increase in the number of cracked eggs (MRID 44486901 and 43616002). Compared to the control, the percentage of eggs cracked at 250 ppm ai represented a 2.1x increase in MRID 44486901 and and a 24.2x increase in MRID 43616002. Cracking of eggs usually causes the embryo to die before hatching. Additionaly, a dietary concentration of 250 ppm ai fed to mallards reduced the percentage of eggs hatched and the percent survival to the 3-week embryo and 14-day-old chick stages (MRID 44486901 and 43616002).

The guidelines for avian reproduction testing with an upland gamebird (71-4a) and with a waterfowl (71-4b) have been fulfilled (MRIDs 44486901 and 43616001).

iii. Mammals, Acute and Chronic

Wild mammal testing is required on a case-by-case basis, depending on the results of lower tier laboratory mammalian studies, intended use pattern and pertinent environmental fate characteristics. In the case of bensulide, however, rat or mouse toxicity values obtained from the Agency's Health Effects Division (HED) substitute for wild mammal testing.

A single-dose oral LD_{50} study (MRID 92005011) was performed in which technical bensulide (92.5 % pure) was administered to the laboratory rat (*Rattus norvegicus*) . The LD_{50} was 360 mg/kg for males and 270 mg/kg for females. The geometric mean of the values for males and females was 312 mg/kg. Since the rat LD_{50} falls within the range of 51 to 500 mg/kg, bensulide is moderately toxic to small mammals on an acute oral basis. The acute toxicity of bensulide appears to be considerably greater for mammals than for birds.

Chronic Mammalian Toxicity

Species	% ai	Test Type	Endpoint	NOEC (ppm)	LOEC (ppm)	MRID No.
Laboratory rat (*Rattus norvegicus*)	92.4	Multigeneration reproduction	Systemic effects	>900	--	43948701
			F_2 pup survival	150	900	
			Cholinesterase inhibition	--	25	

For the purpose of assessing the risk of chronic ecological effects in mammals, the NOEL is 150 ppm and the LOEL is 900 ppm. Rats fed 900 ppm of bensulide had decreased pup survival, whereas rats fed 150 ppm had no effects on reproduction. Plasma cholinesterase activity was significantly reduced compared to control at dietary concentrations as low as 23 ppm. No developmental effects were observed in rats administered oral doses as great as 95 mg/kg/day, which is approximately equivalent to 1900 ppm in the diet (MRID 00146585). Other chronic effects have been observed in rats and rabbits at doses between 25 and 95 mg/kg/day (MRID 00146585 and 00152845), but EFED does not consider them to be ecologically significant. These effects included tremors (rabbits), increased liver/body weight (rabbits), decreased body weight, and decreased feed consumption.

iv. Insects

Atkins et al. (1975) found that the honey bee acute contact LD_{50} is 1.6 micrograms bensulide per bee. This result indicates that bensulide is highly toxic to bees on an acute contact basis. The guideline (141-1) is fulfilled (MRID 00036935).

Although the acute contact study indicated that honeybee LD_{50} of bensulide is less than 11 micrograms per bee, the Agency is waiving the requirement for a toxicity of residues on foliage study with honeybees (GLN 141-2). Bensulide is applied as a spray only to bare ground (vegetables uses) or to turf. These uses are expected to result in little exposure to flowering plants, thus exposure to bees is expected to be minimal.

b. Toxicity to Freshwater Aquatic Animals

i. Freshwater Fish, Acute

Two freshwater fish toxicity studies using the TGAI are required to establish the toxicity of bensulide to fish. The preferred test species are rainbow trout (a coldwater fish) and bluegill sunfish (a warmwater fish). Results of these tests are tabulated below.

Freshwater Fish Acute Toxicity

Species, Test Type (Flow-through or Static)	% ai	96-hour LC50 (ppm ai)	Toxicity Category	MRID No. Author/Year	Study Classification
Rainbow trout (*Oncorhynchus mykiss*), static	92.9	1.1	moderately to highly toxic	157315 McAllister et al. 1986	Core
Rainbow trout (*Oncorhynchus mykiss*), static	95.0	0.72	highly toxic	40098001 Mayer and Ellersieck 1986	Core
Bluegill sunfish (*Lepomis macrochirus*), static	95.0	0.81	highly toxic	40098001 Mayer and Ellersieck 1986	Core
Channel catfish	not reported	0.38	highly toxic	McCorkle et al. 1977	Supplemental (unreviewed open literature)

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Since the $LC_{50's}$ for the rainbow trout and bluegill sunfish fall in the range of 0.1 to 1.0 ppm, bensulide is highly toxic to freshwater fish on an acute basis. The guideline (72-1) is fulfilled (MRIDs 157315 and 40098001).

ii. Freshwater Fish, Chronic

A freshwater fish early life-stage test using the TGAI is required for bensulide because (1) the end-use product is expected to be transported to water from the intended use site, (2) aquatic acute fish LC_{50}'s and the waterflea EC_{50} are less than 1 mg/l, and (3) the EEC in water is equal to or greater than 0.01 of acute LC_{50} and EC_{50} values. A further factor that triggers this test is that bensulide is very persistent in water (hydrolysis half-life is 220 days). The preferred test species is the rainbow trout.

No data have been submitted to the Agency on the chronic effects of bensulide to freshwater fish. The guideline (72-4a) is not fulfilled. A freshwater fish life-cycle study (GLN 72-5) may be required depending on the results of the freshwater fish early life-stage test.

iii. Freshwater Invertebrates, Acute

A freshwater aquatic invertebrate toxicity test using the TGAI is required to establish the toxicity of bensulide to aquatic invertebrates. The preferred test species is *Daphnia magna*. Results of this test are tabulated below.

Freshwater Invertebrate Acute Toxicity

Species/Test Type	% ai	LC50 (ppm ai)	Toxicity Category	MRID No. Author/Year	Study Classification
Waterflea (*Daphnia magna*), static	92.9	0.58	highly toxic	159322 Forbis, Burgess, and Frazier, 1985	Supplemental[1]
Amphipod (*Gammarus fasciatus*), static	95.0	3.3 (48-hr) 1.4 (96-hr)	moderately toxic	40098001 Mayer and Ellersieck 1986, also 05001497 Sanders, 1970	Supplemental[2]

1 The dissolved oxygen at the four highest test concentrations were unacceptably low (27.2-48.9%).

2 These LC_{50}'s are for mature organisms. The test procedure deviated significantly from the guidelines.

Acceptable toxicity data on the effects of bensulide to freshwater invertebrates are lacking. The data from MRID 05001497, which were also reported in MRID 40098001, are from a study that is scientifically sound but was not conducted according to EPA's test guidelines. Also, the study was a test of adult organisms, whereas the EPA test guidelines require testing with immature organisms that are usually more sensitive to toxicants. Results from the study with the waterflea (MRID 159322) are uncertain because the low dissolved oxygen at the higher dose levels could have contributed to the observed mortality. However, since the dissolved oxygen problem probably reduced the observed LC_{50}, this value can be used to give a conservative (i.e., possibly overprotective) assessment of risk.

Based on supplemental data, the LC_{50} falls in the range of 0.1 to 1.0 ppm, classifying bensulide as highly toxic to freshwater invertebrates on an acute basis. The guideline (72-2) is not fulfilled.

iv. Freshwater Invertebrate, Chronic

A freshwater aquatic invertebrate life-cycle test using the TGAI is required for bensulide because the end-use product is expected to be transported to water from the intended use site, aquatic acute fish LC_{50}'s and the waterflea EC_{50} are less than 1 mg/l, and the EEC in water is equal to or greater than 0.01 of acute LC_{50} and EC_{50} values. A further factor that triggers this test is that bensulide is very persistent in water (hydrolysis half-life is 220 days). The preferred test species is *Daphnia magna*.

No data have been submitted to the Agency on the chronic effects of bensulide to freshwater invertebrates. The guideline (72-4b) is not fulfilled.

c. Toxicity to Estuarine and Marine Animals

i. Estuarine and Marine Fish, Acute

Acute toxicity testing with estuarine/marine fish using the TGAI is required for bensulide because the end-use product is expected to be transported to estuarine and/or marine habitat from turf and golf course sites, as well as from vegetable sites in certain regions (Florida and the Lower Rio Grande Valley). The preferred test species is sheepshead minnow. Results of these tests are tabulated below.

Estuarine/Marine Fish Acute Toxicity

Species, Test Type	% ai	96-hour LC50 (ppb ai)	Toxicity Category	MRID No. Author/Year	Study Classification
Sheepshead minnow *(Cyprinodon variegatus)*, Flow-through	92.0	560 (measured)	Highly toxic	42750201 Morrow and Ward, 1993	Core
Spot (*Leistomus xanthurus*), Flow-through	95.0	320 (nominal)	Highly toxic	40228401 Mayer 1986	Supplemental

Since the LC_{50}'s fall in the range of 100 to 1000 ppb ai, bensulide is highly toxic to estuarine/marine fish on an acute basis. The guideline (72-3a) is fulfilled (MRID 42750201).

ii. Estuarine and Marine Fish, Chronic

An estuarine/marine fish early life-stage toxicity test using the TGAI is required for bensulide because the end-use product is expected to be transported to estuarine and/or marine habitat from some the sites (turf, golf courses, and vegetables), aquatic acute LC_{50}'s are less than 1 mg/l, the EEC in water is equal to or greater than 0.01 of acute LC_{50}'s, and the pesticide is persistent in water (hydrolysis half-life is 220 days). The preferred test species is sheepshead minnow.

No data have been submitted to the Agency on the chronic effects of bensulide to marine/estuarine fish. The guideline (72-4a) is not fulfilled. A marine/estuarine fish life-cycle study (GLN 72-5) may be required dependent on the results of the freshwater invertebrate life-cycle test and marine/estuarine fish early life-stage test.

iii. Estuarine and Marine Invertebrates, Acute

Acute toxicity testing with estuarine/marine invertebrates using the TGAI is required for bensulide because the end-use product is expected to be transported to estuarine and/or marine habitat from turf and golf course sites, as well as from vegetable sites in certain regions (Florida and the Lower Rio Grande Valley). The preferred test species are mysid shrimp and eastern oyster. Results of these tests are tabulated below.

Estuarine/Marine Invertebrate Acute Toxicity

Species/Test Type	% ai.	96-hour LC_{50} or EC50 (ppb ai)	Toxicity Category	MRID No. Author/Year	Study Classification
Eastern oyster (*Crassostrea virginica*), Flow-through shell deposition	92.0	250 (measured)	Highly toxic	42750202 Morrow and Ward, 1993	Core
Eastern oyster (*Crassostrea virginica*), Flow-through shell deposition	95.0	450 (nominal)	Highly toxic	40228401 Mayer, 1986	Core
Mysid (*Americamysis bahia*), Flow-through	92.0	62.4 (measured)	Very highly toxic	42750203 Morrow and Ward, 1993	Core
Brown shrimp (*Penaeus aztecus*), Flow-through	95.0	> 1000 (nominal)	Moderately toxic	40228401 Mayer, 1986	Core

The mysid is the most sensitive of the species tested. Since the mysid LC_{50} is less than 100 ppb ai, bensulide is very highly toxic to estuarine/marine invertebrates on an acute basis. The guidelines (72-3b and 72-3c) are fulfilled (MRIDs 42750201, 42750202, and 40228401).

iv. Estuarine and Marine Invertebrate, Chronic

An estuarine/marine invertebrate life-cycle toxicity test using the TGAI is required for bensulide because the end-use product is expected to be transported to estuarine and/or marine habitat from some the sites (turf, golf courses, and vegetables), aquatic acute LC_{50}'s are less than 1 mg/l, the EEC in water is equal to or greater than 0.01 of acute LC_{50}'s, and the pesticide is persistent in water (hydrolysis half-life is 220 days). The preferred test species is mysid.

No data have been submitted to the Agency on the chronic effects of bensulide to marine/estuarine invertebrates. The guideline (72-4b) is not fulfilled.

d. Toxicity to Plants

i. Terrestrial Plants

No acceptable data have been submitted to the Agency on the phytotoxicity of bensulide to nontarget terrestrial plants. Tier 2 terrestrial plant testing is required for bensulide because it is an herbicide that has terrestrial non-residential outdoor use patterns, it could move off the application site via runoff or (for chemigation uses) via spray drift, and might have endangered or threatened plant species associated with the application sites. The required testing consists of seedling emergence and vegetative vigor tests with ten crop species. Six of the species must be dicotyledonous and represent at least four families. One of these species must be soybean (*Glycine max*) and a second must be a root crop. The remaining four species must be monocotyledonous and represent at least two families. One of these species must be corn (*Zea mays*). The test guideline for phytotoxicity to nontarget terrestrial plants (GLN 123-1) are not fulfilled.

ii. Aquatic Plants

No data have been submitted to the Agency on the toxicity of bensulide to aquatic plants. Tier 2 aquatic plant testing is required for bensulide because it is an herbicide that has outdoor non-residential terrestrial uses it might move off-site via runoff or (for chemigation applications) spray drift. Phytotoxicity testing is required with five aquatic plant species: *Kirchneria subcapitata*, *Lemna gibba*, *Skeletonema costatum*, *Anabaena flos-aquae*, and a freshwater diatom. The test guideline for phytotoxicity to aquatic plants (GLN 123-2) are not fulfilled.

e. Incident Reports

There are no incidents reported in the EPA's Ecological Incident Information System that are attributed to the use of bensulide.

4. Ecological Risk Assessment

a. Introduction

Risk assessment integrates the results of the exposure and ecotoxicity data to evaluate the likelihood of adverse ecological effects. One method of risk assessment is the quotient method. In this method, risk quotients (RQs) are calculated by dividing exposure estimates by acute and chronic ecotoxicity values:

RQ = EXPOSURE/TOXICITY

RQs are then compared to OPP's levels of concern (LOCs). These LOCs are criteria used by OPP to indicate potential risk to nontarget organisms and the need to consider regulatory action. The criteria identify when a pesticide used as directed has the potential to cause adverse effects on nontarget organisms. LOCs currently address the following risk presumption categories: (1) **acute high**--potential for acute risk is high; regulatory action may be warranted in addition to restricted use classification, (2) **acute restricted use**--the potential for acute risk is high but may be mitigated through restricted use classification, (3) **acute endangered species**--endangered species may be adversely affected; regulatory action may be warranted, and (4) **chronic risk**--the potential for chronic risk is high; regulatory action may be warranted. Currently, EFED does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to birds or mammals.

The ecotoxicity test values (i.e., measurement endpoints) used in the acute and chronic risk quotients are derived from required studies. Examples of ecotoxicity values derived from short-term laboratory studies that assess acute effects are: (1) LC_{50} (fish and birds), (2) LD_{50} (birds and mammals), (3) EC_{50} (aquatic plants and aquatic invertebrates), and (4) EC_{25} (terrestrial plants). Examples of toxicity test effect levels derived from the results of long-term laboratory studies that assess chronic effects are: (1) LOEC (birds, fish, and aquatic invertebrates), (2) NOEC (birds, fish and aquatic invertebrates), and (3) MATC (fish and aquatic invertebrates). For birds and mammals, the NOEC is generally used as the ecotoxicity test value in assessing chronic effects, although other values may be used when justified. Generally, the MATC (defined as the geometric mean of the NOEC and LOEC) is used as the ecotoxicity test value in assessing chronic effects to fish and aquatic invertebrates. However, the NOEC is used if the measurement end point is production of offspring or survival.

Risk presumptions, along with the corresponding RQs and LOCs, are tabulated below.

Risk Presumptions for Terrestrial Animals

Risk Presumption	RQ	LOC
Acute High Risk	EEC[1]/LC50 or LD50/sqft[2] or LD50/day[3]	0.5
Acute Restricted Use	EEC/LC50 or LD50/sqft or LD50/day (or LD50 < 50 mg/kg)	0.2
Acute Endangered Species	EEC/LC50 or LD50/sqft or LD50/day	0.1
Chronic Risk	EEC/NOEC	1

[1] abbreviation for Estimated Environmental Concentration (ppm) on avian/mammalian food items

[2] $\frac{\text{mg/ft}^2}{\text{LD50 * wt. of bird}}$ [3] $\frac{\text{mg of toxicant consumed/day}}{\text{LD50 * wt. of bird}}$

Risk Presumptions for Aquatic Animals

Risk Presumption	RQ	LOC
Acute High Risk	EEC[1]/LC50 or EC50	0.5
Acute Restricted Use	EEC/LC50 or EC50	0.1
Acute Endangered Species	EEC/LC50 or EC50	0.05
Chronic Risk	EEC/MATC or NOEC	1

[1] EEC = (ppm or ppb) in water

Risk Presumptions for Plants

Risk Presumption	RQ	LOC
	Terrestrial and Semi-Aquatic Plants	
Acute High Risk	EEC[1]/EC25	1
Acute Endangered Species	EEC/EC05 or NOEC	1
	Aquatic Plants	
Acute High Risk	EEC[2]/EC50	1
Acute Endangered Species	EEC/EC05 or NOEC	1

[1] EEC = lbs ai/A
[2] EEC = (ppb/ppm) in water

b. Nontarget Terrestrial Animals

For pesticides applied as a nongranular product (e.g., liquid, dust), the estimated environmental concentrations (EECs) on food items following product application are compared to LC_{50} values to assess risk. The predicted 0-day maximum and mean residues of a pesticide that may be expected to occur on selected avian or mammalian food items immediately following a direct single application at 1 lb ai/A are tabulated below.

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Estimated Environmental Concentrations on Avian and Mammalian Food Items (ppm) Following a Single Application at 1 lb ai/A

Food Items	EEC (ppm) Predicted Maximum Residue[1]	EEC (ppm) Predicted Mean Residue[1]
Short grass	240	85
Tall grass	110	36
Broadleaf/forage plants, and small insects	135	45
Fruits, pods, seeds, and large insects	15	7

[1] Predicted maximum and mean residues are for a 1 lb ai/a application rate and are based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994).

Terrestrial EECs for bensulide were calculated by linear extrapolation of the above values to other use rates. Predicted terrestrial residues (EECs) were not estimated for multiple applications of bensulide. A negligible amount of residues on living vegetation and insects are expected to carry over from the first application to the second because of the long interval between applications (120 days). Terrestrial residues after the second application are expected to be similar to those after the first application.

i. Birds

EC Products

Subacute dietary tests with both the northern bobwhite and the mallard found no mortality or overt signs of toxicity when birds were fed dietary concentrations as great as 5620 ppm. Residue levels in the terrestrial environment are predicted to be well below this maximum test level. The maximum EEC is 3000 ppm on short grass following application on turf at 12.5 lb ai/A. Therefore, it is concluded that all uses of bensulide pose minimal risk of acute toxicity to birds. Also, bensulide is not predicted to pose a significant acute risk to T&E species.

Chronic toxicity of bensulide poses a greater risk to birds. Chronic risk quotients were based on a low observable effects concentration (LOEC) instead of a no observable effects concentration (NOEC) since the latter was not available for the most sensitive test species (the mallard). Use of an LOEC in place of an NOEC makes the risk quotient lower and less protective. Therefore, any indication of risk based on these RQ's represent a greater certainty of adverse effects compared to typical chronic RQ's. Risk quotients were calculated based on day-0 EECs because bensulide residues are stable to various routes of degradation (hydrolysis, photolysis, aerobic soil metabolism) and therefore are expected to decline only slowly. The chronic risk quotients for spray and chemigation applications of EC products are tabulated below.

Avian Chronic Risk Quotients for Single Application of EC Products Based on Maximum EECs and an NOEC of the Mallard.

Site, Appl. Method	Application Rate (lbs ai/A)	Food Items	Maximum EEC (ppm)	NOEC (ppm)	Chronic RQ (EEC/LOEC)
Garlic and onions, broadcast and banded spraying and chemigation	3.0	Short grass	720	2.5	290*
		Tall grass	330	2.5	130*
		Broadleaf plants and Insects	405	2.5	160*
		Seeds	45	2.5	18*
Vegetables, broadcast and banded spraying and chemigation	6.0	Short grass	1,400	2.5	560*
		Tall grass	660	2.5	260*
		Broadleaf plants and Insects	810	2.5	320*
		Seeds	90	2.5	36*
Turf and ornamentals, broadcast spraying	12.5	Short grass	3,000	2.5	1200*
		Tall grass	1,375	2.5	550*
		Broadleaf plants and Insects	1,688	2.5	680*
		Seeds	188	2.5	75*

* Exceeds chronic risk LOCs.

For a single broadcast application of EC products, RQs for all registered uses far exceed the LOC for chronic risk to birds. These results indicate that all registered uses of bensulide pose a high risk of causing reproductive impairment in birds. High risk is predicted for all birds that feed in treated fields, regardless of their diet. High chronic risk is also presumed for reptiles and terrestrial stages of amphibians. Chronic effects may harm T&E species of these groups.

Avian reproduction studies with the mallard (MRID 44486901 and 43616002) found that an exposure level of 250 ppm causes severe eggshell thinning, increasing the number of cracked eggs. Decreased survival of embryos and young were also observed at this level. EECs are expected to exceed 250 ppm for all uses and for all food types except seeds. Therefore, there is a high certainty that use of bensulide will impair reproduction of birds.

Bensulide is sometimes applied twice a year with an interapplication period of approximately 120 days. Considering the persistence of bensulide in the laboratory degradation studies, some residues from the first application are likely to carry over to the second application. Niemczyk and Krause (1994) measured residues of bensulide in soil and thatch after two successive years of application at 12 lb ai/A. They found that 13% of the maximum residues found in the thatch and 0-2.5 cm depth after the first application carried over to a second application made at the same time the following year. Due to the long interapplication period (120 days), little residues are likely to remain on foliage of growing grass or weeds, but considerable carryover may occur on dormant seeds. EFED did not have sufficient information to estimate the carryover residues of bensulide on seeds, but it appears that they could be enough to increase the seed risk quotient above the LOC for use on turf and ornamentals at the maximum use rate of 12.5 lb ai/A.

Granular Products

Birds may be exposed to granular pesticides ingesting granules when foraging for food or grit. They also may be exposed by other routes, such as by walking on exposed granules or drinking water contaminated by granules. The number of lethal doses (LD_{50}'s) that are available within one square foot immediately after application ($LD_{50}s/ft^{2})$ is used as the risk quotient for granular products. Risk quotients are calculated for three separate weight class of birds: 1000 g (e.g., waterfowl), 180 g (e.g., upland gamebird) and 20 g (e.g., songbird).

The acute risk quotients for broadcast applications of granular products are tabulated below.

Avian Risk Quotients for Granular Products (Broadcast) Based on a Bobwhite LD50.

Site, Application Method	Max. Rate (lbs ai/A)	Proportion of Pesticide Left on the Surface	LD50 (mg/kg)	Body Weight (g)	Acute RQ[1] ($LD50/ft^2$)
Turf and ornamentals, broadcast	7.5	1.0	1386	20	2.8***
	7.5	1.0	1386	180	0.31**
	7.5	1.0	1386	1000	0.06
Turf and ornamental herbs, broadcast	10	1.0	1386	20	3.8***
	10	1.0	1386	180	0.42**
	10	1.0	1386	1000	0.08
Turf and ornamentals, broadcast	12.5	1.0	1386	20	4.7***
	12.5	1.0	1386	180	0.52***
	12.5	1.0	1386	1000	0.09

[1] $RQ = \frac{\text{Appl. Rate (lbs ai/A)} * (453{,}590 \text{ mg/lbs}/43{,}560 \text{ ft}^2\text{/A})}{\text{LD50 mg/kg} * \text{Weight of Animal (g)} * 1000 \text{ g/kg}}$

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

These results indicate that the use of granular formulations of bensulide poses a high risk of acute toxicity to some birds. For all uses of granular products, the avian acute risk quotients exceed the high acute LOC for small birds (20 g). Acute risk quotients for uses at

12.5 lb ai/A or greater also exceed the high acute LOC for medium sized birds (180 g). For all uses, acute risk quotients exceed the restricted use and endangered species LOCs for small and medium birds. In conclusion, use of granular bensulide on turf is predicted to pose high risk to some birds, and triggers concern for T&E species.

ii. Mammals

EC Products

Estimating the potential for adverse effects to wild mammals is based upon methods of Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994). The concentration of bensulide in the diet that is expected to be acutely lethal to 50% of the test population (LC_{50}) is determined by dividing the LD_{50} value (usually rat LD_{50}) by the fraction of the body weight consumed per day. A risk quotient is then determined by dividing the EEC by the derived LC_{50} value. Risk quotients are calculated for three separate weight classes of mammals (15, 35, and 1000 g), each presumed to consume four different kinds of food (grass, forage, insects, and seeds). The acute risk quotients for broadcast applications of EC products are tabulated below.

Acute Risk Quotients for Herbivorous and Insectivorous Mammals, Based on a Single Application of EC Bensulide Product

Application Rate (lbs ai/A)	Body Weight (g)	% Body Weight Consumed	Rat LD50 (mg/kg)	EEC (ppm)			Acute RQ[1]		
				Short Grass	Forage & Small Insects	Large Insects	Short Grass	Forage & Small Insects	Large Insects
Garlic and onions, broadcast and banded spraying and chemigation									
3	15	95	312	720	405	45	2.2***	1.2***	0.14*
3	35	66	312	720	405	45	1.5***	0.86***	0.10*
3	1000	15	312	720	405	45	0.35**	0.19*	0.02
Vegetables, broadcast and banded spraying and chemigation									
6	15	95	312	1440	810	90	4.4***	2.5***	0.27**
6	35	66	312	1440	810	90	3.0***	1.7***	0.19*
6	1000	15	312	1440	810	90	0.69***	0.39**	0.04
Turf and ornamentals, broadcast spraying									
12.5	15	95	312	3000	1690	188	9.1***	5.1***	0.57***
12.5	35	66	312	3000	1690	188	6.3***	3.6***	0.40**
12.5	1000	15	312	3000	1690	188	1.4***	0.81***	0.09

[1] $RQ = \frac{\text{EEC (ppm)}}{\text{LD50 (mg/kg)/ \% Body Weight Consumed}}$

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

Acute Risk Quotients for Granivorous Mammals for a Single Application of EC Bensulide Product

Application Rate (lb ai/A)	Body Weight (g)	% Body Weight Consumed	Rat LD50 (mg/kg)	EEC (ppm) Seeds	Acute RQ[1] Seeds
Garlic and onions, broadcast and banded spraying and chemigation					
3	15	21	312	45	0.03
3	35	15	312	45	0.02
3	1000	3	312	45	0.00
Vegetables, broadcast and banded spraying and chemigation					
6	15	21	312	90	0.06
6	35	15	312	90	0.04
6	1000	3	312	90	0.01
Turf and ornamentals, broadcast spraying					
12.5	15	21	312	188	0.13*
12.5	35	15	312	188	0.09
12.5	1000	3	312	188	0.02

[1] $RQ = \frac{\text{EEC (ppm)}}{\text{LD50 (mg/kg)/ \% Body Weight Consumed}}$

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

The acute risk of bensulide appears to be greater for mammals than for birds. Risk quotients for all uses of EC products fall in the range of high acute risk for some herbivorous and insectivorous mammals. The high risk for registered uses on vegetables (maximum application rate of 3 to 6 lb ai/A) is limited to the more vulnerable herbivorous and insectivorous mammals (i.e. smaller species that feed on plants or small insects). The high risk for registered uses on turf (12.5 lb ai/A) covers a wide range of herbivorous and insectivorous mammals (all except medium to large mammals feeding on large insects). Use of EC products do not pose a high risk to granivorous mammals.

Risk quotients indicate that registration as restricted use is warranted for all registered EC uses. They also indicate that all EC uses pose a risk that triggers concern for T&E species of mammals.

As discussed above for the acute risk of bensulide to birds, there is a potential for significant residues on seeds and waste grain to carryover between applications when two applications are made within the same year. Because the acute risk quotients are low for granivorous mammals, it is not likely that these additional residues would raise the risk quotients above the high risk LOC.

The chronic risk quotients for broadcast applications of nongranular products are tabulated below.

Mammalian Chronic Risk Quotients for Single Application of EC Products Based on Maximum EECs and a Reproductive NOEC of the Rat.

Site, Appl. Method	Application Rate (lbs ai/A)	Food Items	Maximum EEC (ppm)	NOEC (ppm)	Chronic RQ (EEC/NOEC)
Garlic and onions, broadcast and banded spraying and chemigation	3.0	Short grass	720	150	4.8*
		Tall grass	330	150	2.2*
		Broadleaf plants and Insects	405	150	2.7*
		Seeds	45	150	0.30
Vegetables, broadcast and banded spraying and chemigation	6.0	Short grass	1,440	150	9.6*
		Tall grass	660	150	4.4*
		Broadleaf plants and Insects	810	150	5.4*
		Seeds	90	150	0.60
Turf and ornamentals, broadcast spraying	12.5	Short grass	3,000	150	20*
		Tall grass	1,375	150	9.2*
		Broadleaf plants and Insects	1,688	150	11*
		Seeds	188	150	1.3*

* Exceeds chronic risk LOCs.

For a single broadcast application of EC products, risk quotients for all registered uses exceed the LOC for chronic risk to mammals. Risk quotients exceed the chronic risk LOC for all categories of wildlife food types for use on turf and ornamentals, and all wildlife food types except seeds for use on vegetables. These results indicate that ali registered uses of bensulide pose a high risk of causing chronic reproductive effects in mammals and may harm endangered mammal species.

As discussed previously, when there are two applications within the same year, there is a potential for some residues from the first application to carryover to the time of the second application. This could increase the chronic risk when bensulide is applied twice within one year. The only wildlife food item on which surface residues might persist for several months would be dormat seeds, which would not be very abundant in bare fields or well maintained turf areas. Therefore, it is unlikely that addition of carried over residues would significantly affect the risk to mammals.

Granular Products

Mammals may be exposed to granular pesticides by ingesting granules, either intentionally for grit or unintentionally while foraging. They also may be exposed by other routes, such as by walking on exposed granules and drinking water contaminated by granules. The number of lethal doses (LD_{50}'s) that are available within one square foot immediately after application (LD_{50}'s/ft^2) can be used as a risk quotient for the various types of exposure to granular pesticides. Risk quotients are calculated for three separate weight classes of mammals: 15 g, 35 g and 1000 g.

Mammalian Acute Risk Quotients for Granular Products (Broadcast) Based on a Rat LD_{50}.

Site, Application Method	Application Rate (lbs ai/A)	Fraction of Pesticide Exposed on the Surface	Body Weight (g)	Rat LD50 (mg/kg)	Acute RQ[1] (LD50/ft^2)
Turf, broadcast	7.5	1	15	312	17 ***
	7.5	1	35	312	7.1 ***
	7.5	1	1000	312	0.25 **
Turf and ornamental herbs, broadcast	10	1	15	312	22 ***
	10	1	35	312	9.5 ***
	10	1	1000	312	0.33 **
Turf and ornamentals, broadcast	12.5	1	15	312	28 ***
	12.5	1	35	312	12 ***
	12.5	1	1000	312	0.42 **

[1] RQ = $\frac{\text{Appl. Rate (lbs ai/A)} * (453{,}590 \text{ mg/lbs}/43{,}560 \text{ ft}^2\text{/A})}{\text{LD50 mg/kg} * \text{Weight of Animal (g)} * 1000 \text{ g/kg}}$

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

The acute risk of bensulide is greater for mammals than for birds. Risk quotients for all uses of granular products indicate high acute risk for mammals. The risk quotients for uses from 6 to 12.5 lb ai/A exceed the LOC for high risk for small and medium sized mammals. Risk quotients for all uses indicate that registration under restricted use may be appropriate, and indicates risk to T&E species of mammals.

Currently, EFED does not have a standard procedure for assessing chronic risk to mammalian species for granular products.

iii. Insects

Currently, EFED does not assess risk to nontarget insects. However, with an acute contact LD_{50} of 1.6 microgram ai per bee, bensulide is highly toxic to nontarget insects. Considering the high use rates of this herbicide, use of the EC formulations of bensulide potentially poses a high risk to bees and other beneficial insects. Exposure to honeybees is expected to be low for vegetable uses, in which applications are made on bare ground, but high for turf uses. Use of granular formulations are assumed to pose a low risk to these organisms.

c. Nontarget Freshwater Animals

i. Freshwater Fish

Risk quotients for freshwater fish are given below.

Freshwater Fish Acute Risk Quotients for Single Application Based on a Rainbow Trout LC_{50}

Use Site	Application Method	Rate in lb ai/A	Number of Applications	LC50 (ppb)	Peak EEC (ppb)	Acute RQ (EEC/LC50)
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	720	47	0.06*
	Broadcast EC spray, incorporated	3	1	720	30	0.04
	Banded EC spray, unincorporated	3	1	720	21	0.03
	Banded EC spray, incorporated	3	1	720	15	0.02
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	720	93	0.13**
	Broadcast EC spray and chemigation, unincorporated	6	2	720	165	0.23**
	Broadcast EC spray, incorporated	6	1	720	60	0.08*
	Broadcast EC spray, incorporated	6	2	720	118	0.16**
	Banded EC spray, unincorporated	6	1	720	42	0.06*
	Banded EC spray, unincorporated	6	2	720	74	0.10**
	Banded EC spray, incorporated	6	1	720	30	0.04
	Banded EC spray, incorporated	6	2	720	59	0.08*
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	720	267	0.37**
	Broadcast granular application, unincorporated	7.5	2	720	587	0.82***
	Broadcast granular application, unincorporated	10	1	720	356	0.49**
	Broadcast granular application, unincorporated	10	2	720	783	1.1***
	Broadcast EC spray, unincorporated	12.5	1	720	171	0.24**
	Broadcast EC spray, unincorporated	12.5	2	720	353	0.49**
	Broadcast granular application, unincorporated	12.5	1	720	445	0.62***
	Broadcast granular application, unincorporated	12.5	2	720	979	1.4***

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

The risk quotients indicate high risk to freshwater fish from once-per-year applications of granular bensulide at a rate of 12.5 lb ai/A, and twice-per-year applications of granular bensulide at 7.5 lb ai/A or more. Risk quotients for all remaining turf and ornamental uses exceed the LOC for consideration of restricted use classification. For vegetable uses at 6 lb ai/A, the restricted use LOC is exceeded for single broadcast applications without soil incorporation, and all twice-per year applications except those that are both banded and incorporated. For vegetable uses at 3 lb ai/A, no LOC is exceeded except that for threatened and endangered species, which is exceeded for unincorporated applications.

In summary, uses of granular bensulide on turf and ornamentals generally poses a high acute risk to freshwater fish. Use of EC formulations do not pose a high risk to freshwater fish. However, unincorporated broadcast applications of EC formulations on turf, ornamentals, vegetables at 6 lb ai/A or greater pose a risk that may warrant restricted use classification. Risks are reduced when the following application methods are applied: (1) using of lower application rates, (2) limiting the number of application to one per year, (3) incorporating applications in the soil, and (3) using banded applications.

ii. Freshwater Invertebrates

Risk to freshwater invertebrates was assessed based on supplemental toxicity results for *Daphnia magna*. In this acute study, low dissolved oxygen concentrations were present in the four highest test concentrations, and oxygen levels declined as the test concentration increased. The low oxygen levels might have contributed to the observed mortality, thus decreasing the observed LC_{50}. Despite this uncertainty, the actual LC_{50} for *Daphnia magna* is not likely to be greater than the observed value of 0.58 mg ai/L. This value was thus therefore used to give a conservative (i.e., possibly overprotective) assessment of the risk of bensulide to freshwater invertebrates. This assessment should be revised when acceptable acute toxicity data for a freshwater invertebrate becomes available.

The acute risk quotients are tabulated below.

Freshwater Invertebrate Acute Risk Quotients Based on a *Daphnia magna* LC_{50} and PRZM/EXAMS exposure estimates.

Use Site	Application Method	Rate in lb ai/A	Number of Applications	LC50 (ppb)	Peak EEC (ppb)	Acute RQ (EEC/LC50)
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	580	47	0.081*
	Broadcast EC spray, incorporated	3	1	580	30	0.052*
	Banded EC spray, unincorporated	3	1	580	21	0.036
	Banded EC spray, incorporated	3	1	580	15	0.026
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	580	93	0.16**
	Broadcast EC spray and chemigation, unincorporated	6	2	580	165	0.28**
	Broadcast EC spray, incorporated	6	1	580	60	0.10**
	Broadcast EC spray, incorporated	6	2	580	118	0.20**
	Banded EC spray, unincorporated	6	1	580	42	0.072*
	Banded EC spray, unincorporated	6	2	580	74	0.13**
	Banded EC spray, incorporated	6	1	580	30	0.052*
	Banded EC spray, incorporated	6	2	580	59	0.10**
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	580	270	0.47**
	Broadcast granular application, unincorporated	7.5	2	580	590	1.0***
	Broadcast granular application, unincorporated	10	1	580	360	0.62***
	Broadcast granular application, unincorporated	10	2	580	780	1.3***
	Broadcast EC spray, unincorporated	12.5	1	580	170	0.29**
	Broadcast EC spray, unincorporated	12.5	2	580	350	0.60***
	Broadcast granular application, unincorporated	12.5	1	580	450	0.78***
	Broadcast granular application, unincorporated	12.5	2	580	980	1.7***

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.

** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

Risk quotients indicate that turf and ornamental uses generally exceed the LOC for high acute risk to freshwater invertebrates. The only exception is the risk quotient for a single application of granular product at 7.5 lb ai/A, which falls just below the high risk LOC. The greatest risk quotient is 1.7 for two granular applications of bensulide at 12.5 lb ai/A each. Risk quotients for vegetable uses at 6 lb ai/A do not exceed the LOC high acute risk; however, they exceed the LOC for risk that may warrant restricted use for all twice-per-year applications and single broadcast and incorporated applications that are not incorporated. For all uses of bensulide, the risk quotient exceed the LOC for risk to T&E species except for banded applications 3 bl.

In summary, most uses of bensulide on turf and ornamentals pose a high acute risk to freshwater invertebrates. Use of bensulide on vegetables pose a risk that might be mitigated by restricted use when the use rate is 6 lb ai/A and applications are not banded, and whenever more than one application is made per year.

d. Estuarine and Marine Animals

i. Estuarine and Marine Fish

The acute risk quotients for estuarine and marine fish are tabulated below.

Estuarine/Marine Fish Acute Risk Quotients for Single Application Based on a Spot LC_{50}

Use Site	Application Method	Rate in lb ai/A	Number of Applications	LC50 (ppb)	Peak EEC (ppb)	Acute RQ (EEC/LC50)
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	320	47	0.15**
	Broadcast EC spray, incorporated	3	1	320	30	0.09*
	Banded EC spray, unincorporated	3	1	320	21	0.07*
	Banded EC spray, incorporated	3	1	320	15	0.05
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	320	93	0.29**
	Broadcast EC spray and chemigation, unincorporated	6	2	320	165	0.51***
	Broadcast EC spray, incorporated	6	1	320	60	0.19**
	Broadcast EC spray, incorporated	6	2	320	118	0.37**
	Banded EC spray, unincorporated	6	1	320	42	0.13**
	Banded EC spray, unincorporated	6	2	320	74	0.23**
	Banded EC spray, incorporated	6	1	320	30	0.09*
	Banded EC spray, incorporated	6	2	320	59	0.18**
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	320	267	0.83***
	Broadcast granular application, unincorporated	7.5	2	320	587	1.8***
	Broadcast granular application, unincorporated	10	1	320	356	1.1***
	Broadcast granular application, unincorporated	10	2	320	783	2.4***
	Broadcast EC spray, unincorporated	12.5	1	320	171	0.53***
	Broadcast EC spray, unincorporated	12.5	2	320	353	1.1***
	Broadcast granular application, unincorporated	12.5	1	320	445	1.4***
	Broadcast granular application, unincorporated	12.5	2	320	979	3.1***

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

The risk quotients indicate that all uses of bensulide on turf and ornamentals pose a high risk to estuarine and marine invertebrates. For vegetables, high risk is indicated only for twice-per-year unincorporated broadcast applications at 6 lb ai/A. All other uses on vegetables at 6 lb ai/A exceed the LOC for risk that may warrant restricted use classification. The restricted use LOC is also exceeded for unincorporated broadcast applications at 3 lb ai/A. All uses of bensulide pose a risk to T&E species except for applications on vegetables at 3 lb ai/A that are both banded and incorporated.

In summary, all uses of bensulide on turf and ornamentals generally pose a high acute risk to marine and estuarine fish. Twice-per-year applications on vegetables at 6 lb ai/A each also poses a high risk. Most other uses on vegetables pose a risk that may warrant restricted use classification. The exceptions are once per year applications at 6 lb ai/A that are both banded and soil incorporated, and applications at 3 lb ai/A that are banded application and/or soil incorporation. Note that these conclusions apply only to use in areas where bensulide is likely to be transported from the use site to marine and estuarine habitats (see section 5 below).

ii. Estuarine and Marine Invertebrates

The acute risk quotients for estuarine and marine invertebrates are tabulated below.

Estuarine/Marine Invertebrate Acute Risk Quotients for Single Application Based on a Mysid LC_{50}

Use Site	Application Method	Rate in lb ai/A	Number of Applications	LC50 (ppb)	Peak EEC (ppb)	Acute RQ (EEC/LC50)
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	62.4	47	0.75***
	Broadcast EC spray, incorporated	3	1	62.4	30	0.48**
	Banded EC spray, unincorporated	3	1	62.4	21	0.33**
	Banded EC spray, incorporated	3	1	62.4	15	0.24**
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	62.4	93	1.5***
	Broadcast EC spray and chemigation, unincorporated	6	2	62.4	165	2.6***
	Broadcast EC spray, incorporated	6	1	62.4	60	0.96***
	Broadcast EC spray, incorporated	6	2	62.4	118	1.9***
	Banded EC spray, unincorporated	6	1	62.4	42	0.67***
	Banded EC spray, unincorporated	6	2	62.4	74	1.2***
	Banded EC spray, incorporated	6	1	62.4	30	0.48**
	Banded EC spray, incorporated	6	2	62.4	59	0.95***
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	62.4	270	4.3***
	Broadcast granular application, unincorporated	7.5	2	62.4	590	9.4***
	Broadcast granular application, unincorporated	10	1	62.4	360	5.7***
	Broadcast granular application, unincorporated	10	2	62.4	780	13***
	Broadcast EC spray, unincorporated	12.5	1	62.4	170	2.7***
	Broadcast EC spray, unincorporated	12.5	2	62.4	350	5.7***
	Broadcast granular application, unincorporated	12.5	1	62.4	450	7.1***
	Broadcast granular application, unincorporated	12.5	2	62.4	980	16***

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

Risk quotients indicate high risk to estuarine and marine invertebrates for all uses on turf and ornamentals, all uses on vegetables at 6 lb ai/A other than single applications that are banded and incorporated, and use on vegetables at 3 lb ai/A with unincorporated broadcast application. All remaining uses exceed the risk quotient for risk that may warrant restricted use. All uses pose a risk to T&E species of freshwater invertebrates.

In summary, most uses of bensulide pose a high acute risk to marine and estuarine invertebrates. High risk for most vegetable uses (with a maximum rate of 6 lb ai/A) may be avoided only by using banded applications with soil incorporation and making only one application per year. However, even this application results in risk that may warrant restricted use classification. Note that these conclusions apply only to use in areas where bensulide may be transported from the use site to marine and estuarine areas (see section 5 below).

e. Exposure and Risk to Nontarget Plants

Risks to nontarget terrestrial, semiaquatic, and aquatic plants cannot be assessed at this time because acceptable phytotoxicity data are not available for bensulide. Efficacy data suggest that while bensulide would likely effect seed germination and seedling emergence, it would not likely effect nontarget plants that are already emerged.

f. Bioaccumulation

Measured bioconcentration factors (BCFs) of bensulide in bluegill sunfish were 550 in whole fish, 550 in muscle tissue, and 640 in visceral tissues (MRID 41931001). This indicates that the bioconcentration of bensulide is not very great despite having a high K_{ow} (1.65×10^4 at 25°C), which indicates a strong affinity to lipids. Bensulide depurates rapidly from fish when they are placed in uncontaminated water. The elimination half-life in bluegill (whole body) was 1.5 ± 0.19 days, and 98% of the radioactive residue was eliminated from the whole fish tissue by day 14 (MRID 41931001). A rat metabolism study (MRIDs 42007901-42007904) found that bensulide was rapidly metabolized and excreted in the urine. Total urinary excretion of ^{14}C-bensulide equivalents during 7 days after administration accounted for 70-88% of the administered dose. Very low residual radioactivity (0.02-0.21% of the dose) was found in organs and tissues 7 days after a single dose administration.

These results suggest that vertebrates are efficient at biotransforming bensulide into metabolites that can be readily excreted. Bioaccumulation of bensulide in vertebrate tissues through bioconcentration or biomagnification is therefore not expected from short-term exposures. Because bensulide is persistent in aquatic environments, however, organisms in aquatic habitats where the water is not flowing (such as ponds) may be exposed to relatively high levels of bensulide for extended durations. Bensulide in tissues of these organisms may remain several hundred times greater than the ambient concentrations, and birds, mammals, and reptiles feeding on these organisms would be exposed to these elevated concentrations. Risk to piscivorous birds and mammals from food chain exposure is assessed below.

Based on the PRZM/EXAMS modeling, 21-day average EECs of bensulide in water are expected to range from 28 to 966 ppb, depending on use rate and application method. Based on a BCF of 550, birds consuming whole fish would be exposed to dietary concentrations of 15.4 to 531 ppm. Avian reproduction studies show that eggshell thinning occurs in birds at dietary concentrations as low as 25 ppm ai, with an NOAEL of 2.5 ppm ai. The NOAEL for ecologically significant chronic effects in mammals is 150 ppm ai. Therefore, it appears that birds and mammals feeding on fish in water contaminated with bensulide could receive enough exposure to cause chronic effects. The risk is especially high for fish eating birds that are sensitive to eggshell thinning. The risk is likely to be limited to situations where animals feed on fish in stagnant water where high concentrations of bensulide are persistent. In flowing water, bensulide would rapidly depurate from fish once the contamination passes, causing tissue concentrations to decline.

g. Endangered Species

Most uses of bensulide pose risk of harming threatened and endangered (T&E) plants and animals of all taxa if they occur in or near the use area. Acute and/or chronic risk quotients exceed the LOC for endangered species for birds, mammals, fish, and aquatic invertebrates. Because bensulide is highly toxic to the honey bee, risk is assumed for T&E insects. For use on vegetables, acute risk to fish may be avoided if the application is banded and soil incorporated and only a single application is made per year. However, without data on chronic effects to fish, even this use could pose unacceptable risk from chronic exposures. In the Southwest desert region, risk to T&E aquatic species is not expected unless the species occur in drainage ditches or canals adjacent to the application areas. Risk to T&E plants is assumed because bensulide is an herbicide and phytotoxicity data have not been submitted to the Agency to indicate otherwise. Measures should be taken to protect all T&E species if there distribution and natural history are such that they may be exposed to bensulide.

The Endangered Species Protection Program is expected to become final in the future. Limitations in the use of bensulide will be required to protect endangered and threatened species, but these limitations have not been defined and may be formulation specific. EPA anticipates that a consultation with the Fish and Wildlife Service will be conducted in accordance with the species-based priority approach described in the Program. After completion of consultation, registrants will be informed if any required label modifications are necessary. Such modifications would most likely consist of the generic label statement referring pesticide users to use limitations contained in county Bulletins.

5. Risk Characterization

Risk characterization is a qualitative assessment of risks that expands on the environmental fate and ecological effects risk assessments. It includes discussions of other factors that may affect risk but were not considered in the quantitative risk assessments.

a. Vegetable Uses

Bensulide is applied on various vegetable crops in the spring for preemergent control of grass weeds. The primary geographical areas of this use are the desert Southwest (specifically Imperial Co., CA and Yuma Co., AZ), the Central Valley of California, the Rio Grande Valley of Texas, and in other isolated regions of Texas, Colorado, Idaho, and Florida. Bensulide is applied to vegetable crops as an EC spray at a maximum rate of 6 lb ai/A per application, with typical rates ranging from 5 to 6 lb ai/A per application. There may be two applications per year, for a maximum rate of 12 lb ai/A per year. Fields are sprayed normally with ground equipment, or by chemigation using drip or microjet irrigation systems. None of these application methods are expected to result in appreciable spray drift.

<u>Risk to Terrestrial Ecosystems</u>

Bensulide has low acute toxicity to birds. The dietary LC_{50} of the northern bobwhite and the mallard are greater than 5620 ppm, the maximum concentration tested. The acute toxicity of bensulide is significantly greater for mammals than for birds. The LD_{50} of bensulide is 360 and 270 mg/kg for male and female rats, respectively, compared to 1386 mg/kg for the bobwhite. The risk assessment indicated a high acute risk for mammals but not for birds. However, there are several factors which were not considered in this assessment that would likely reduce the acute risk to mammals:

- Bensulide is normally applied to bare ground in the spring to control weeds before they emerge. There is therefore little vegetation on a treated field that would receive direct spray. Dietary exposure to wildlife feeding in the fields would be primarily limited to insects and seeds, for which predicted pesticide residues are low compared to residues on vegetation (Fletcher et al., 1994; Hoeger and Kenaga, 1972). Furthermore, many of these seeds and insects will be beneath the soil surface and thus would not receive direct spray.

- Bensulide is applied to vegetable fields using ground equipment that directs the spray to the ground or using drip or microjet chemigation systems which produce minimal spray drift. Therefore, little exposure is expected due to residues on vegetation in offsite habitats.

- To be effective, bensulide must be incorporated into the soil either by mechanical incorporation or by irrigation. This is clearly stated on the label. This practice would distribute the chemical into the soil, making less available to wildlife feeding on the surface.

Because of the above factors, use of bensulide is not expected to pose serious risk to terrestrial plants and animals, including mammals, due to acute effects.

However, the risk assessment indicated that residues on wildlife food items (if sprayed directly) would be great enough to pose a high chronic risk to birds and mammals. Risk quotients for these food items ranged from 18 to 560 for birds and from 5.4 to 9.6 for mammals. The very high risk quotients for birds reflect the potent ability of bensulide to reduce the shell thickness of bird eggs. Despite the factors discussed above for acute risk, this chronic risk of bensulide cannot be discounted. The environmental fate assessment clearly indicates that bensulide is very persistent in the environment, which increases the concern for chronic risk. Laboratory studies indicate that bensulide is immobile and stable to degradation, and field dissipation studies confirmed that bensulide residues can persist in soil (half-lives were approximately 100 days). There is thus uncertainty as to where the chemical goes in the environment. It is possible that bensulide may be taken up by plants and invertebrates and thereby may enter the food web, ultimately affecting higher organisms. Bensulide has a high K_{ow} (1.65×10^4), which is correlated with accumulation in organisms. Although bensulide does not bioconcentrate to a great extent in fish (BCFs 550-640), the amount of bioaccumulation in plants and invertebrates is unknown. In addition, the high persistence of bensulide increases the opportunity for routes of exposure other than in the diet. Unless information from field studies become available that indicates otherwise, the use of bensulide on vegetable crops should be considered to have the potential to cause chronic effects on wildlife, especially birds.

Estimation of risk to terrestrial organisms is uncertain because the model used to estimate residues on terrestrial plants may not be reliable at the very high use rates used for bensulide. The model of Hoeger and Kenaga, as modified by Fletcher et al. (1994), is based on data primarily for applications at relatively low application rates (less than 3 lb ai/A). For bensulide, the model was used to predict residues for application rates as high as 12.5 lb ai/A. There is therefore uncertainty in these estimates because they were derived by extrapolating well outside the scope of the empirical data. Actual exposure may be either greater than or less than the predicted exposure, resulting in somewhat greater or less than risk. However, the large magnitude of the risk quotients for birds increase the certaintly that the conclusion of high risk is appropriate.

<u>Risk to Aquatic Ecosystems</u>

Bensulide does not pose a high risk to freshwater ecosystems from acute toxicity. For vegetable uses, acute risk to fish is not high but is sufficient to warrant restricted use classification for some types of uses. The Agency cannot accurately assess the risk to freshwater invertebrates since acceptable acute and chronic data have not been provided. However, supplemental data *Daphnia magna* indicate that use of bensulide on vegetables does not pose a high risk to aquatic invertebrates. Although not assessed, runoff of bensulide could potentially harm aquatic plants.

Chronic risk to fish and invertebrates is a serious concern because aquatic residues of bensulide are expected to be very persistent in water and aquatic sediments, and because chronic effects usually occur at lower concentrations than acute effects. It is imperative that aquatic tests be conducted to measure the chronic toxicity of bensulide. In the meantime, the Agency should assume that the chronic risk to aquatic organisms is high.

Concern for aquatic risk is reduced in the major use areas of Arizona and California because regional conditions create a low potential for transporting bensulide in runoff. These areas are very flat and have very little rainfall. The irrigation systems used in these areas are generally drip or microjet sprayers, neither of which generates a significant amount of runoff. In addition, aquatic habitats in this region are scarce. Except for endangered species, risk to aquatic ecosystems in these areas is not a major concern. There is a greater concern for use in other areas that are in more moist climates, such as Dade County of Florida and the Lower Rio Grande Valley of Texas.

Risk to marine and estuarine habitats is greater than that for freshwater habitats due to the apparent greater sensitivity of saltwater species to bensulide. All risk quotients for turf indicate high acute risks to fish and invertebrates. However, much of the use of bensulide on vegetables is in areas that are not associated with marine or estuarine habitats. Bensulide is used in desert areas along the lower Colorado River in California and Arizona, but there is very little runoff from agricultural fields that would flow into this river. Areas of the Central Valley region of California drain into the Sacramento River, which eventually flows into the San Francisco Bay, but bensulide residues probably would be diluted to insignificant amounts by the time they reached this estuary. The only use areas where there is a risk to marine and estuarine areas are the lower Rio Grande Valley in Texas and Dade County in Florida. The high amount of rainfall exacerbates the risk to estuarine habitats in these areas.

Reduction of application rate, banding applications, and soil incorporation appear to be effective ways to mitigate acute aquatic risks. These methods are especially effective when two or more are used together. However, without chronic data, it is not known if these measures could reduce chronic risk to an acceptable level.

b. Turf and Ornamental Uses

Bensulide is used to prevent emergence of grassy weeds on turf and around ornamentals. It is applied by ground in EC or granular form at a maximum application rate 12.5 lb ai/A. Applications at this rate can be twice a year, in the spring and fall. The largest turf use is application on the greens of golf courses. Bensulide is also applied to lawns by homeowners and lawn care professionals, as well as sod farms. The very small amount of bensulide applied around ornamentals in small-scale spot uses. The environmental risk associated with ornamental use is considered insignificant. The risk characterization therefore will focus on turf uses.

Risk to Terrestrial Ecosystems

Bensulide has low acute toxicity to birds (bobwhite LD_{50}=1390 mg/kg), but is more toxic to mammals (rat LD_{50}= 360 males, 270 females). The combination of moderate toxicity and high use rates on turf creates high acute risk for mammals. Risk quotients are as high 9.1 for EC products and 17 for granular products. Use on lawns poses a great risk to mammals. Mammals such as rabbits and voles that feed on grass and other herbaceous plants in lawns may be killed. Use on golf course greens probably poses less of a risk since herbaceous mammals would probably be less attracted to the very short grass of highly manicured greens compared to the thicker grass of other parts of the golf course.

To be effective, bensulide must be incorporated into the soil through irrigation soon after application. This practice would reduce the acute risk to mammals since it would wash granules and residues off of the vegetation and into the soil. The reduction of risk would depend on how soon and how well the area is irrigated after application. Although the amount that risk would be reduced through irrigation is not known, it would probably reduce the acute risk to birds to a minimal level in most cases. Risk to mammals also would be reduced by irrigation after application, but it is not certain that this would eliminate the acute hazard. Mammals that forage in the thatch and soil would still be exposed through ingestion, as well as through additional exposure from dermal absorption and inhalation. This exposure might be enough to cause acute effects in mammals, which are more sensitive to bensulide than birds.

Risk quotients indicate that use of bensulide on turf poses high chronic risk to wildlife, especially to birds. Chronic risk quotients based on the NOAEL are as high as 20 for mammals and as high as 1200 for birds. Avian reproduction data show that severe eggshell thinning (11-15%), leading to cracking of eggs and death of the embryos, occurs at a dietary concentration of 250 ppm. Birds that feed on treated grass sprayed with bensulide are predicted to receive dietary concentrations up to 12 times greater than this amount. The eggshell thinning effect was observed in the mallard, a waterfowl. Some species of waterfowl, including the Canada goose, the snow goose, and the American wigeon, feed extensively on grasses (Bellrose 1980). Irrigation after application would reduce residues on grass somewhat, but with chronic risk quotients as high as 1200, it likey would be insufficient to mitigate chronic risk. Furthermore, due to the bioconcentration, tissue concentrations of bensulide in fish are expected to be great enough in some cases to cause eggshell thinning in piscivorous birds. Some piscivorous raptors, such as the osprey and the bald eagle, are known to be highly susceptable to eggshell thinning.

The high persistence of bensulide in the environment exacerbates this chronic risk because animals would be exposed to high concentrations for extended periods of time. Although the required irrigation may wash bensulide off vegetation, residues will persist in the thatch and upper layer of soil. A study conducted on a golf course in Ohio demonstrated that bensulide residues are persistent in upper soil layers (Niemczyk and Krause, 1994). Furthermore, numerous field dissipation studies conducted on established turf showed that bensulide residues gradually wash out of the thatch, contaminating the soil beneath it. Animals feeding in the thatch and upper soil layers therefore are predicted to receive long-term exposures. Additionally, the persistence in the upper soil compartment may result in considerable amounts of bensulide accumulating in the tissue of plants and/or invertebrates. It thereby may enter the food web, ultimately affecting higher organisms.

Exposure to bensulide may be especially high for migratory waterfowl that graze on treated turf that has not been adequately irrigated. Three species of North American migratory waterfowl frequently graze on short grass: the Canada goose (*Branta canadensis*), the American wigeon (*Anas americana*), and the brant (*Branta bernicla*) (Bellrose, 1976). According to the registrant, about two-thirds of the turf use of bensulide is in the "mid-latitudes", described as the area lying between U.S. Route 70 and U.S. Route 80. This area lies south of the major breeding areas of migratory Canada geese and American wigeon in Montana, Wyoming, and the Dakotas (Bellrose, 1976). However, these birds may be exposed to bensulide when they cross this mid-latitude region during their spring migration. It is also likely that a relatively small amount of bensulide is used on lawns within the breeding areas, which would cause additional exposure. Use of bensulide on turf probably poses even greater risk to nonmigratory populations of waterfowl, which breed throughout the high-use area, although these populations are considered overabundant and a nuisance in most areas.

Chronic effects of bensulide pose a risk to terrestrial species other than migratory birds. Small mammals and reptiles that feed on grass and other herbaceous vegetation in lawns would be at risk. Examples of such species are the cottontail rabbit, the meadow vole, and the box turtle. Other birds and mammals that feed on seeds and invertebrates in thatch and upper soil layer would also be exposed and may be at risk of chronic effects. This risk is uncertain because the amount of residues on seeds and invertebrates in the soil and thatch is unknown.

Chronic risk is uncertain for use on golf course greens. Greens make up a small proportion of the landscape of a golf course. It is not certain if wildlife would spend enough time feeding on golf greens to receive a significant exposure to bensulide. It appears likely that wildlife would be less attracted to the greens than to the fairway and "rough" where vegetation would be thicker.

Estimation of risk to terrestrial organisms is uncertain because the model used to estimate residues on terrestrial plants may not be reliable at the very high use rates used for bensulide. The model of Hoeger and Kenaga, as modified by Fletcher et al. (1994), is based on data primarily for applications at relatively low application rates (less than 3 lb ai/A). For bensulide, the model was used to predict residues for application rates as high as 12.5 lb ai/A. There is therefore uncertainty in these estimates because they were derived by extrapolating well outside the scope of the empirical data. Actual exposure, and therefore risk, might be greater than or less than that predicted.

Bensulide is highly toxic to bees. Use on turf would expose bees there flowering weeds such as clover and dandelion are present. Flowering weeds would be directly sprayed with application of EC products, which may pose a significant hazard to foraging bees. Flowering weeds are likely to be prevalent on some home lawns, but not on most golf course greens. Use of granular products is not expected to result in significant exposure to bees.

Eggshell Thinning: A Comparison to DDT

The deleterious effects of DDT, and its toxic metabolite DDE, on the thickness of bird eggshells is well known. Use of DDT and other organochlorine pesticides resulted in reproduction failure in birds that caused dramatic reductions in many populations, driving some species to the brink of extinction. In 1975, the Agency described the impact of eggshell thinning on bird populations in *DDT: A Review of Scientific and Economic Aspects of the Decision to Ban its Use as a Pesticide*:

> "Certain wild birds, in their natural breeding areas, are affected by DDT-related residues in the diet and bioaccumulated into tissues in such a way as to produce reproductive impairment. This impairment is associated with the production of eggs with shells thinner than historical norms and results in deleterious phenomena as cracking, crushing, egg-eating by the parents, and nest abandonment. These phenomena result in reduced reproductive success among natural populations, and in some cases, failure of large breeding colonies to reproduce the young needed to sustain the population. These effects can result ultimately in partial or complete loss of whole species."

A comparative assessment was conducted to compare the risk of eggshell thinning between bensulide and DDT. Table X compares data obtained in reproduction tests with the mallard on the effects of bensulide, DDT, and DDE on eggshell thickness.

Table X. Eggshell thickness (percent reduction relative to control) measured in mallards exposed to bensulide, DDT, and DDE in the diet.

	Dietary Concentration (ppm)					
	0	2.5	10	25	40/25[a]	250
Bensulide (MRID 43616002)	0.40	--	--	--	--	0.34* (15.0%)
Bensulide (MRID 44486901)	0.34	0.34 (0%)	--	0.32* (5.9%)	--	0.30* (11.3%)
DDT[b]	0.38	0.36 (5.3%)	0.35 (8.6%)	--	0.33* (13.2%)	--
DDE[b] (1967)	0.38	--	0.35 (7.9%)	--	0.33* (13.1%)	--
DDE (1968)	0.37	--	0.33* (10.8%)	--	0.32* (13.5%)	--

[a] Birds were exposed to 40 ppm during the first year and 25 ppm during the second year.
[b] From Heath et al. (1969).

The findings indicate that bensulide can produce effects on eggshell thickness that are similar to the effects of DDT and DDE, but an approximately 10 times greater concentration of bensulide is required to produce an effect equal in magnitude. Therefore, on a gram per gram basis, bensulide is less potent that DDT and DDE by approximately a factor of 10. However, bensulide is registered at greater use rates than DDT was. The maximum rates for bensulide are 6 lb ai/A for vegetables and 12.5 lb ai/A for turf, whereas the former maximum rates for using DDT on cotton were 1-3 lb ai/A. Therefore, on an acre per acre basis, the risk of reproduction impairment through eggshell thinning for bensulide appears to be similar or just slightly less than that of DDT when used at the maximum use rate. Relative to DDT, the chronic risk of bensulide would be reduced by soil incorporation or irrigation after application, but by an unknown amount. Soil incorporation or irrigation would likely reduce exposure through consumption of vegetation, but would not reduce indirect exposure through the terrestrial food chain. Of course, the extent of effects would be much less for bensulide than it was for DDT because bensulide is used on much less area than DDT was. Nevertheless, this comparison attests that the risk of impairing the reproduction in birds by the use of bensulide is very high.

Risk to Aquatic Ecosystems

Although bensulide does not have high acute toxicity to freshwater fish, its high use rate and persistence create high acute risk to freshwater fish for some uses. Risk quotients predict high risks for a single application of granular bensulide at 12.5 lb ai/A, as well as twice-per-year granular applications at 7.5 lb ai/A or greater. The risk quotient for twice-per-year applications of the EC formulation at 12.5 lb ai/A is slightly less than the high risk LOC of 0.5. The apparent greater sensitivity to bensulide of marine and estuarine fish put them at greater risk. Risk quotients indicate that all uses of bensulide, including the EC formulation, pose a high acute risk to marine and estuarine fish.

Because adequate toxicity data are not available for freshwater invertebrates, data from a supplemental study was used in this assessments. This creates uncertainty in the conclusion of high risk to freshwater invertebrates from turf uses. Risk quotients for freshwater invertebrates ranged from 0.29 for a single spray application at 12.5 lb ai/A to 1.7 for twice-per-year granular applications at 12.5 lb ai/A. Although not assessed, there is also a potential for runoff of bensulide to harm aquatic plants.

As turf use will result in little or no spray drift, exposure to surface water would be limited to movement of the pesticide in runoff and subsurface flow. Subsurface flow should be minimal because bensulide is not mobile in soils. Also, little erosion of soil is expected on turf sites. Thus, movement will be primarily as dissolved material in surface runoff. There is a high potential for this type of movement because bensulide persists in the upper soil layer; it neither leaches nor degrades at an appreciable rate. High soil residues are therefore likely to persist until the next runoff event.

The largest turf use of bensulide is on golf course greens. This use is expected to result in relatively low exposure to surface water for several reasons. First, golf course greens make up a relatively small portion of the total golf course landscape. The PRZM/EXAMS model used to estimate exposure assumes a large contiguous area will be treated, whereas greens represent relatively small and widely dispersed treatment areas. Therefore, aquatic residues are expected to be much less than predicted by this model. Furthermore, the untreated areas that surround the greens will serve as a buffer zone, reducing the amount of bensulide that will reach surface water. Finally, greens are generally flat and would not generate much runoff. Use on greens is therefore not expected to result in significant exposure to surface water. Conversely, use on golf course fairways and other turf areas are expected to result in high exposure and high risk to aquatic organisms. A field study confirmed that high concentrations of bensulide may be transported in runoff from golf course fairways (Odanaka et al., 1994).

The risk assessment indicates that use of bensulide on turf will pose a high acute risk to marine and estuarine fish and invertebrates. Although EFED does not know the exact distribution of bensulide use on turf, golf courses and turf sites in coastal areas are often associated with marine and estuarine habitats. Therefore, some exposure to marine and estuarine organisms is expected.

There is a high potential for use on turf to result in chronic exposure to aquatic invertebrates. Because bensulide is persistent in the upper layer of the soil, it is available to gradually wash off in runoff for many weeks or months after application. Numerous field dissipation studies conducted on established turf found that bensulide residues also gradually wash out of the thatch into the soil, thereby increasing the persistence of residues in the soil.

Once it enters surface water, it is also persistent, degrading very slowly by hydrolysis and aquatic photolysis. These factors increase the potential for chronic exposure to fish and invertebrates.

An additional factor that increases the potential of chronic effects of bensulide is repeated applications. Bensulide is frequently applied to turf in both the spring and the autumn. Since predicted half lives of bensulide are greater than the 120 application interval, more than half of the bensulide residues from the first application will be present in the soil at the second application. Residues can also carryover from year to year. In a field study conducted on a golf course treated with granular bensulide, residues of bensulide were observed to persist in the thatch layer from one spring application to the next (Niemczyk and Krause, 1994). Therefore, not only will treated areas continuously contaminate aquatic habitats, but the amount of contamination may increase over time if bensulide accumulates in soil and thatch from repeated applications.

It is imperative that chronic toxicity data for aquatic species be submitted to the Agency to allow this risk to be assessed. In the interim, until these data are submitted and reviewed, the Agency must assume high chronic risk to all aquatic organisms.

c. Surface Water

Modeling results suggest bensulide will persist in surface waters following transport by surface runoff or spray drift. The modeling indicates dissipation does not occur rapidly and may occur principally by binding to suspended and bottom sediments. The limited dissipation results primarily from the slow degradation observed in the aerobic soil metabolism study (half-life of 1 year) and the high sorption coefficient (mean K_{oc} = 2,943 ml/g). Considerable uncertainty exists in this assessment because only one laboratory study was evaluated to estimate the degradation rate constant.

The Tier 2 modeling assumes a single 10-hectare field generates runoff which is collected in a 1-hectare pond with no outlet. Pesticide application is assumed to be made on the entire field during a single day. The "closed system" (pond with no outlet) is a limitation for estimating surface water concentrations for drinking water sources. Other surface water bodies used as drinking water sources may exhibit considerable flow-through (rivers, streams) or turnover (reservoirs, lakes). Bensulide concentrations in such waters would be considerably less than the predicted values.

Because EFED does not have a PRZM/EXAMS scenario specific for estimating the concentration of a pesticide in surface waters adjacent to golf courses, concentrations were instead estimated by a standard turf scenario. This scenario was created to represent an agricultural turf site such as a sod farm. The estimated concentrations of bensulide in surface water generated using this turf scenario may not be applicable for use in a national drinking water assessment specific to the golf course use. The size of the treated areas and the small surface water bodies associated with them are not well modeled by the standard turf scenario. In addition, water management practices on golf courses are not reflected in the standard turf scenario. This increases the uncertainty associated with EEC's associated with golf course use. Finally, the risk to drinking water is unknown because the lack of information on the location of drinking water intakes relative to treated golf courses.

The surface water concentrations were assessed assuming application of bensulide over large areas, such as whole golf courses, since this is permitted by the current label. In practice, however, application of bensulide is often restricted to just the tees and greens. This would reduce the risk associated with exposure from drinking water by greatly reducing the amount of area treated, as tees and greens comprise only a small proportion of a whole golf course.

The limited amount of laboratory and field data on the environmental fate of bensulide generates uncertainty in the modelling of concentrations in surface water. Only a single half-life value was available for aerobic soil metabolism. This 363 day half-life was not multiplied by a factor of 3 (as described in current OPP modeling input guidance, dated June 1995) because the approximately 1-year half-life value indicated limited degradation occurs via aerobic metabolic processes. It is desirable to have information from field dissipation studies to supplement information obtained in laboratory studies. Although numerous field dissipation studies have been conducted with bensulide, they are all flawed and failed to adequately describe the degredation and dissipation processes that occur. The aerobic soil metabolism half-life is the input parameter in the PRZM model, not the field dissipation half-life. However, because bensulide appears to degrade primarily through aerobic soil metabolism, an acceptable field dissipation study would be used in the reevaluation of our assessment.

d. Ground Water

Based on environmental fate data, bensulide is very persistent but not mobile in the soil. The environmental fate characteristics of bensulide and ground water modeling support the conclusion that bensulide is not expected to leach to ground water. Monitoring data for bensulide is very limited.

No detections of bensulide in ground water have been reported; however, the monitoring data is considered very limited because the majority of the wells sampled were not located in bensulide use areas. Wells in Alabama and California had a high limit of detection and a small number of samples and were not considered useful. The majority of the wells sampled in Texas were not in the bensulide use area; however, eight wells in Hidalgo County were important since they are within a bensulide use area, are likely to be near crops treated with bensulide, and are in an area that appears to be highly vulnerable to ground water contamination. Although no bensulide residues were detected in this area, only a general screening method was used to analyze samples and the detection limit is not known.

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PATRIOT modeling for bensulide was conducted on representative soils in the Yuma and Imperial Valley's of Arizona and California, in the Rio Grande Valley of Texas, and in Ohio for turf. Each of these scenarios used the maximum labeled application rates, the maximum number of applications allowed per year, irrigation, and very shallow ground water (3-6 ft) to simulate "worst-case" conditions. PATRIOT modeling predicted that bensulide would not leach to very shallow ground water.

Results from the SCI-GROW screening model predicted that the maximum chronic concentration of bensulide in shallow ground water is not expected to exceed 0.9 μg/L for the majority of the use sites. This is considered to be a "worst case" or "upper bound" for residues of bensulide in ground water. Bensulide was modeled using a 25 lb ai/acre/season application to turf. Typical use rates of bensulide for turf and vegetables are significantly less than this amount therefore any bensulide residues reaching ground water should be much less than predicted. Additional modeling of bensulide use on vegetables for the Yuma and Imperial Valleys (maximum of 12 lb/ai/season) resulted in a predicted concentration of 0.46 ppb. Bensulide use on vegetables for other use areas (max. 6 lb ai/season) resulted in a predicted concentration of 0.2 ppb.

The SCI-GROW model is based on small-scale ground water monitoring studies conducted on highly vulnerable sandy soils with shallow ground water (10-30 ft in depth). These types of soils would be classified as belonging to Hydrologic Group A soils. Highly vulnerable Hydrologic Group A soils generally do not occur in the bensulide use area. Soils in the bensulide use area are predominately Hydrologic Group B soils with limited areas of Group C and D soils. Soils belonging to these groups have less potential for leaching and a greater potential for surface water runoff.

Although the PATRIOT model adjusted for general irrigation, it did not account for use of micro-jet/sprinkler irrigation which is now commonly used in the desert areas of the Imperial and Yuma Valleys. These systems use significantly less water that traditional irrigation methods. When bensulide is used with microjet irrigation it is applied as chemigation and is applied with the irrigation water that is delivered to the plants. Lower application rates are often used with chemigation, and rates as low as 4 lb/ai may be used. The use of less irrigation water and lower application rates should decrease the potential for leaching of bensulide in these areas.

Both the PATRIOT and SCI-GROW screening models predicted little or no contamination of ground water, even though "worst-case" assumptions were used caused overestimation of the leaching potential of bensulide. Therefore, bensulide is not expected to leach to ground water.

6. Labeling Requirements

a. Manufacturing-Use Products

Labels for manufacturing-use products currently contain the following Environmental Hazard statement:

> "This product is toxic to fish and aquatic invertebrates. Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans or other waters unless in accordance with the National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance contact your state Water Board or Regional Office of the EPA."

This label statement is adequate.

b. End-use Products

Labels for end-use product currently contain the following Environmental Hazard statement:

> "This product is toxic to fish and aquatic invertebrates. Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwater or rinsate"

Labels for EC products currently contain the following statement:

> "Do not apply when weather conditions favor drift from the treated area."

This statement is beneficial in reducing risks to nontarget plants and animals. It should be retained.

Because bensulide is highly toxic to honey bees, the following statement is recommended for the label of EC products containing bensulide:

> "This product is highly toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees are visiting the treatment area."

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APPENDIX A

Detailed Descriptions of Major Geographical Areas Where Bensulide Is Used

"Desert Southwest" (Arizona and California)

Lettuce Production

The "Desert S.W" is part of the major land resource region known as the Western Range and Irrigated Region. The Western Range and Irrigated Region is a semi-desert to desert region of plateaus, plains, basins, and mountains. Most of the plains and basins receive less than 10 inches per year of precipitation. Much of the areas is used for range however irrigated agriculture is practiced where the is water available (Austin, 1972).

The principle use of bensulide in these areas is on lettuce in the Yuma and Imperial Valleys which are part of the Imperial Valley major land resources area (Austin, 1972, Gowan, 1997b).

The Imperial and Yuma Valley area has intensive irrigated agriculture and is noted for its vegetable, fruit, cotton and grain production. The Valley is a nearly level plain ranging in elevation from 125 feet below sea level to 600 feet above. Annual precipitation ranges from 2 to 4 inches and water is scarce. Irrigation for crops is almost entirely dependent upon water from the Colorado and Gila Rivers. Some wells provide local irrigation (Austin, 1972).

The dominant soils are Fluvents, Orthents and Psamments. They are described as very deep with a "hyperthermic temperature regime and aridic moisture regime" (Austin, 1981). The Imperial Valley is predominately Hydrologic Group D soils with a small area of Hydrologic Group B soils in the northern part of the Valley. The Yuma Valley is predominately Hydrologic Group A soils with limited areas of Group B soils (Kellogg, et al., 1992).

Irrigation on lettuce in the Yuma and Imperial Valleys uses furrow irrigation or "micro-jet" applicators. Bensulide is applied using chemigation, which means it is applied with the irrigation water that is delivered to the plants (Gowan, 1997b).

"Central Valley" (California)

Cucurbits (Melon) Production

The Central Valley of California is part of the major land resource region known as the California Subtropical Fruit, Truck, and Specialty Crop Region. This region consists of low mountains and broad valleys. It has a long growing season and low precipitation. Vegetables, fruits, and nuts are major crops in this region. Rice sugar beets, cotton and grain crops are also important (Austin, 1972).

In the central portion of the California Subtropical Fruit, Truck, and Specialty Crop Region is the major land resource area of the Sacramento and San Joaquin Valleys. This represents what is commonly known as the "Central Valley." The majority of the Valley is in ranches and farms. About one-half of the land is cropland of which three-fourths is irrigated. The area has broad level valleys bordered by sloping alluvial plains and terraces. Elevations range from sea level to 500 feet. Average rainfall ranges from 5 to 25 inches. Low rainfall and small streamflow result in a scarcity of water. Irrigation water is supplied from the mountains and from wells. The southern areas are suffering from declining water tables resulting from irrigation (Austin, 1972).

The dominant soils are Xeralfs, Xerolls, Xererts, Aquents, Aquolls, Ochrepts, Orthents, Fluvents, Psamments, and Argids. They have a thermic temperature regime (Austin, 1981). Hydrologic Group B soils predominate in the southern end of the Central Valley, while Hydrologic Group D soils in the northern areas (Kellogg, et al., 1992).

Bensulide is used principally on melon production in the Central Valley. Water is provided by drip irrigation (Gowan, 1997b).

"Mid-latitudes"

"Turf" Use

The principle use of bensulide on "turf" is on golf course greens. Bensulide is not generally used on golf fairways due to its cost. It is estimated that approximately one-half of the golf courses in the U.S. are treated with bensulide, most use the 4 lb ai/gal. EC. About two-thirds of the bensulide use on turf occurs in the "mid-latitudes," an area described as lying between U.S. Route 70 and U.S. Route 80 (Gowan, 1997a, Gowan, 1997b). This area forms an east-west trending belt through in the central part of the U.S and may include parts of New Jersey, Pennsylvanian, Ohio, Indiana, Illinois, Iowa, Missouri, Kansas, Nebraska, Colorado and possibly Wyoming and Utah. A major portion of this potential use area occurs in the Central Feed Grain and Livestock Region. This region is characterized by fertile soils, and favorable climate with 25 to 35 inches of rainfall annually. Much of the area has been glaciated and glacial drift, loess, and till plains are common (Austin, 1972).

Hydrologic group B and Group C soils predominate in this "belt" across the midwest. Hydrologic Group B soils occur in central Indiana, northern Illinois, Iowa, eastern Nebraska, western Kansas, and eastern Colorado. Hydrologic Group C soils occur in northern New Jersey, Pennsylvania, central Ohio, southern Indiana, southern Illinois, southern Iowa, eastern Kansas, and northern Missouri. Hydrologic Group A and Group D soils are not common in most of these areas (Kellogg, et al., 1992).

Rio Grande Valley (Texas)

Melon and Onion Production

The Rio Grande Valley is within the major land resource region known as the Southwestern Plateaus and Plains Range and Cotton Region. Rangeland is the dominant land use in this region with some agricultural areas in the southeastern areas along the Rio Grande Valley. This region receives moderate rainfall however the high temperatures reduce the effectiveness of the precipitation (Austin, 1972).

The major land resource area known as the Rio Grande Valley, is a nearly level plain ranging in elevation from sea level to 1,000 feet in the northwest. Citrus, fruit, melons, vegetables, cotton, and corn are grown in the Valley, especially along the Rio Grande and Nueces rivers which provide water for irrigation. Average annual rainfall ranges from 20 to 35 inches. Ground water is "abundant" with some use for irrigation (Austin, 1972).

Most of the soils are Ustalfs. They are deep, moderately fine textured and fine textured soils, that formed in alluvial sediments. They have a hyperthermic temperature regime, and an ustic moisture regime, and mixed mineralogy. Ustolls having mixed mineralogy are reported as extensive (Austin, 1981). The irrigated areas along the Rio Grande are predominately Hydrologic Group B soils with areas of Hydrologic Group A, and Group C soils in the interior of the region (Kellogg, et al, 1992).

South Central Texas

Gowan also reports one county with bensulide use on vegetables. A portion of the county falls in the major land resource area described above, while the other portion falls in the southwest part of the major land resource area known as the Southwestern prairies Cotton and Forage Region. This area is mostly farms with cotton, and grain sorghum as the major crops. Elevation ranges from 40 to 80 feet. Annual precipitation ranges from 30 to 49 inches. Rainfall is adequate in most years. Ground water is scarce and reservoirs and ponds are commonly used as water sources. Most of the soils are Usterts, Ustolls, Aqualfs and Ustalfs. They are well drained to somewhat poorly drained, and medium to fine textured. These soils have a thermic temperature regime, an ustic or aquic moisture regime and montmorillonitic, mixed, or carbonate mineralogy (Austin, 1981).

Colorado

Onion Production

Onion production is reported to also occur in northeastern Colorado (Gowan, 1997b). This is part of the major land resource region known as the Western Great Plains Range and Irrigated

Region. In this section of the Great Plains, the soils are often unfavorable for agriculture and moisture is often limited. A large part of the area is rangeland with some dryfarming.

Two counties along the South Platte River reported use of bensulide. These counties are in the major land resource area known as the Central High Plains. Most of the land is in ranches and farms. Corn, vegetables, melons, sugar beets and potatoes are grown on irrigated land. The elevation ranges from 3,500 to 6,000 feet. The precipitation ranges from 13 to 17 inches annually and varies widely from year to year. Much of the irrigation water is derived from the South Platte River and its tributaries. Ground water is described as "adequate" from the sands and gravels. Areas where shale is near the surface, ground water is scarce (Austin, 1972). Most of the soils are Ustolls and Argids. They are deep and medium textured and fine textured and have mixed or montmorillonitic mineralology. They have an aridic moisture regime that is borderline to ustic and a mesic temperature regime (Austin, 1981). The soils in this area are predominately Hydrologic Group B and Group C soils (Kellogg, et al., 1992).

Idaho

Bensulide is reportedly used on vegetables in one county along the Snake River in Idaho. This is part of the major land resource region known as the Northwestern Wheat and Range Region. This area along the Snake River is in farms and ranches. Areas bordering the river are irrigated. Potatoes, grain, sugar beets beans and hay are reportedly grown in this area. Elevations range from 2,000 to 5,500 feet. Alluvial fans, bottom lands and terraces are described as gently to moderately sloping. Annual average precipitation ranges from 7 to 13 inches. Large amounts of water are available for irrigation from the Snake River and its tributaries. Ground water is abundant in the deeper alluvial deposits and has been extensively used for irrigation (Austin, 1972). The dominant soils are Orthids, Argids, and Orthents. They have a meic or frigid temperature regime (Austin, 1981). The soils are predominately Hydrologic Group B soils (Kellogg, et al., 1992).

Florida

Three counties in Florida have reported use of bensulide on vegetables. The principle use is in southern Florida in Dade County. This area is part of the major land resource region known as the Florida Subtropical Fruit, Truck Crop, and Range Region. Dade County specifically is in the major land resource area known as the Florida Everglades and Associated Areas. The area is composed largely of open marsh, and swamps with broad poorly defined streams. Cypress forests and mangroves are widespread along the coast. The elevation ranges from sea level to 25 feet, canals and ditches drain areas for crops and pasture. Winter vegetables and citrus are grown in the dryer areas (eastern Dade County). The area receives 50 to 64 inches of precipitation annually. There is an abundance of water from rainfall, surface water and ground water (Austin, 1972).

The soils for this area are described as Saprists and Fibrists. They are very poorly drained, organic soils that have a hyperthermic temperature regime and an aquic moisture regime. Many soils in Dade County are very shallow with limestone and marl near the surface (Austin 1981). This soils in this area has not been classified into Hydrologic Groups (Kellogg, et al., 1992)

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APPENDIX B

Summaries of Unacceptable Field Dissipation Studies for Bensulide

40534901.

This study is unacceptable and cannot be upgraded because substantial residues of bensulide were recovered at all sampling depths immediately following the first application (≥ 0.79 ppm; limit of quantitation 0.05 ppm; no residues had been found in the samples taken from the plots prior to treatment) and concentrations were increased ten-fold in the lower sampling depths immediately following the second application (from 0.13-0.14 ppm to 1.18-1.84 ppm). In addition, soil samples were only taken to a depth of 12 inches, which did not permit a determination of the depth of leaching for either parent or degradate. An additional problem with the study is that there was no confirmation of application rate at either of the two specified application dates; at day 0 after the first application approximately 37% of the application rate was accounted for, and after the second application approximately 35% of the applied material was confirmed from the soil. No bare-ground plots were used for confirmation of application (the study plot was established turf), and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch.

Two applications of BETASAN 4-E were made at a rate of 12.5 lb ai/A per application to the surface of established turf on silt loam soil located near Leland, Mississippi. The first application was made on 18 April 1986; the second application was made 112 days later on 8 August 1986. Soil samples were collected to a depth of 12 inches up to 364 days following the second application. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon; grass and thatch were not analyzed.

Bensulide was found at all sampling depths immediately posttreatment. The reported half-life for bensulide in the top 3 inches of soil was 91 days for the first application ($r^2=0.72$) and 96 days for the second application ($r^2=0.72$). The bensulide oxygen analog residue data indicate that bensulide oxon was found predominately in the top 3 inches of soil at appreciable amounts up until 104 days following the second application and was detected as far down as the 6-12 inch soil stratum during that same period.

40534902

This study is unacceptable and cannot be upgraded because substantial residues of bensulide were recovered at all sampling depths immediately following application (≥ 0.65 ppm; limit of quantitation 0.05 ppm; no residues had been found in the samples taken from the plots prior to treatment). In addition, soil samples were only taken to a depth of 12 inches, which did not permit a determination of the depth of leaching for bensulide. An additional problem with the study is that there was no confirmation of application rate. At day 0, approximately 55% of the application rate was accounted for. No bare-ground plots were used for confirmation of application (the study plot was established turf), and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch.

One application of BETASAN 4-E was made at a rate of 12.5 lb ai/A on May 9, 1986 to established turf on silt loam soil located near Orange Cove, California. Samples of turf and soil were collected up to 91 days posttreatment; soil samples were taken to a depth of 12 inches. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon; grass and thatch were not analyzed.

Bensulide was found at all sampling depths immediately posttreatment. The reported half-life (time at which half of the calculated initial concentration of the analyte remained) for bensulide in the top 3 inches of soil was 34 days (r^2=0.89). Bensulide residues persisted in the top 3 inches of soil throughout the study, although levels had dissipated to approximately 12% of the amount found immediately after application. After 7 days no detectable residues of bensulide were found below 6 inches and levels were below the detection limit (0.05 ppm) in the 3-6 inch stratum after 31 days. Bensulide oxon was found at detectable levels only in the top 3 inches of soil throughout the 91-day sampling period.

40534903

This study is unacceptable and cannot be upgraded because substantial residues of bensulide were recovered at all sampling depths immediately following both applications ($\geq$ 0.13 ppm and $\geq$ 0.35 ppm after the first and second applications, respectively; limit of quantitation 0.05 ppm; no residues had been found in the samples taken from the plots prior to treatment). In addition, soil samples were only taken to a depth of 12 inches, which did not permit a determination of the depth of leaching for bensulide. An additional problem was that dissipation half-lives could not be determined. Although the study author reported half-lives for bensulide of 210 days for the first application and 101 days for the second application made 133 days later on the same treatment plots, no definite pattern of decline was evident following either application due to variability in the bensulide residues in the 0-3 inch soil stratum. Also, there was no confirmation of application rate. Following the first application, approximately 28% of the application rate was accounted for; after the second application approximately 77% of the applied material was confirmed from the soil. No bare-ground plots were used for confirmation of application (the study plot was established turf), and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch.

Two applications of BETASAN 12.5-G were surface applied at a rate of 12.5 lb/A bensulide to established turf on silt loam soil located near Leland, Mississippi. The first application was made on 21 October 1986, and a second application was made 133 days later on 3 March

1987. Soil samples were collected up to 167 days following the second application to a depth of 12 inches. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon; grass and thatch were not analyzed.

Bensulide residues were recovered from soil samples taken from the 3-6 and 6-12 inch soil strata on the day of application and in all samples taken through 127 days posttreatment. A definite pattern of decline was not evident due to variability in the bensulide residues in the 0-3 inch soil stratum (r^2=0.146 following the first application and r^2=0.425 following the second). Detectable bensulide oxon residues were confined to the top 3 inches of soil during the time following the first application. However, after the second application, detectable residues of bensulide oxon were found at all sampling depths on day 14 posttreatment; in the 3- to 6-inch soil stratum, a maximum of 0.12 ppm was found at 79 days posttreatment.

40534904.

This study is unacceptable and cannot be upgraded because substantial residues of bensulide were recovered at all sampling depths immediately following application (≥ 0.13 ppm; limit of quantitation 0.05 ppm; no residues had been found in the samples taken from the plots prior to treatment). In addition, soil samples were only taken to a depth of 12 inches, which did not permit a determination of the depth of leaching for bensulide. An additional problem was that there was no confirmation of application rate. Immediately following application, the maximum residues recovered were approximately 51% of the application rate. No bare-ground plots were used for confirmation of application (the study plot was established turf), and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch.

BETASAN 12.5-G Granular Selective Herbicide (active ingredient bensulide) was applied postemergence surface (POES) with a shaker can to established turf on a silt loam soil near Orange Cove, California. One application of BETASAN 12.5-G (12.5 lb/A bensulide) was made on 9 May 1986. Soil samples were collected to a depth of 12 inches up to 92 days posttreatment. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon; grass and thatch were not analyzed.

The reported half-life (time at which half of the calculated initial concentration of the analyte remained) for bensulide in the top 3 inches of soil was 30 days (r^2=0.768). Bensulide residues persisted in the top 3 inches of soil throughout the study, although levels had dissipated to approximately 10% of the amount found immediately after application. Detectable residues of bensulide were found at the greatest sampling depth (12 inches) at time of application and at 7 days posttreatment. Bensulide oxon was found at detectable levels only in the top 3 inches of soil throughout the 91-day sampling period, reaching a maximum of 0.79 ppm at 31 days posttreatment.

81/104

40534905.

This study is unacceptable and cannot be upgraded because substantial residues of bensulide were recovered at all sampling depths immediately following application (≥ 0.30 ppm; limit of quantitation 0.05 ppm; no residues had been found in the samples taken from the plots prior to treatment). In addition, soil samples were only taken to a depth of 12 inches, and substantial residues of bensulide were recovered at all sampling depths at time of application and through 28 days following application, which did not permit a determination of the depth of leaching for bensulide. An additional problem was that there was no confirmation of application rate. Immediately following application, approximately 31% of the application rate was accounted for, and at no following interval was more that 53% recovered. In addition, it is uncertain what the condition of the field plot was at the time of application (conflicting descriptions were provided as to whether the treated area was bare ground or established sod).

PREFAR 4-E Selective Herbicide (active ingredient bensulide) was applied pre-plant incorporated (PPI) with a tractor-mounted boom sprayer at an application rate of 6.0 lbs of bensulide per acre to a silt loam soil at a test site near Orange Cove, California on 9 May 1986. Cotton was seeded into the plots immediately after application (no mention was made how these plots were prepared for seeding after application). Soil samples were collected to a depth of 12 inches up to 154 days posttreatment. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon.

The reported half-life (time at which half of the calculated initial concentration of the analyte remained) for bensulide was 15 days ($r^2 = 0.94$). Detectable residues of bensulide were found at the greatest sampling depth (12 inches) up until 28 days posttreatment. Detectable bensulide oxon residues were confined to the top 3 inches of soil throughout this field dissipation study at a maximum of 0.29 ppm at 14 days posttreatment.

40534906.

This study is unacceptable and cannot be upgraded because substantial residues of bensulide were recovered in the 3- to 6-inch soil segments immediately following application (1.44 ppm) and were present at ≥0.38 ppm at all soil depths at 3 days posttreatment (limit of quantitation 0.05 ppm; no residues had been found in the samples taken from the plots prior to treatment). In addition, soil samples were only taken to a depth of 12 inches, and substantial residues of bensulide were recovered at all sampling depths up through 27 days following application, which did not permit a determination of the depth of leaching for bensulide. An additional problem was that there was no confirmation of application rate. Immediately following application, approximately 139% of the application rate was accounted for in the 0- to 3-inch soil depth, and decreased to 55% by 3 days posttreatment. In addition, it is uncertain what the condition of the field plot was at the time of application (conflicting descriptions were provided as to whether the treated area was bare ground or established sod).

PREFAR 4-E Selective Herbicide(active ingredient bensulide) was applied pre-plant incorporated (PPI) with a tractor mounted boom sprayer at an application rate of 6.0 lb/A of bensulide to a silt loam soil near Leland, Mississippi on 18 April 1986. Cotton was seeded on the plots 4 days after application (no mention was not made how these plots were prepared for seeding after bensulide application). Soil samples were collected up to 363 days post application to a depth of 12 inches. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon.

Analysis of the soil samples showed that bensulide was recovered at all sampling depths by day 3 posttreatment. At day 0 there was 8.35 ppm bensulide recovered in the 0-3 inch soil stratum and 1.44 ppm in the 3-6 inch depth soil stratum. By day 3 posttreatment bensulide residues were reported at 3.37 ppm in the top 3 inches of soil, 0.38 ppm in the 3-6 inch soil stratum, and 0.39 ppm in the 6-12 inch soil stratum. Bensulide residues were detected in the 6-12 inch soil stratum until 27 days posttreatment, and in the 3-6 inch soil stratum until 87 days posttreatment.

The reported half-life (time at which half of the calculated initial concentration of the analyte remained) for bensulide was 30 days (r^2=0.816). Detectable bensulide oxon residues were confined to the top 3 inches of soil throughout this field dissipation study with a maximum concentration of 0.24 ppm at 27 days posttreatment.

41694201.

This study is unacceptable and cannot be upgraded because there was no confirmation of application rate at either of the two specified application dates. At day 0 after the first application only 1.33% of the application rate was accounted for in the soil, and after the second application only 3.06% of the applied material was confirmed. No bare-ground plots were used for confirmation of application (the study plot that had been planted to turf several weeks prior to the first application) and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch.

Two applications of BETASAN 4E were made on 1- to 2-inch high turf at a rate of 12.5 lb ai/A per application. The plots located in Tulare County near Porterville, CA. were planted with turf (hybrid Bermuda) on 29 June 1988. The first application was made on 21 July 1988 and the second application was made on 21 September 1988 (61 day treatment interval). Soil samples were collected up to 275 days postapplication to a maximum depth of 39.5 inches. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon; grass and thatch were not analyzed.

After the second application, bensulide was reportedly detected down to the 27.5 inch soil segment (0.75 ppm at day 62) and bensulide oxon was detected as far as the 27.5 inch soil segment (0.08 ppm at day 62). It appears that bensulide residues were continually leaching into the soil from the thatch or turf. The application rate could not be confirmed nor was an apparent consistent decline of parent material observed. Reviewer-calculated half-lives were 185.8 days for the first application ($r^2=0.007$) and 61.3 days for the second application ($r^2=0.335$).

41694202.

This study as reported is unacceptable and cannot be upgraded because there was no confirmation of application rate at either of the two specified application dates. At day 0 after the first application approximately 37% of the application rate was accounted for; after the second application approximately 28% of the applied material was confirmed from the soil. No bare-ground plots were used for confirmation of application (the study plot had been sodded to turf several weeks prior to the first application) and no mention was made of how the turf and thatch in the samples were separated from the soil or of any attempt to extract residues from the turf or thatch.

Two applications of BETASAN 12.5-G were made on 1- to 2-inch high turf (tall fescue, Blue Fylking which had been sodded 40 days prior to use) located in Tulare County near Visalia, CA on Foster fine sandy loam soil at a rate of 12.5 lb ai/A per application. The first application was made on 24 May 1988 and 57 days later a second application was made on 21 July 1988. Soil samples were collected to a depth of 39.5 inches up to 278 days following the second application.. Residue analysis consisted of analysis of soil for bensulide and bensulide oxon; grass and thatch were not analyzed.

The application rate could not be confirmed nor was an apparent consistent decline of parent material observed. Reviewer-calculated half-lives were 77 days for the first application ($r^2=0.064$) and 37 days for the second application ($r^2=0.74$). Bensulide was not detected below the 3.5 to 7.0 inch soil segment at any sampling interval after either of the two applications in this study. Bensulide oxon was not reported below the 0-3.5 inch soil segment; maximum concentration was 0.1 ppm at 30 days posttreatment.

APPENDIX C

Ground Water Modeling Input for Bensulide

K_{oc} = 2943 (mean)
= 3006 (median)
Aerobic soil T ½ = 363 days

PATRIOT modeling Input

Vegetables

MLRA 031 (Yuma/Imperial Valley)
App. Rate: 12 lb/acre/year
Weather: Yuma Arizona 1974-1983
Depth G/W: 158 cm
Corr. for Evap and Irrigation

MLRA 083D (Rio Grande Valley)
App. Rate: 6 lb/acre/year
Weather: Brownsville 1954-1963
Depth G/W: 174 cm
Corr. for Evap and Irrigation

Turf

Grass/Pasture/Hay Scenario for Ohio
App. Rate: 25 lb/acre/year
Depth G/W: 91 cm
Corr. for Evap. and Irrigation

APPENDIX D

Physical Chemical Properties and Structures

Bensulide chemistry values for background info. Updated as of May 30, 1997.

Parameter	Bensulide (009801)
63-2 - Color	White (Pure active); light amber (Technical) [41532001]
63-3 - Physical State	Solid (Pure active and Technical) [41532001]
63-4 - Odor	Odorless (Pure active); "oily, camphor-like, reminiscent of sulfur-containing compounds" (Technical) [41532001]
63-5 - Melting Point	36°C (Pure active); 33-36°C (Technical) [41532001]
63-6 - Boiling Point	N/A (material is a solid) [41532001]
63-8 - Solubility	Water: 5.6 mg/L @ 25°; 1-Octanol: 78.4 g/100 mL; kerosene: 5.2 g/100 mL; miscible at room temperature in acetone, chlorobenzene, ethanol, xylene, and dichloromethane [41532001]
63-9 - Vapor Pressure	1.1×10^{-4} Pa; 8.2×10^{-7} mm Hg/Torr (Pure active) [41532001]
63-10 - Dissociation constant (pKa)	N/A (material does not dissociate) [41532001]
63-11 - Octanol/water Partition Coefficient (K_{ow})	average 1.65×10^{4} at ambient temperature (Pure active) [157314]; Log K_{ow}: 4.217
63-12 - pH	In 1% solutions in water: 8 ± 1 (Pure active); 5.0 ± 0.1 (Technical) [41532001]

CHEMICAL:

Common Name:	Bensulide	Bensulide oxon	Benzenesulfonamide
CAS No.:	741-58-2	20243-81-6	-
PC Code No.:	009801	-	-

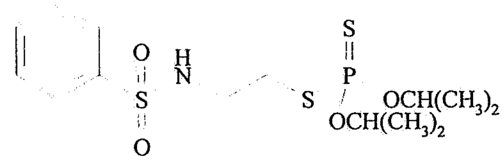
Chemical Name: Bensulide: [S-(O,O-diisopropyl phosphorodithioate) ester of N-(2-mercapto)benzenesulfonamide]); [S-benzenesulfonamidoethyl O,O-diisopropyl phosphorodithioate

Bensulide oxon: N-[(2-(diisopropoxyphosphinoylthio)-1-ethyl]-benzenesulfonamide

Trade Names: (from LUIS report dated February, 1996)

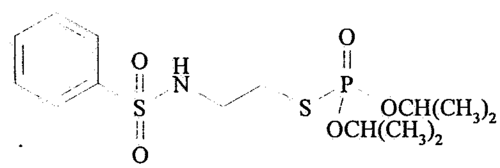
Prefar 4-C (emulsifiable concentrate); Betasan (granular)

Chemical Structures:



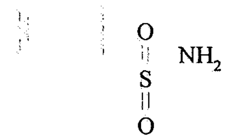
Bensulide

Molecular Formula: $C_{14}H_{24}NO_4PS_3$
Molecular Weight: 397.52 g/mol



Bensulide oxon

Molecular Formula: $C_{14}H_{24}NO_6PS_2$
Molecular Weight: 381 g/mol
Melting point: 64.5-65.5°C



Benzenesulfonamide

Molecular Formula: $C_6H_5SO_2NH_2$
Molecular Weight: 157.14 g/mol
K_a: 10^{-10}

References:

157314 - Lee, K-S. 1986. Odor, corrosion rate, and octanol water partition coefficient of bensulide. Unpublished study performed and submitted by Stauffer Chemical Company, Richmond CA.

41532001 - Lee, K-S. 1990. Bensulide - Physical properties. Unpublished study performed and submitted by ICI Americas Inc., Richmond, CA.

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ADDENDUM 1

Updates to the Risk Assessment of the Bensulide RED Based on Recently Submitted Data on Ecological Effects

I. Toxicity Data

A. Chronic Data for Freshwater Fish

A freshwater fish early life-stage test using the TGAI is required for bensulide because (1) the end-use product is expected to be transported to water from the intended use site, (2) aquatic acute fish LC_{50}'s and the waterflea EC_{50} are less than 1 mg/l, and (3) the EEC in water is equal to or greater than 0.01 of acute LC_{50} and EC_{50} values. A further factor that triggers this test is that bensulide is very persistent in water (hydrolysis half-life is 220 days). The preferred test species is the rainbow trout.

Chronic Toxicity to Freshwater Fish

Species, Test Type	% ai	NOAEL (ppb ai)	LOAEL (ppb ai)	MATC (ppb ai)	Endpoints Affected	MRID No. Author/Year	Study Classification
Fathead minnow (*Pimephales promelas*), flow-through early life-stage test	93.4	374	789	543	Larval growth and survival	44720408 Kranzfelder *et al.*, 1998	Core

The test shows that the larval growth and survival of freshwater fish will begin to be affected at bensulide concentrations between 374 and 789 ppb ai. The guideline for a freshwater fish early life-stage study (72-4a) has been fulfilled. A freshwater fish life-cycle study (GLN 72-5) may be required depending on the results of the freshwater fish early life-stage test. (MRID 44720408)

B. Chronic Data for Freshwater Invertebrate

A freshwater aquatic invertebrate life-cycle test using the TGAI is required for bensulide because the end-use product is expected to be transported to water from the intended use site, aquatic acute fish LC_{50}'s and the waterflea EC_{50} are less than 1 mg/l, and the EEC in water is equal to or greater than 0.01 of acute LC_{50} and EC_{50} values. A further factor that triggers this test is that bensulide is very persistent in water (hydrolysis half-life is 220 days). The preferred test species is *Daphnia magna*.

Chronic Toxicity to Freshwater Invertebrates

Species, Test Type	% ai	NOAEL (ppb ai)	LOAEL (ppb ai)	MATC (ppb ai)	Endpoints Affected	MRID No. Author/Year	Study Classification
Waterflea (*Daphnia magna*), flow-through life-cycle test	93.4	Not determined	6.93[a]	Not determined	Growth and reproduction	44720407 Kranzfelder *et al.*, 1998	Supplemental

[a] The solvent used in this test (DMF) appeared to stimulate growth and reproduction in the solvent control. The solvent concentration varied between test solutions. Differences in the solvent concentrations between the solvent control and the lower-level treatment solutions could have contributed to the observed differences in responses.

This test indicates that bensulide concentrations as low as 6.9 ppb ai could reduce the growth and reproduction of freshwater invertebrates. Although this determination of the LOAEL is uncertain because of possible stimulatory effects of the solvent, it appears certain from this study that bensulide concentrations of 11.0 ppb ai or greater causes adverse effects on growth and reproduction. This study does not fulfill the guideline for a freshwater invertebrate life-cycle study (72-4b).

C. Aquatic Plants

Tier 2 aquatic plant testing is required for bensulide because it is an herbicide that has outdoor non-residential terrestrial uses and it therefore may move off-site via runoff or (for chemigation applications) spray drift. Phytotoxicity testing is required with five aquatic plant species: *Pseudokirchneria subcapitata*, *Lemna gibba*, *Skeletonema costatum*, *Anabaena flos-aquae*, and a freshwater diatom.

Results of Tier II toxicity testing on technical bensulide are tabulated below.

Nontarget Aquatic Plant Toxicity (Tier II)

Species	% ai	EC_{50} (ppm)	NOAEL or EC_{05} (ppm)	MRID No. Author/Year	Study Classification
			Vascular Plants		
Duckweed *Lemna gibba*	93.4	0.14	0.017	447204-06	Supplemental[1]
			Nonvascular Plants		
Green algae *Pseudokirchneria subcapitata*	93.4	1.8	0.93 (EC_{05})	447204-02	Core
Marine diatom *Skeletonema costatum*	93.4	0.78	0.635	447204-05	Core
Blue-green algae *Anabaena flos-aquae*	93.4	>3.58	3.58	447204-03	Core

[1] This study failed to determine the NOAEL and the lowest test levels were too high to accurately estimate the EC_{05}.

Bensulide appears to be more toxic to aquatic vascular plants than to algae and diatoms. The most sensitive test species is the duckweed (*Lemna gibba*), for which the EC_{50} is 140 μg/L. The estimated EC_{05} (17 μg/L) is approximate because the test did not includes levels low enough to well define this part of the dose response curve. The marine diatom (*Skeletonema costatum*) is the most sensitive nonvascular aquatic plant. The guideline (123-2) is not fulfilled because acceptable data have not been submitted for the freshwater diatom (*Navicula pelliculosa*) (MRID 44720402, 44720403, 44720405, and 447204-06).

II. Risk Assessment

A. Chronic Risk for Freshwater Fish

Chronic risk quotients for freshwater invertebrates are tabulated below.

Chronic Risk Quotients for Freshwater Fish Based on a Fathead Minnow NOAEC and PRZM/EXAMS exposure estimates.

Use Site	Application Method	Rate in lb ai/A	Number of Applications	NOAEC (ppb)	56-day mean EEC (ppb)	Chronic RQ (EEC/ NOAEL)
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	374	44	0.12
	Broadcast EC spray, incorporated	3	1	374	28	0.07
	Banded EC spray, unincorporated	3	1	374	20	0.05
	Banded EC spray, incorporated	3	1	374	29	0.07
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	374	88	0.23
	Broadcast EC spray and chemigation, unincorporated	6	2	374	160	0.43
	Broadcast EC spray, incorporated	6	1	374	55	0.15
	Broadcast EC spray, incorporated	6	2	374	113	0.30
	Banded EC spray, unincorporated	6	1	374	40	0.11
	Banded EC spray, unincorporated	6	2	374	72	0.19
	Banded EC spray, incorporated	6	1	374	28	0.07
	Banded EC spray, incorporated	6	2	374	57	0.15
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	374	263	0.70
	Broadcast granular application, unincorporated	7.5	2	374	578	1.5*
	Broadcast granular application, unincorporated	10	1	374	350	0.94
	Broadcast granular application, unincorporated	10	2	374	770	2.1*
	Broadcast EC spray, unincorporated	12.5	1	374	167	0.45
	Broadcast EC spray, unincorporated	12.5	2	374	349	0.93
	Broadcast granular application, unincorporated	12.5	1	374	438	1.2*
	Broadcast granular application, unincorporated	12.5	2	374	963	2.6*

* Exceeds chronic LOC.

Risk quotients indicate that some uses of bensulide on turf exceed the LOC for chronic risk to freshwater fish. Specifically, two applications of granular products at a rate of 7.5 lb ai/A per application will result in a high chronic risk to freshwater fish. A single unincorporated application of granular product will also result in a high risk. In addition, risk quotients are for a single unincorporated application of granular product at 10 lb ai/A, and a twice-per-year spray application of EC products at 12.5 lb ai/A each, approach the LOC.

These uses of bensulide on turf pose a risk to threatened and endangered species as well. Use of bensulide on vegetables does not pose a high chronic risk to freshwater fish.

B. Chronic Risk to Freshwater Invertebrates

Chronic risk quotients for freshwater invertebrates are tabulated below.

Chronic Risk Quotients for Freshwater Invertebrates Based on a *Daphnia magna* LC_{50} and PRZM/EXAMS exposure estimates.

Use Site	Application Method	Rate in lb ai/A	Number of Applications	NOAEC (ppb)	21-day mean EEC (ppb)	Chronic RQ (EEC/ NOAEL)
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	<6.93	45	>6.5*
	Broadcast EC spray, incorporated	3	1	<6.93	28	>4.0*
	Banded EC spray, unincorporated	3	1	<6.93	20	>2.9*
	Banded EC spray, incorporated	3	1	<6.93	14	>2.0*
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	<6.93	90	>13*
	Broadcast EC spray and chemigation, unincorporated	6	2	<6.93	161	>23*
	Broadcast EC spray, incorporated	6	1	<6.93	56	>8.1*
	Broadcast EC spray, incorporated	6	2	<6.93	115	>17*
	Banded EC spray, unincorporated	6	1	<6.93	40	>5.8*
	Banded EC spray, unincorporated	6	2	<6.93	72	>10*
	Banded EC spray, incorporated	6	1	<6.93	28	>4.0*
	Banded EC spray, incorporated	6	2	<6.93	58	>8.4*
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	<6.93	267	>39*
	Broadcast granular application, unincorporated	7.5	2	<6.93	587	>85*
	Broadcast granular application, unincorporated	10	1	<6.93	356	>51*
	Broadcast granular application, unincorporated	10	2	<6.93	783	>113*
	Broadcast EC spray, unincorporated	12.5	1	<6.93	168	>24*
	Broadcast EC spray, unincorporated	12.5	2	<6.93	350	>51*
	Broadcast granular application, unincorporated	12.5	1	<6.93	445	>64*
	Broadcast granular application, unincorporated	12.5	2	<6.93	979	>141*

* Exceeds chronic LOC.

Risk quotients indicate that all uses of bensulide exceed the LOC for chronic risk to freshwater invertebrates. Chronic risk is especially high for turf uses, for which time-averaged EEC's are 39 to 141 times greater than a concentration that produced growth and reproduction. The exact risk quotients are uncertain because the solvent used in the study appeared to have influenced the test results. Nevertheless, risk quotients this great indicate a high certainty of chronic risk to freshwater invertebrates, especially from turf uses. Threatened and endangered aquatic invertebrates are also at risk.

C. Risk to Aquatic Plants

Exposure to nontarget aquatic plants may occur through runoff or spray drift. An aquatic plant risk assessment for acute high risk is usually made for aquatic vascular plants from the surrogate duckweed *Lemna gibba*. Non-vascular acute high aquatic plant risk assessments are performed using either algae or a diatom, whichever is the most sensitive species. An aquatic plant risk assessment for threatened and endangered species is made for aquatic vascular plants from the surrogate duckweed *Lemna gibba*. To date there are no known non-vascular plant species on the endangered species list. Runoff and drift exposure is computed from PRIZM3/EXAMS 2.95. The risk quotient is determined by dividing the pesticide's initial or peak concentration in water by the plant EC_{50}.

Risk quotients for **nonendangered** species of aquatic plants are tabulated below.

Aquatic Plant Risk Quotients for Nonendangered Species, Based on a *Lemna gibba* EC_{50} and PRZM/EXAMS exposure estimates.

Use Site	Application Method	Rate in lb ai/A	Number of Applications	EC_{50} (ppb)	Peak EEC (ppb)	Acute RQ (EEC/EC_{50})
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	140	47	0.34
	Broadcast EC spray, incorporated	3	1	140	30	0.21
	Banded EC spray, unincorporated	3	1	140	21	0.15
	Banded EC spray, incorporated	3	1	140	15	0.11
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	140	93	0.66
	Broadcast EC spray and chemigation, unincorporated	6	2	140	165	1.2*
	Broadcast EC spray, incorporated	6	1	140	60	0.43
	Broadcast EC spray, incorporated	6	2	140	118	0.84
	Banded EC spray, unincorporated	6	1	140	42	0.30
	Banded EC spray, unincorporated	6	2	140	74	0.53
	Banded EC spray, incorporated	6	1	140	30	0.21
	Banded EC spray, incorporated	6	2	140	59	0.42
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	140	270	1.9*
	Broadcast granular application, unincorporated	7.5	2	140	590	4.2*
	Broadcast granular application, unincorporated	10	1	140	360	2.6*
	Broadcast granular application, unincorporated	10	2	140	780	5.6*
	Broadcast EC spray, unincorporated	12.5	1	140	170	1.2*
	Broadcast EC spray, unincorporated	12.5	2	140	350	2.5*
	Broadcast granular application, unincorporated	12.5	1	140	450	3.2*
	Broadcast granular application, unincorporated	12.5	2	140	980	7.0*

* Exceeds high risk LOC for nonendangered species.

All uses of bensulide on turf pose a high risk to nontarget aquatic plants. Use of bensulide on vegetables does not pose a high risk to nontarget aquatic plants. For vegetables, the RQ exceeds the LOC only for twice-per-year unincorporated applications at 6 lb ai/A. Considering that these twice-per-year applications are made only in the Desert Southwest, where the potential of runoff from agricultural fields into aquatic environments is minimal, the risk from even this use is probably small.

Risk quotients for **threatened and endangered** species of aquatic plants are tabulated below.

Aquatic Plant Risk Quotients for Endangered Species, Based on a *Lemna gibba* EC_{50} and PRZM/EXAMS EEC's.

Use Site	Application Method	Rate in lb ai/A	Number of Applications	NOAEC (ppb)	Peak EEC (ppb)	Acute RQ (EEC/ NOAEL)
Garlic and onions	Broadcast EC spray and chemigation, unincorporated	3	1	17	47	2.8*
	Broadcast EC spray, incorporated	3	1	17	30	1.8*
	Banded EC spray, unincorporated	3	1	17	21	1.2*
	Banded EC spray, incorporated	3	1	17	15	0..88
Vegetables	Broadcast EC spray and chemigation, unincorporated	6	1	17	93	5.5*
	Broadcast EC spray and chemigation, unincorporated	6	2	17	165	9.7*
	Broadcast EC spray, incorporated	6	1	17	60	3.5*
	Broadcast EC spray, incorporated	6	2	17	118	6.9*
	Banded EC spray, unincorporated	6	1	17	42	2.5*
	Banded EC spray, unincorporated	6	2	17	74	4.4*
	Banded EC spray, incorporated	6	1	17	30	1.8*
	Banded EC spray, incorporated	6	2	17	59	3.5*
Turf and ornamentals	Broadcast granular application, unincorporated	7.5	1	17	270	16*
	Broadcast granular application, unincorporated	7.5	2	17	590	35*
	Broadcast granular application, unincorporated	10	1	17	360	21*
	Broadcast granular application, unincorporated	10	2	17	780	46*
	Broadcast EC spray, unincorporated	12.5	1	17	170	10*
	Broadcast EC spray, unincorporated	12.5	2	17	350	21*
	Broadcast granular application, unincorporated	12.5	1	17	450	26*
	Broadcast granular application, unincorporated	12.5	2	17	980	58*

* Exceeds LOC for high risk to aquatic plants, including endangered species.

These risk quotients indicate that practically all uses of bensulide pose enough risk to cause concerned for possible adverse effects to threatened or endangered species of aquatic plants. The risk is greatest for use on turf.

ADDENDUM 2

Updates to the Risk Assessment of the Bensulide RED Based on Recently Submitted Data on Persistence of Residues on Grass

I. Persistence of Bensulide on Grass

A. Methods of Grass Clipping Study

Gowan Company has submitted data of residues on grass to aid in the assessment of dietary exposure to terrestrial wildlife. These data were collected in conjunction with a study on the dislodgable bensulide residues on turf (MRID 447990-01). In this study, bensulide was applied at a rate of 12.63 lb ai/A to turf plots in Wayne County, New York. Applications were made with a tractor-mounted spray boom. Grass was sampled by clipping plants in one square-foot subplots to just above the crown. Sampling was done preapplication, immediately post application, and at 8-12 hours, and at 1, 2, 3, 4, 5, 6, 7, 10, 14, 21, 28, and 35 days after treatment. The turf was irrigated after application, as directed on the label, with 0.56 inches of water. This irrigation took place after the immediate post-application sampling but before the 8-12 hours sampling. Grass was mowed to a height of 5 inches on Days 8, 14, 21, and 30. Grass clippings were collected and removed.

A total of 8.48 inches of rainfall occurred during the 35 days of sampling. Major rain events (> 0.5 inches) occurred on Days 15, 23, 24, 27, 28, and 32. Moderate rain events (0.1 to 0.5 inches) occurred on Days 0, 10, 14, 21, 29, and 35. Minor rain events (< 0.1 inches) occurred on Days 6, 8, 9, 11, 12, and 16.

B. Washoff from Initial Irrigation

One of the major questions answered by this study is how much of the bensulide residues on grass will be removed by the irrigation that is required within 36 hours after application. In the field study, irrigation of 0.56 inches of water was applied between the initial post-application sampling and the 8-12 hour sampling. Therefore, the reduction in residues between these two sampling times gives an estimation of the amount removed by washoff from irrigation. Mean bensulide residues on grass clippings were reduced 33.1%, from 1390 ppm post-application to 930 ppm at 8-14 hours. Total residues of bensulide plus bensulide oxon were reduced 32.2%, from 1461 ppm post-application to 991 ppm at 8-14 hours. Therefore, we conclude that irrigation will remove approximately one-third of the initial residues on short grass foliage.

C. Dissipation of Residues on Grass Foliage

Dissipation from factors other than initial irrigation was estimated based on the residues measured between 8-12 hours and 35 days after application. This dissipation comprises washing off by rainfall, volatilization, physical and microbial degradation mechanisms, and dilution due to growth of new plant tissue. These sources of reduction might be offset somewhat through uptake into the plants through the roots. Plant uptake might explain the unexpected increase in bensulide residues that was observed between sampling on Day 7 and

Day 10. Light rainfall occurred prior to and during the sampling on Day 10, which might have promoted increased uptake of residues along with soil moisture.

EFED calculated the half-life for total residues of bensulide and bensulide oxon, beginning with the sample on Day 0 taken **after** the initial irrigation on Day 0, as 4.91 days. Residues were expressed as amount per wet weight of grass clippings. The authors of the study report calculated half-lives from data that included Day 0 samples taken before irrigation. Their analysis yielded half-lives of 4.8 days when residues were expressed in terms of residues per mass of grass clippings, and 5.6 days when expressed as amount of residues on grass per unit area of ground. The former half-life is more relevant for dietary exposure to wildlife.

D. Risk Assessment for Terrestrial Organisms

Acute Risk

Exposure estimates for terrestrial organisms are reduced by one-third of their original values based on the finding that approximately one-third of the foliar residues is removed by the required irrigation after application. This reduces the risk quotients by one-third. Acute risk quotients are not otherwise affected. They are still calculated based on predicted maximum residues estimated by the methods of Kenaga and Hoeger (1972), as modified by Fletcher *et al.* (1994). They are not based on residues measured in the field study because the assessment is designed to reflect a high risk scenario, whereas the residues obtained from a single field study would represent a typical risk scenario. In addition, predicted maximum residues are used to compensate in part for other routes of exposure that are not taken into account in the risk assessment. Acute risk quotient are not dependent on the foliar half-life.

Subacute dietary tests with both the northern bobwhite and the mallard found no mortality or overt signs of toxicity when birds were fed dietary concentrations as great as 5620 ppm. Residue levels in the terrestrial environment are predicted to be well below this maximum test level. The maximum EEC after irrigation is 2000 ppm on short grass following application on turf at 12.5 lb ai/A. Therefore, it is concluded that all uses of bensulide pose minimal risk of acute toxicity to birds.

Tables 1 and 2 give revised acute risk quotients for mammals for use of EC products on turf. The acute risk quotients continue to show that use of bensulide on turf will pose a high acute risk to small mammals that feed on grass, broadleaf plants, and small insects. Bensulide does not pose a high acute risk to granivorous mammals.

Table 1. Acute Risk Quotients for Herbivorous and Insectivorous Mammals, Based on a Single Application of EC Bensulide Product on Turf after Irrigation

Application Rate (lbs ai/A)	Body Weight (g)	% Body Weight Consumed	Rat LD50 (mg/kg)	EEC (ppm)			Acute RQ[1]		
				Short Grass	Forage & Small Insects	Large Insects	Short Grass	Forage & Small Insects	Large Insects
12.5	15	95	312	2000	1125	125	6.1***	3.4***	0.38**
12.5	35	66	312	2000	1125	125	4.2***	2.4***	0.27**
12.5	1000	15	312	2000	1125	125	0.93***	0.54***	0.06

[1] $RQ = \frac{\text{EEC (ppm)}}{\text{LD50 (mg/kg)/ \% Body Weight Consumed}}$

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

Table 2. Acute Risk Quotients for Granivorous Mammals for a Single Application of EC Bensulide Product on Turf after Irrigation

Application Rate (lb ai/A)	Body Weight (g)	% Body Weight Consumed	Rat LD50 (mg/kg)	EEC (ppm) Seeds	Acute RQ[1] Seeds
12.5	15	21	312	125	0.08
12.5	35	15	312	125	0.06
12.5	1000	3	312	125	0.01

[1] $RQ = \frac{\text{EEC (ppm)}}{\text{LD50 (mg/kg)/ \% Body Weight Consumed}}$

*** Exceeds acute high, acute restricted, and acute endangered species LOCs.
** Exceeds acute restricted and acute endangered species LOCs.
* Exceeds acute endangered species LOC.

Chronic Risk

For a screen, bird risk quotients were calculated for birds based on peak residue levels expected after irrigation. The maximum EEC values, and thus the risk quotients, were reduced by one-third relative to those in the original RED chapter to account for removal by irrigating immediately after application. Table 3. gives revised chronic risk quotients for birds.

Table 3. Avian Chronic Risk Quotients for Single Application of EC Products Based on Maximum EECs after Irrigation and an NOAEL of the Mallard.

Site, Appl. Method	Application Rate (lbs ai/A)	Food Items	Maximum EEC (ppm)	NOAEL (ppm)	Chronic RQ (EEC/NOAEL)
Turf and ornamentals, broadcast spraying	12.5	Short grass	2,000	2.5	800*
		Tall grass	917	2.5	367*
		Broadleaf plants and Insects	1,125	2.5	450*
		Seeds	125	2.5	50*

* Exceeds chronic risk LOCs.

For a single broadcast application of EC products, RQs for all registered uses far exceed the LOC for chronic risk to birds. These results indicate that all registered uses of bensulide pose a high risk of causing reproductive impairment in birds. High risk is predicted for all birds that feed in treated fields, regardless of their diet. High chronic risk is also presumed for reptiles and terrestrial stages of amphibians.

To further characterize chronic risk to birds that feed on grass, the expected bensulide residues on grass were predicted and compared graphically to the NOAEL and LOAEL for avian reproduction effects. The mean concentration measured at 8-12 hours after application (after irrigation) was used to establish the initial "measured" residue levels on short grass. The maximum residues level was also calculated based on the method of Kenaga and Hoeger (1972), as modified by Fletcher *et al.* (1994). This is the typical method used in EFED terrestrial risk assessments. For an application of 12.5 lb ai/A, this method predicts a maximum initial concentration of 3000 ppm. This level was reduced by one-third (to 2000 ppm) to account for removal by irrigating after application. Dissipation curves for both measured and maximum residues were then drawn based the half-life of 4.91 days that was derived in the field study. Figure 1 shows these predicted residue levels relative to the NOAEL and LOAEL from the avian reproduction study with the northern bobwhite. The NOAEL and LOAEL are based on egg shell thinning. In this graph, the NOAEL (2.5 ppm) is so small relative to the predicted residue values it is indistinguishable from the x-axis.

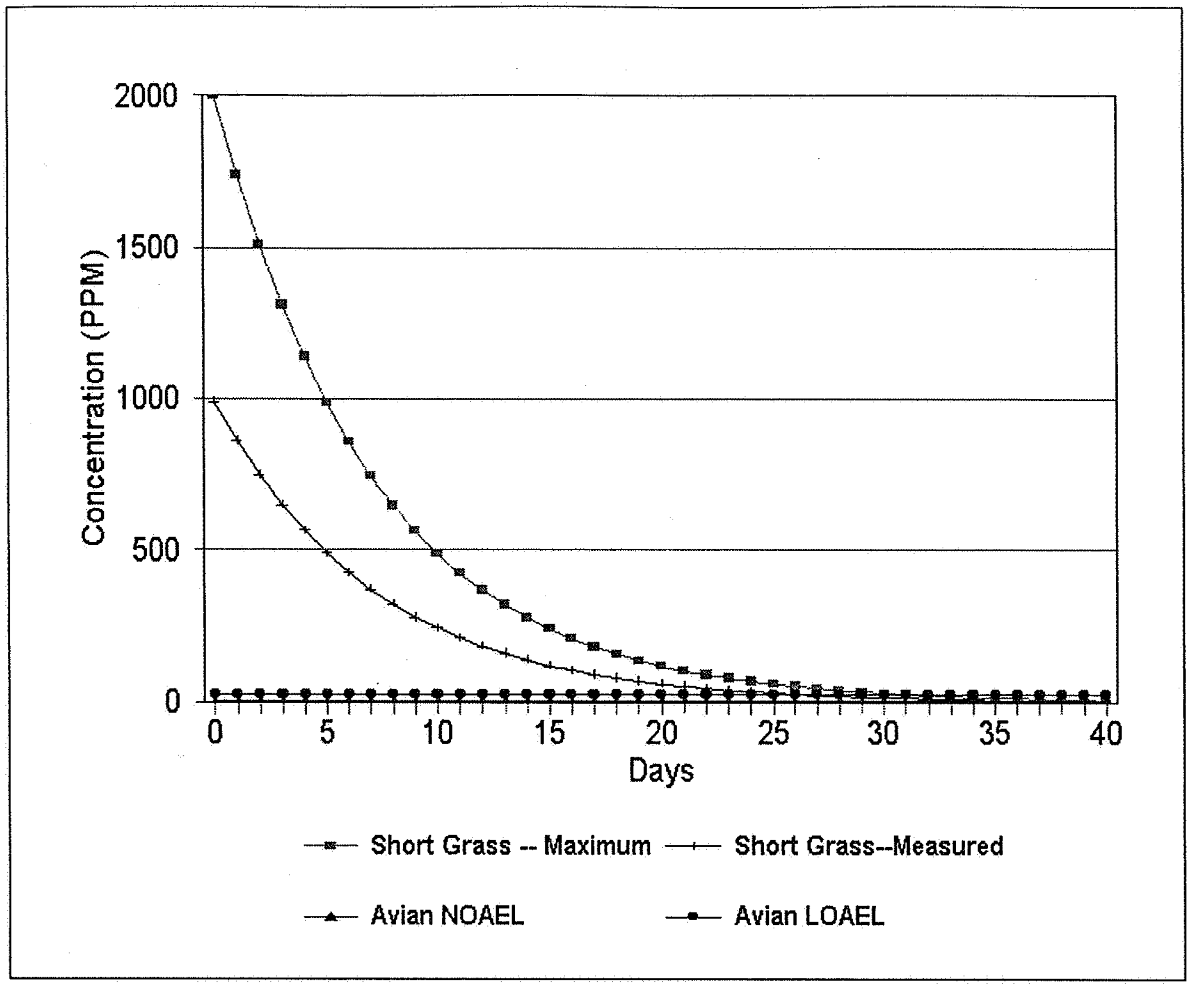

Figure 1. Predicted residues on short grass relative to chronic avian toxicity levels.

Figure 1 clearly shows that initial residues greatly exceed the NOAEL and even the LOAEL for eggshell thinning, despite the initial reduction of approximately 33% due to irrigation. Furthermore, despite a relatively short half-life on foliage, residues remain at a chronically toxic level for an extended period of time. Residues are predicted to exceed the avian LOAEL and NOAEL for egg shell thinning for up to 32 and 48 days, respectively. This level and duration of exposure certainly poses a significant chronic hazard to birds that feed on short grass, such as the Canada goose and the American wigeon. Bensulide may be applied on turf twice per year, typically in the spring and in the fall. Thus, birds may be experience two exposure events per year, which increases the chronic risk even further.

Chronic risk for mammals was assessed similarly as for birds. Table 4 gives revised chronic risk quotients.

Table 4. Mammalian Chronic Risk Quotients for Single Application of EC Products Based on Maximum EECs and a Reproductive NOEC of the Rat.

Site, Appl. Method	Application Rate (lbs ai/A)	Food Items	Maximum EEC (ppm)	NOAEL (ppm)	Chronic RQ (EEC/NOAEL)
Turf and ornamentals, broadcast spraying	12.5	Short grass	2,000	150	13*
		Tall grass	917	150	6.1*
		Broadleaf plants and Insects	1,125	150	7.5*
		Seeds	125	150	0.83

* Exceeds chronic risk LOCs.

For a single broadcast application of EC products, the revised risk quotients exceed the LOC for chronic risk to mammals, except for those which diet consists of only seeds. These results indicate use of bensulide may pose a high risk of causing chronic reproductive effects in mammals.

Chronic risk to mammals is further characterized by graphically comparing predicted residue levels to the NOAEL and LOAEL for chronic toxicity to mammals (Fig. 2). The methods used were the same as those described above for birds.

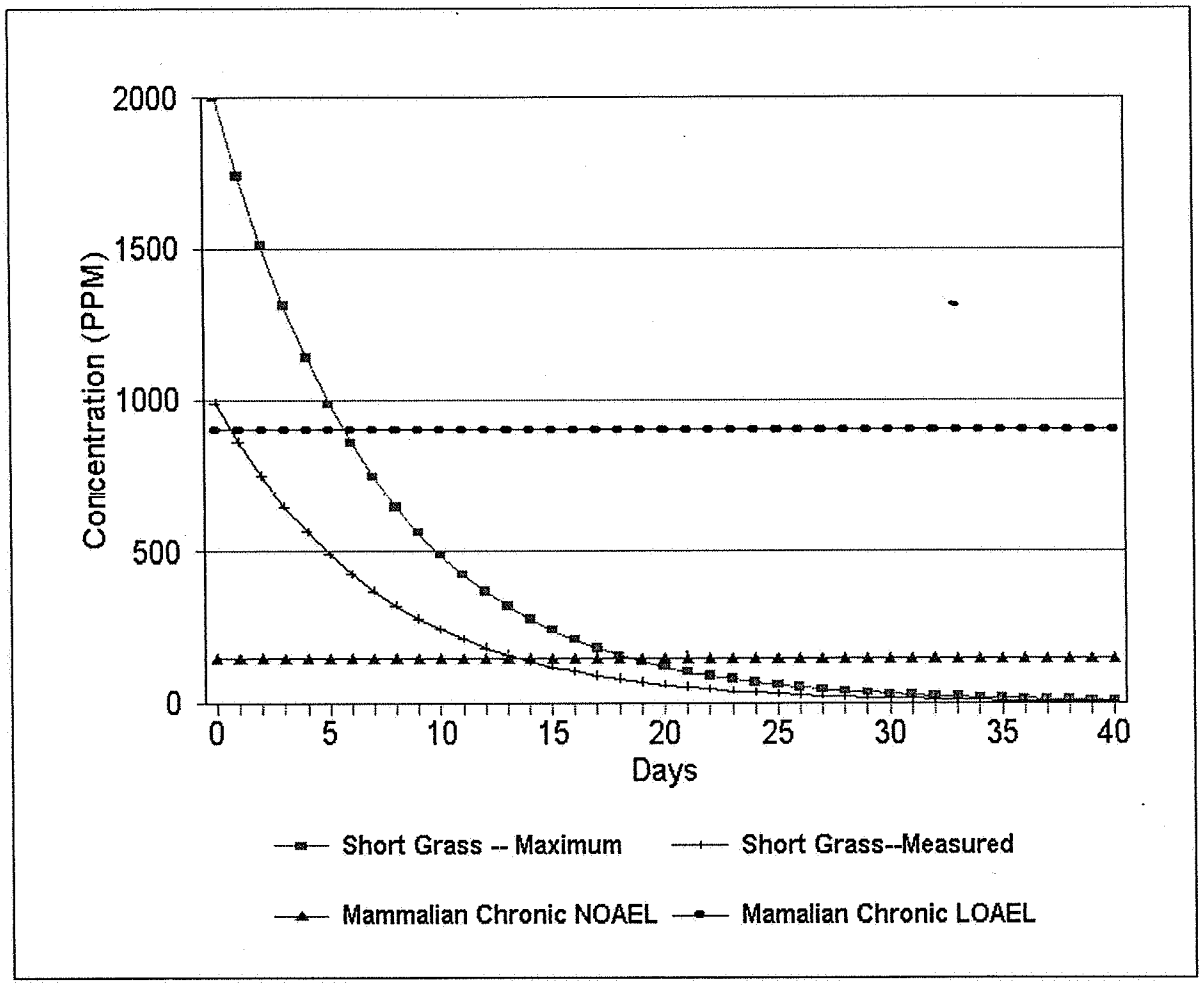

Figure 5. Predicted residues on short grass relative to chronic mammalian toxicity levels.

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Figure 2 indicates a potential but uncertain high chronic risk to herbivorous mammals that may feed on treated grass, such as voles and rabbits. Residues of bensulide on turf will exceed the mammalian LOAEL, the level known to cause chronic effects in the laboratory, for 1 to 6 days. Residues will then remain between the LOAEL and NOAEL for approximately 10 more days. Levels in this range may or may not produce chronic effects. This analysis shows that initial bensulide residues are in the range that is chronically toxic to mammals, even after residues are reduced by irrigation. However, it is uncertain if magnitude and duration of exposure would be great enough to produce significant chronic effects.

E. Conclusions

Measurement of bensulide residues show that the concentration on short grass is reduced by approximately one-third by irrigation that is required after application. Afterwards, residues were found to be variable but generally followed first-order dissipation with a half-life of 4.91 days. Based on these findings, the refined risk assessment continued to indicate high chronic risk to birds, and high acute and chronic risk to mammals. The conclusion of high chronic risk to birds due to egg shell thinning is highly certain because exposure levels exceed toxic levels by a large magnitude and for a long duration. In addition, the use of actual measured residues and foliage dissipation rate reduced the uncertainty in this assessment. For mammals, the conclusion of high acute risk is quite certain for small herbivorous mammals that may feed on treated grass. The conclusion of high chronic risk for mammals, however, is uncertain.