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THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

HAZARD ASSESSMENT OF THE INSECTICIDE METHOMYL TO AQUATIC ORGANISMS IN THE SAN JOAQUIN RIVER SYSTEM

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PREFACE

The California Department of Fish and Game (CDFG) is responsible for protection and management of fish and wildlife. The CDFG protects fish and wildlife from pesticide hazards through consultation with the California Environmental Protection Agency's Department of Pesticide Regulation (DPR) Pesticide Registration and Evaluation Committee and Pesticide Advisory Committee. The State Water Resources Control Board and the Regional Water Quality Control Boards also protect fish and wildlife by promulgating and enforcing water quality standards for pesticides and other toxic materials. In recognition of the need for applicable environmental standards for fish and wildlife, DPR contracted with CDFG to assess the effects of pesticides on fish and wildlife and to facilitate the development of water quality criteria to protect aquatic organisms.

This document is the seventh in a series of pesticide hazard assessments. Hazard assessments have also been prepared for the herbicides molinate and thiobencarb and the insecticides methyl parathion, carbofuran, chlorpyrifos, diazinon, and methidathion.

Hazard Assessment of the Insecticide Methomyl to Aquatic Organisms in the San Joaquin River System

by

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SUMMARY

A freshwater Water Quality Criterion (WQC) for protection of aquatic organisms from the insecticide methomyl was developed and a hazard assessment was performed for California's San Joaquin River system. Insufficient data were available to derive a saltwater WQC.

Seventy tests on the acute and chronic effects of methomyl to aquatic organisms were reviewed and evaluated. The most acutely sensitive freshwater species tested was the cladoceran *Daphnia magna* with a species mean acute value (SMAV) of 22 μg/L. The lowest Maximum Acceptable Toxicant Concentration (MATC) value was 2.23 μg/L for the cladoceran *Daphnia magna*. The calculated freshwater Final Acute Value (FAV) was 11 μg/L. The Final Acute-Chronic Ratio (FACR) was 21, and the Final Chronic Value (FCV) was 0.5 μg/L (FCV = FAV/FACR)

Freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of methomyl does not exceed 0.5 μg/L, and if the one-hour average concentration does not exceed 5.5 μg/L more than once every three years.

The U.S. Environmental Protection Agency (EPA) has not established a WQC for the protection of aquatic life. The California Department of Fish and Game WQC was derived using current toxicity data and hazard assessment procedures.

Although methomyl has been detected in concentrations as high as 5.4 μg/L, more typical concentrations ranged from 0.05 to 0.3 μg/L (Table 1). A comparison of detected concentrations of methomyl with toxicity data and the freshwater WQC indicates that methomyl does not likely present an acute toxicity hazard to aquatic species in the San Joaquin River system. However, methomyl may present a chronic toxicity hazard to aquatic species. Generally, invertebrates are more sensitive to methomyl than are fish.

Acute toxicity data were available for seven of the eight

freshwater families recommended by the EPA for development of numerical criteria. An acute toxicity test should be conducted on a freshwater mollusk or rotifer to complete the eight families, however it is unlikely that this value will lower the WQC significantly. Paired acute and chronic tests should be performed with other invertebrates such as *Neomysis mercedis* and cladoceran *Ceriodaphnia dubia*. Paired acute and chronic tests should also be performed with rainbow trout *Oncorhynchus mykiss* or other fish.

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ACKNOWLEDGEMENTS

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INTRODUCTION

The carbamate insecticide methomyl is used on soybeans, cotton, fruits, vegetables, ornamentals, and other crops. In the San Joaquin River system, most methomyl use occurs during the spring and summer months. In 1992, the most recent year for which reliable data are available, 358,404 kg of methomyl were used in California (California Department of Pesticide Regulation [DPR] n.d.).

The Central Valley Regional Water Quality Control Board (CVRWQCB) and the California Department of Pesticide Regulation (DPR) monitored methomyl in the San Joaquin River system. Detected concentrations ranged from 0.05 to 5.4 µg/L. The U.S. Environmental Protection Agency (EPA) has not established an aquatic life water quality criterion (WQC) for methomyl.

The effects of methomyl were assessed by evaluating toxicity tests for conformance with specific criteria adapted from the EPA and the American Society of Testing and Materials (ASTM). Although toxicity tests were not required to comply with all criteria, tests were rejected if they did not observe certain fundamental procedures. The WQC was calculated using accepted data and methods adapted from EPA (1985a) guidelines (Appendix A).

Table 1. Concentrations of methomyl (µg/L) detected in the San Joaquin River system, March 1991 through February 1993.

Date	Location[a]	Concentration
10/24/91	Ingram\Hospital Creeks	3.2[b]
12/04/91	Ingram\Hospital Creeks	2.6[b]
12/15/91	Ingram\Hospital Creeks	5.4[b]
7/31/92	Ingram\Hospital Creeks	0.19[c]
8/28/92	Ingram\Hospital Creeks	0.29[c]
7/27/92	Mud Slough	0.13[c]
7/29/92	Orestimba Creek	0.06[c]
8/26/92	Orestimba Creek	0.20[c]
7/27/92	Salt Slough	0.13[c]
8/24/92	Salt Slough	0.06[c]
7/16/91	San Joaquin River at Laird Park	0.16[c]
7/23/91	San Joaquin River at Laird Park	0.07[c]
7/30/91	San Joaquin River at Laird Park	0.21[c]
8/02/91	San Joaquin River at Laird Park	0.10[c]
8/06/91	San Joaquin River at Laird Park	0.09[c]
8/09/91	San Joaquin River at Laird Park	0.76[c]
8/13/91	San Joaquin River at Laird Park	0.09[c]
8/16/91	San Joaquin River at Laird Park	0.10[c]
8/20/91	San Joaquin River at Laird Park	0.19[c]
8/23/91	San Joaquin River at Laird Park	0.12[c]
8/27/91	San Joaquin River at Laird Park	0.06[c]
8/30/91	San Joaquin River at Laird Park	1.84[c]
9/03/91	San Joaquin River at Laird Park	0.14[c]
9/06/91	San Joaquin River at Laird Park	0.16[c]
9/10/91	San Joaquin River at Laird Park	0.24[c]
9/13/91	San Joaquin River at Laird Park	0.12[c]
7/08/92	San Joaquin River at Laird Park	0.08[c]
7/15/92	San Joaquin River at Laird Park	0.12[c]
7/29/92	San Joaquin River at Laird Park	0.47[c]
8/05/92	San Joaquin River at Laird Park	0.05[c]
8/12/92	San Joaquin River at Laird Park	0.05[c]
8/19/92	San Joaquin River at Laird Park	0.05[c]
8/27/92	San Joaquin River at Laird Park	0.13[c]
9/02/92	San Joaquin River at Laird Park	0.20[c]
9/09/92	San Joaquin River at Laird Park	0.16[c]
7/31/92	San Joaquin River at Maze Blvd	0.10[c]
8/28/92	San Joaquin River at Maze Blvd	0.18[c]
7/23/91	San Joaquin River at Merced	0.42[c]
7/30/91	San Joaquin River at Merced	0.32[c]
8/02/91	San Joaquin River at Merced	0.09[c]
8/06/91	San Joaquin River at Merced	0.13[c]
8/09/91	San Joaquin River at Merced	0.07[c]
8/13/91	San Joaquin River at Merced	0.14[c]
8/16/91	San Joaquin River at Merced	0.10[c]
8/20/91	San Joaquin River at Merced	0.37[c]
8/23/91	San Joaquin River at Merced	0.18[c]
8/27/91	San Joaquin River at Merced	0.20[c]

Table 1. Continued -2-

Date	Location[a]	Concentration
8/30/91	San Joaquin River at Merced	0.20[c]
9/03/91	San Joaquin River at Merced	0.27[c]
9/06/91	San Joaquin River at Merced	0.08[c]
9/10/91	San Joaquin River at Merced	0.16[c]
9/13/91	San Joaquin River at Merced	0.14[c]
7/08/92	San Joaquin River at Merced	0.05[c]
7/15/92	San Joaquin River at Merced	0.08[c]
7/22/92	San Joaquin River at Merced	0.08[c]
8/05/92	San Joaquin River at Merced	0.25[c]
8/12/92	San Joaquin River at Merced	0.08[c]
8/19/92	San Joaquin River at Merced	0.06[c]
9/02/92	San Joaquin River at Merced	0.06[c]
7/23/91	San Joaquin River at Patterson	0.27[c]
7/30/91	San Joaquin River at Patterson	0.14[c]
8/02/91	San Joaquin River at Patterson	0.11[c]
8/06/91	San Joaquin River at Patterson	0.11[c]
8/09/91	San Joaquin River at Patterson	0.16[c]
8/13/91	San Joaquin River at Patterson	0.10[c]
8/16/91	San Joaquin River at Patterson	0.20[c]
8/20/91	San Joaquin River at Patterson	0.07[c]
8/23/91	San Joaquin River at Patterson	0.10[c]
8/27/91	San Joaquin River at Patterson	0.19[c]
8/30/91	San Joaquin River at Patterson	0.12[c]
9/03/91	San Joaquin River at Patterson	0.10[c]
9/06/91	San Joaquin River at Patterson	0.17[c]
9/10/91	San Joaquin River at Patterson	0.15[c]
9/13/91	San Joaquin River at Patterson	0.12[c]
7/22/92	San Joaquin River at Patterson	0.14[c]
7/29/92	San Joaquin River at Patterson	0.08[c]
8/05/92	San Joaquin River at Patterson	0.12[c]
8/26/92	San Joaquin River at Patterson	0.09[c]
9/02/92	San Joaquin River at Patterson	0.10[c]
9/09/92	San Joaquin River at Patterson	0.08[c]
8/16/91	San Joaquin River at Patterson	0.20[c]
8/20/91	San Joaquin River at Patterson	0.07[c]
8/23/91	San Joaquin River at Patterson	0.10[c]
7/31/92	San Joaquin River at Vernalis	0.05[c]
7/30/92	Tuolumne River	0.16[c]

[a] These and other locations were sampled in 1991, 1992, and 1993. Only the dates on which methomyl was detected are listed.

[b] Unpublished data from monitoring by the Central Valley Regional Water Quality Control Board

[c] Unpublished data from monitoring by the Department of Pesticide Regulation

ENVIRONMENTAL FATE

Methomyl is a carbamate insecticide. Methomyl's photolysis half-life ($t_{1/2}$) value at soil pH 5 has been measured as two to three days (Harvey 1986). Methomyl is relatively stable to hydrolysis under neutral and acidic conditions (EPA 1989), but has a hydrolysis $t_{1/2}$ value of 30 days at pH 9 (Friedman 1986). Methomyl has a water solubility of 54.4 g/L (DPR 1994). Methomyl soil adsorption is low with a soil adsorption coefficient (K_{oc}) of 43 cm^3/g (DPR 1994). Methomyl's low K_{oc} value, high water solubility, and long hydrolysis $t_{1/2}$ value indicate that methomyl could potentially be carried by field runoff into surface waters. Methomyl has been detected in groundwater (EPA 1989; Rigsby et al. 1993), and is mobile in sandy loam and silty clay loam soils (EPA 1989). The anaerobic soil metabolism $t_{1/2}$ value of methomyl is one day (DPR 1994), and the aerobic soil metabolism $t_{1/2}$ value is reported as 46 days (DPR 1994).

TOXICITY TO AQUATIC ORGANISMS

Acute Toxicity to Aquatic Animals

Sixty-four tests on the acute toxicity of methomyl to aquatic animals were evaluated (Appendix B). Forty-six of these tests were accepted (Table B-1), and 18 were not accepted (Table B-2). EPA (1985a) guidelines recommend eight families of freshwater organisms for which data should be available to derive a freshwater Final Acute Value (FAV) (Table 2), and eight families of saltwater organisms to derive a saltwater FAV (Table 3).

Acceptable data were available for seven of the eight recommended freshwater families (Table 3), and EPA (1985a) guidelines were used to calculate a freshwater FAV. Genus Mean Acute Values (GMAVs) were calculated using data from accepted acute toxicity tests and were ranked in ascending order (Table 4). Freshwater GMAVs ranged from 22 µg/L, the mean 48-h LC_{50} for the cladoceran *Daphnia magna*, to 2,430 µg/L, the mean 96-h LC_{50} value for the fathead minnow *Pimephales promelas*.

The four lowest GMAVs are the most significant determinants of the FAV. For the freshwater FAV, three of the four lowest GMAVs were for invertebrate species. The freshwater FAV for methomyl was 11 µg/L. No freshwater or saltwater GMAV was lower than the freshwater FAV.

Although only seven of the eight freshwater families are represented, additional data for a family in the remaining category would likely be for a mollusk or a rotifer. As indicated by data from previous hazard assessments, mollusks and rotifers do not appear to be very sensitive to insecticides. For example, Menconi and Cox (1994) cite LC_{50} values for diazinon of 880 µg/L for eastern oyster and 29,220 µg/L for the freshwater rotifer *Branchionus calyciflorus*. Menconi and Paul (1994) cite LC_{50} values for chlorpyrifos of >806 µg/L for the freshwater snail *Aplexa hypnorum* and 1,991 µg/L for the saltwater eastern oyster *Crassostrea virginica*. Menconi and Gray (1992) cite LC_{50} values for carbofuran of >10,000 µg/L for eastern oyster. Therefore, data for the remaining category would not be likely to significantly change the FAV.

Acceptable data were available for five of the eight recommended saltwater families (Table 3), and EPA (1985a) guidelines were used to calculate an interim saltwater FAV. Saltwater GMAVs ranged from 19 µg/L, the 96-h LC_{50} for the pink shrimp *Penaeus duorum*, to 2,380 µg/L, the 96-h LC_{50} value for the fiddler crab *Uca pugilator*.

For the interim saltwater FAV, all of the four lowest GMAVs were for invertebrate species. The interim saltwater FAV for methomyl was 5 μg/L. No freshwater or saltwater GMAV was lower than the saltwater FAV.

Additional data are needed for two families in the phylum Chordata, and one family not in phylum Arthropoda or Chordata. These data would likely be for a saltwater fish and for a saltwater mollusk or rotifer. Only one of the four species most sensitive to methomyl was a fish, and mollusks and rotifers are not likely to be very sensitive to methomyl, as discussed previously. However, only five data points were used to derive the saltwater FAV, and a small data set results in a lower FAV. Therefore, additional data could significantly change the FAV.

Table 2. Eight families of saltwater aquatic animals recommended by EPA (1985a) for deriving a saltwater FAV and representative species for which methomyl acute toxicity data were available.

Family	Animal
1, 2. Two families in phylum Chordata	Not available
3. One family not in phylum Arthropoda or Chordata	Not available
4, 5, 6. Three other families not in phylum Chordata	Grass shrimp, pink shrimp, fiddler crab
7. A mysid or penaeid	Mysid
8. One other family not already represented	Mud crab

Table 3. Eight families of freshwater aquatic animals recommended by EPA (1985a) for use in deriving the FAV and representative species for which methomyl acute toxicity data were available.

Family	Animal
1. One Salmonid	Rainbow trout
2. Another family in class Osteichthyes	Bluegill
3. Another family in phylum Chordata	Fathead minnow
4. One family not in phylum Arthropoda or Chordata	Not available
5. One insect family or any phylum not already represented	Midge
6. One planktonic crustacean	Cladoceran
7. One benthic crustacean	Amphipod
8. One insect	Stonefly

Table 4. Ranked Genus Mean Acute Values (GMAVs) from accepted acute toxicity tests on methomyl used to calculate the freshwater FAV.

Rank	Value (µg/L)	Species
1	22[a]	Cladoceran *Daphnia magna*
2	88	Midge *Chironomus plumosus*
3	343	Stonefly *Isogenus sp.*
4	530	Channel catfish *Ictalurus punctatus*
5	896[a]	Atlantic salmon *Salmo salar*
6	908[a]	Bluegill *Lepomis macrochirus*
7	920	Amphipod *Gammarus pseudolimnaeus*
8	1250	Largemouth bass *Micropterus salmoides*
9	1467[a]	Rainbow trout *Oncorhynchus mykiss*
10	1817[a]	Brook trout *Salvelinus namaycush*
11	2430[a]	Fathead minnow *Pimephales promelas*

Freshwater FAV: 11 µg/L

[a] Species Mean Acute Value: geometric mean of values from several toxicity tests on this species. Individual values are listed in Table B-1.

Table 5. Ranked Genus Mean Acute Values (GMAVs) from accepted acute toxicity tests on methomyl used to calculate the saltwater FAV.

Rank	Value (µg/L)	Species
1	19	Pink shrimp *Penaeus duorarum*
2	80[a]	Grass shrimp *Palaemonetes vulgaris*
3	220	Mysid *Mysidopsis bahia*
4	410	Mud crab *Neopanope texana*
5	2380	Fiddler crab *Uca pugilator*

Saltwater FAV: 5 µg/L

[a] Species Mean Acute Value: geometric mean of values from several toxicity tests on this species. Individual values are listed in Table B-1.

Chronic Toxicity to Aquatic Animals

Six tests on the chronic toxicity of methomyl were evaluated for use in deriving the Final Chronic Value (FCV) (Appendix C). Three of these tests were accepted (Table C-1); three were not accepted (Table C-2). The lowest Maximum Acceptable Toxicant Concentration (MATC) value $(NOEC \times LOEC)^{1/2}$ was 2.23 µg/L for the cladoceran *Daphnia magna* (Table C-1).

The EPA (1985a) guidelines specify calculating the Acute-Chronic Ratio (ACR) for a species using for the numerator the geometric mean of LC_{50} values and for the denominator the geometric mean of MATC values. Freshwater or saltwater Final ACR (FACR) values are derived using ACR values of both freshwater and saltwater species, including at least a fish, an invertebrate, and an acutely sensitive species. The FACR value used to derive a freshwater Final Chronic Value (FCV) should include an acutely sensitive freshwater species. The other species used may be either freshwater or saltwater. For methidathion, acceptable acute and chronic toxicity data were available for one freshwater fish, the fathead minnow *Pimephales promelas*, and one acutely sensitive freshwater invertebrate, the cladoceran *Daphnia magna* (Table 5). These ACR values were used to derive a FACR value of 21 ($[17.1 \times 26.4]^{1/2}$). The FCV was derived by dividing the FAV by the FACR, resulting in a value of 0.5 µg/L. A saltwater FCV was not derived because chronic toxicity data were not available for any saltwater species, and because the saltwater FAV is only an interim value.

Table 6. Acute-Chronic Ratios (ACR) for species for which acute and chronic toxicity data were available.

Species	LC_{50} or SMAV (µg/L)	MATC $(NOEC \times LOEC)^{1/2}$ (µg/L)	ACR $(LC_{50}/MATC)$ (µg/L)
Cladoceran *Daphnia magna*	38.1[a]	2.23[a]	17.1
Fathead minnow *Pimephales promelas*	2430[b]	92.35	26.3

Final Acute-Chronic Ratio: 21

[a] LC_{50} and MATC from same test

[b] Species Mean Acute Value: geometric mean of values from several tests on this species. Individual values are listed in Table A-1.

Toxicity to Aquatic Plants

Six tests on the toxicity of methomyl to aquatic plants were evaluated (Appendix D) for use in deriving a Final Plant Value (FPV). The FPV is the lowest concentration of pesticide that demonstrates a biologically important toxic endpoint (EPA

1985a). The lowest concentration at which growth was inhibited was 100 mg/L for cyanobacteria *Nostoc muscorum* and *Tolypothrix tenuis*; therefore the FPV for methomyl is 100 mg/L. None of the tests indicated that methomyl was more toxic to aquatic plants than to aquatic animals; therefore criteria that protect aquatic animals will also protect aquatic plants.

HAZARD ASSESSMENT

Water Quality Criterion

EPA (1985a) guidelines specify that a WQC consists of two concentrations, the Criterion Maximum Concentration (CMC) and the Criterion Continuous Concentration (CCC). The CMC is equal to one-half the FAV. The CCC is equal to the lowest of three values: the FCV, the FPV, or the Final Residue Value (FRV). The FRV is intended to prevent concentrations in commercially or recreationally important species from affecting marketability because of excedence of applicable action levels, and to protect wildlife that consume aquatic organisms (EPA 1985a).

Methomyl does not appear to bioconcentrate, and is excreted after exposure (Coleman and Dollinger 1977). In addition, neither the U.S. Food and Drug Administration nor the State of California have established methomyl action levels (B. Brodberg California Office of Environmental Health Hazard Assessment pers. comm.).

Therefore, for methomyl, the freshwater CMC is 5.5 µg/L and the freshwater CCC is 0.5 µg/L. The WQC may be refined as more data become available. The U.S. EPA has not established a WQC for methomyl.

The freshwater WQC proposed in this assessment is based on the toxicity of methomyl alone. It appears that the toxicity of some insecticides commonly found together in the San Joaquin River system is additive (CDFG 1992). The freshwater WQC may need to be reevaluated to adequately protect aquatic organisms from the additive effects of pesticides likely to be present concurrently in the San Joaquin River system.

Hazard to Aquatic Animals

Freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of methomyl does not exceed 0.5 µg/L more than once every three years on the average, and if the one-hour average concentration of methomyl does not exceed 5.5 µg/L more than once every three years on the average.

Although methomyl has been detected in the San Joaquin River system at concentrations as high as 5.4 µg/L, more typical concentrations ranged from 0.01 to 0.30 µg/L (Table 1). Concentrations of methomyl in the San Joaquin River system do not appear to exceed the freshwater WQC.

A comparison of detected concentrations of methomyl with toxicity data and the freshwater WQC indicates that methomyl does not likely present an acute toxicity hazard to aquatic species in the San Joaquin River system. However, methomyl may present a chronic toxicity hazard to aquatic species. Generally, invertebrates are more sensitive to methomyl than are fish. The detection limit of 0.01 µg/L commonly used for methomyl is lower than the WQC and is sufficiently sensitive.

Data Requirements

Acute toxicity data were available for seven of the eight freshwater families recommended by the EPA (1985a). An acute toxicity test should be conducted on a freshwater mollusk or rotifer to complete the eight families, however it is unlikely that this value will lower the WQC significantly. Acceptable chronic toxicity data were available for one fish and one invertebrate only. Paired acute and chronic tests should be performed with other invertebrates such as *Neomysis mercedis* and cladoceran *Ceriodaphnia dubia*. *N. mercedis* is a native estuarine mysid, and cladocerans are widely distributed invertebrates. Paired acute and chronic tests should also be performed with rainbow trout *Oncorhynchus mykiss* or other fish.

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APPENDIX A. Procedures used by the California Department of Fish and Game to prepare hazard assessments.

The California Department of Fish and Game (CDFG) Pesticide Investigations Unit assesses the hazard of pesticides to aquatic organisms. The hazard assessment procedure includes evaluation of toxicity studies, establishment of the Water Quality Criterion (WQC), and assessment of potential hazards.

Acute and chronic toxicity data are obtained from studies published in scientific literature and laboratory reports required by the U. S. Environmental Protection Agency for pesticide registration. The CDFG evaluates the quality of these data by evaluating the tests for compliance with standards adapted from the EPA and the American Society for Testing and Materials (ASTM). The tests are evaluated for compliance with standards for test type, method, design and species, and for water quality and toxicant monitoring and maintenance. Although a study need not comply with every standard, tests are rejected if they do not observe certain fundamental procedures or if several important standards are not met. Studies are also rejected if they do not contain sufficient information to be properly evaluated and the necessary information cannot be obtained from the original researcher.

Acute toxicity data from acceptable tests on freshwater and saltwater organisms are used to determine a Final Acute Value (FAV). The EPA (1985) guidelines recommend eight categories of freshwater organisms for which data should be available for deriving a freshwater FAV, and eight categories of saltwater organisms for deriving a saltwater FAV.

The FAV is calculated as follows:

1. The Species Mean Acute Value (SMAV) is the geometric mean of EC_{50} values and LC_{50} values from all accepted toxicity tests performed on that species.

2. The Genus Mean Acute Value (GMAV) is the geometric mean of all SMAVs for each genus.

3. The GMAVs are ranked (R) from "1" for the lowest to "N" for the highest. Identical GMAVs are arbitrarily assigned successive ranks.

4. The cumulative probability (P) is calculated for each GMAV as R/(N+1).

5. The four GMAVs with cumulative probabilities closest to 0.05 are selected. If fewer than 59 GMAVs are available, these will always be the four lowest GMAVs.

6. The FAV is calculated using the selected GMAVs and Ps, as follows:

$$S^2 = \frac{3((\ln GMAV)^2)-((3(\ln GMAV))^2/4)}{3(P) - ((3(\%P))^2/4)}$$

$$L = (3(\ln GMAV) - S(3(\%P)))/4$$

$$A = S(\%0.05) + L$$

$$FAV = e^A$$

Chronic toxicity data from acceptable tests on freshwater and saltwater organisms are used to determine a Final Chronic Value (FCV). If data are available for the eight families, the FCV is calculated using the same procedure as described for the FAV. If sufficient data are not available, the following procedure is used:

1. Chronic values are obtained by calculating the geometric mean of the NOEC and the LOEC values from accepted chronic toxicity tests.

2. Acute-Chronic Ratios (ACR) are calculated for each chronic value for which at least one corresponding acute value is

available. Whenever possible, the acute test(s) should be part of the same study as the chronic test.

3. The Final ACR (FACR) is calculated as the geometric mean of all the species mean ACRs available for both freshwater and saltwater species.

4. FCV = FAV/FACR.

Plant toxicity data from algae or aquatic vascular plants are used to determine a Final Plant Value (FPV). The FPV is the lowest result from a test with a biologically important endpoint.

The EPA guidelines specify that a WQC consists of two concentrations, the Criterion Maximum Concentration (CMC), and the Criterion Continuous Concentration (CCC). The CMC is equal to one-half the FAV. The CCC is equal to the lowest of three values: the FCV, the FPV, or the Final Residue Value (FRV). The FRV is intended to prevent pesticide concentrations in commercially or recreationally important species from affecting marketability because of excedence of applicable action levels, and to protect wildlife that consume aquatic organisms. The WQC can be lowered to protect important resident species (EPA 1985).

The WQC is stated as follows: (Freshwater/saltwater) aquatic organisms should not be affected unacceptably if the four-day average concentration of (pesticide) does not exceed (CCC value), and if the one-hour average concentration does not exceed (CMC value) more than once every three years on the average.

Hazard assessment is an iterative process by which new data are evaluated to refine the WQC. Hazard assessments frequently recommend additional toxicity tests with sensitive native species and commonly-used test organisms listed by ASTM.

APPENDIX B. Abstracts of accepted and unaccepted acute toxicity tests reviewed for hazard assessment.

Accepted acute toxicity tests - The following tests used accepted test methods.

Bentley (1973) - In 1973, 96-h static toxicity tests were performed by Bionomics Laboratories in Wareham, Massachusetts on technical grade methomyl (100%) with grass shrimp *Palaemonetes vulgaris* and fiddler crab *Uca pugilator*. APHA (1970) standards were used. Ten concentrations were tested and a water control was used. Concentrations were not measured. Water quality parameters during the test were: temperature of 21°C; dissolved oxygen of 4.3 to 8.2; and salinity of $25^{o}/_{oo}$. Control survival was 100%. The LC_{50} value was 130 µg/L for grass shrimp and 2380 µg/L for fiddler crab.

Bionomics (1973) - In 1973, 96-h static toxicity tests were performed by Bionomics Laboratory in Wareham, Massachusetts on technical grade methomyl (100%) with grass shrimp *Palaemonetes vulgaris*, pink shrimp *Penaeus duorarum*, and mud crab *Neopanope texana* (life stages not given). APHA (1970) standards were used. Seven concentrations were tested and water and solvent controls were used. Concentrations were not measured. Water quality parameters during the test were: temperature of 21°C; dissolved oxygen of 5.0 to 8.0 mg/L; and salinity of $25^{o}/_{oo}$. Control survival was 100%. The LC_{50} value was 49 µg/L for grass shrimp, 19 µg/L for pink shrimp, and 410 µg/L for mud crabs.

Boeri and Ward (1989) - In 1989, a 96-h static toxicity test was performed by EnviroSystems Laboratory in Hampton, New Hampshire on technical grade methomyl (98%) with juvenile sheepshead minnows *Cyprinodon variegatus*. EPA (1985c) and (1988) standards were used. Six concentrations were tested and a control was used. Concentrations were measured at the beginning and end of the test and measured concentrations were 101 to 133% of nominal concentrations. Water quality parameters during the test were: temperature of 21.0 to 22.2^oC; pH of 7.5 to 8.1; dissolved oxygen of 6.3 to 8.2 mg/L; and salinity of 162 to 175$^o/_{oo}$. Control survival was 100%. The LC_{50} value for sheepshead minnows was 1160 µg/L.

Geiger et al. (1988) - In 1985, a 96-h flow-through toxicity test was performed by USEPA Research Lab at Duluth, Minnesota on technical grade methomyl (99%) with juvenile fathead minnows *Pimephales promelas*. APHA (1980) testing standards were used. Five concentrations were tested and a water control was used. Concentrations were measured daily and measured concentrations averaged 101 to 131% of nominal concentrations. Water quality parameters during the test were: temperature of 24.1^oC; pH of 7.4; dissolved oxygen of 6.6 mg/L; and hardness of 50.5 mg/L. Control survival was 100%. The LC_{50} value for fathead minnows was 2110 µg/L and the EC_{50} based on growth was 2060 µg/L.

McCain (1971) - In 1971, a 96-h static toxicity test was performed by Hazleton Laboratories in Falls Church, Virginia on technical grade methomyl (90%) with rainbow trout *Oncorhynchus mykiss*. No testing standards were mentioned. Eight concentrations were tested and a water control was used. Concentrations were not measured. Water quality parameters during the test were not given. Control survival was 100%. The LC_{50} value for rainbow trout was 3400 µg/L.

Mayer and Ellersieck (1986) - In 1975, 96-h static toxicity tests were performed by Columbia National Fisheries Laboratory of the Fish and Wildlife Service on technical grade methomyl (95%) with rainbow trout *Oncorhynchus mykiss*, bluegill *Lepomis macrochirus*, and channel catfish *Ictalurus punctatus* (life stages not given). Test standards similar to EPA (1975) were used. Seven concentrations were tested for the trout tests and nine for the bluegill and catfish tests. Water controls were used for all tests. Concentrations were not measured. Water quality parameters during the tests were: temperature of 12ºC (trout), 20ºC (bluegill), and 22ºC (catfish); pH of 7.2 (trout) and 7.4 (catfish); and hardness of 40 mg/L (trout and catfish). Control survival was 100% for trout and bluegill and 90% for catfish. The LC_{50} value was 1600 μg/L for rainbow trout, 1050 μg/L for bluegill, and 530 mg/L for channel catfish.

<u>Mayer and Ellersieck (1986)</u> - In 1976, 96-h static toxicity tests were performed by Columbia National Fisheries Laboratory of the Fish and Wildlife Service on technical grade methomyl (95%) with largemouth bass *Micropterus salmoides* (life stage not given) and first year stonefly *Isogenus* sp. Test standards similar to EPA (1975) were used. Four concentrations were tested and solvent controls were used. Concentrations were not measured. Water quality parameters during the tests were: temperature of 7ºC (stonefly) and 22ºC (bass); pH of 7.2 (bass); and hardness of 42 mg/L (stonefly) and 40 mg/L (bass). Control survival was 100% for both tests. The LC_{50} value was 1250 μg/L for largemouth bass and 343 μg/L for stonefly.

<u>Mayer and Ellersieck (1986)</u> - In 1977, 96-h static toxicity tests were performed by Columbia National Fisheries Laboratory of the Fish and Wildlife Service on technical grade methomyl (95%) with bluegill *Lepomis macrochirus* (life stage not given). Three tests were performed at different temperatures. Test standards similar to EPA (1975) were used. Seven concentrations were tested and water controls were used. Concentrations were not measured. Water quality parameters during the tests were: temperature of 12ºC, 17ºC, and 22ºC; pH of 7.4; and hardness of 40 mg/L. Control survival was 100%. The LC_{50} values were 2000 μg/L for the bluegill kept at 12ºC, 1150 μg/L for the bluegill kept at 17ºC, and 860 μg/L for the bluegill kept at 22ºC.

Mayer and Ellersieck (1986) - In 1978, 96-h static toxicity tests were performed by Columbia National Fisheries Laboratory of the Fish and Wildlife Service on technical grade methomyl (95%) with rainbow trout *Oncorhynchus mykiss* (eight tests), Atlantic salmon *Salmo salar* (eight tests), brook trout *Salvelinus namaycush* (two tests) and bluegill *Lepomis macrochirus* (five tests). Life stages were not given. Test standards similar to EPA (1975) were used. The number of concentrations tested was eight for rainbow trout, seven for Atlantic salmon and brook trout, and seven for bluegill. Solvent and water controls were used. Concentrations were not measured. Water quality parameters during the tests were: temperature of 7, 12, and 17°C for rainbow trout, 12 and 17°C for Atlantic salmon, 12°C for brook trout, 17°C for bluegill; pH of 6.0 to 8.5; and hardness of 40 to 320 mg/L. Control survival was 90 to 100%. The LC_{50} values ranged from 860 to 2000 µg/L for the rainbow trout, from 560 to 1220 µg/L for the Atlantic salmon, from 1500 to 2200 µg/L for the brook trout, and from 480 to 1200 µg/L for the bluegill.

Mayer and Ellersieck (1986) - In 1979, a 96-h static toxicity test was performed by Columbia National Fisheries Laboratory of the Fish and Wildlife Service on technical grade methomyl (99%) with fathead minnow *Pimephales promelas* (life stage not given). Test standards similar to EPA (1975) were used. Eight concentrations were tested and both solvent and water controls were used. Concentrations were not measured. Water quality parameters during the tests were: temperature of 17°C; pH of 7.4; and hardness of 40 mg/L. Control survival was 100%. The LC_{50} value for the fathead minnow was 2800 µg/L.

Sanders et al. (1983) - In 1983, a 96-h static toxicity test was performed by Columbia National Fisheries Laboratory of the Fish and Wildlife Service on technical grade methomyl (95 to 98%) with adult amphipods *Gammarus pseudolimnaeus* and 48-h static toxicity tests were performed on technical grade methomyl (95 to 98%) with fourth instar midges *Chironomus plumosus* and first instar cladocerans *Daphnia magna*. Test standards similar to EPA (1975) were used. Eight concentrations were tested and a control was used. Concentrations were not measured. Water quality parameters during the tests were: temperature of 17°C; pH of 7.4; and hardness of 40 mg/L. Control survival was above 90%. The LC_{50} value for the amphipod was 920 µg/L. The EC_{50} values, based on immobilization, were 88 µg/L for the midge, and 8.8 µg/L for the cladoceran.

Summers (1978) - In 1978, a 48-h static toxicity test was performed by Haskell Laboratory in Newark, Delaware on technical grade methomyl (99%) with <24-h cladocerans *Daphnia magna*. No test standards were mentioned. Eight concentrations were tested in replicate and a water control was used. Concentrations were not measured. Water quality parameters during the test were: temperature of 18°C; pH of 8.0 to 8.1; and dissolved oxygen of 8.2 to 8.4 mg/L. Control survival was 100%. The LC_{50} value for *D. magna* was 31.7 µg/L.

Summers (1981) - In 1981, a 48-h static toxicity test was performed by Haskell Laboratory in Newark, Delaware on technical grade methomyl (99%) with <24-h cladocerans *Daphnia magna*. No test standards were mentioned. Eight concentrations were tested in replicate and a water control was used. Concentrations were not measured. Water quality parameters during the test were: temperature of 20°C; pH of 6.7 to 8.1; dissolved oxygen of 7.7 to 7.9 mg/L; and hardness of 101 mg/L. Control survival was 95 to 100%. The LC_{50} value for *D. magna* was 38.1 µg/L.

Ward and Boeri (1989) - In 1989, a 96-h static toxicity test was performed by Envirosystems Laboratory in Hampton, New Hampshire on technical grade methomyl (98%) with juvenile mysids *Mysidopsis bahia*. EPA (1985d) and (1988) testing standards were used. Five concentrations were tested and a water control was used.

Concentrations were measured at the beginning and end of the test and measured concentrations averaged 108 to 130% of nominal concentrations. Water quality parameters during the test were: temperature of 21 to 22°C; pH of 7.9 to 8.2; and dissolved oxygen of 7.5 to 8.2 mg/L. Control survival was 95%. The LC_{50} value for *Mysidopsis bahia* was 220 µg/L.

Unaccepted acute toxicity tests - The following tests did not use accepted test methods and/or produce acceptable results.

Dupont (1991) - In 1991, a 96-h flow-through toxicity test was performed by DuPont on technical grade methomyl (98.35%) with juvenile eastern oysters *Crassostrea virginica*. No test standards were mentioned. Five concentrations were tested and a water control was used. Concentrations were measured. Water quality parameters during the test were: temperature of 21.2 to 23.7°C; pH of 7.4 to 7.9; dissolved oxygen of 6.5 to 7.6; and salinity of $30^{o}/_{oo}$. Control survival was 100%. The EC_{50} value for eastern oysters based on growth was >140 mg/L. The test was not accepted because the mortality range was unacceptable. For a valid LC_{50} value, one treatment other than the control must kill <37% of the test organisms and one treatment must kill >63% of the test organisms.

El-Refai, et al. (1976) - In 1976, a 48-h static toxicity test was performed by Al-Azhar University in Cairo on Lannate (24% active ingredient) with carp *Cyprinus carpio* and tilapia *Tilapia nilotica* (life stages not given). No test standards were mentioned. Several concentrations were tested in replicate. A water control was used. Water quality parameters during the test were: temperature of 22 to 25°C; pH of 7.8 to 8.2; dissolved oxygen of 6.8 to 7.4; and hardness of 116 to 123 mg/L. Control survival was not given. The LC_{50} values were 2.70 µg/L for large carp and 1.35 µg/L for small carp. The LC_{50} values were 2.60

µg/L for large tilapia and 1.40 µg/L for small tilapia. These values were not used because the test duration was too short and the pesticide formulation was too low in active ingredient.

Mayer and Ellersieck (1986) - In 1975, 48-h (cladoceran) and 96-h (trout) static toxicity tests were performed by the Columbia National Fisheries Laboratories of the U.S. Fish and Wildlife Service on technical grade methomyl (95 to 98%) with cutthroat trout *Salmo clarkii* and first instar cladocerans *Daphnia magna*. Test standards similar to EPA (1975) were used. Five concentrations were used for the cladoceran test and nine were used for the trout test. Solvent controls were used. Replicates were not mentioned. Concentrations were not measured. Water quality parameters during the test were: temperature of 10°C (trout) and 17°C (cladoceran); pH of 7.4 (trout and cladoceran); and hardness of 162 mg/L (trout) and 40 mg/L (cladoceran). The LC_{50} values were 6800 µg/L for the cutthroat trout and 8.8 µg/L for the cladoceran. These tests were not accepted because the mortality ranges were unacceptable. For a valid LC_{50} value, one treatment other that the control must kill <37% of the test organisms and one treatment must kill >63% of the test organisms.

Mayer and Ellersieck (1986) - In 1978, 48-h (midge) and 96-h (bluegill and amphipod) static toxicity tests were performed by the Columbia National Fisheries Laboratories of the U.S. Fish and Wildlife Service on technical grade methomyl (95%) with mature amphipods *Gammarus pseudolimnaeus*, third instar midges *Chironomus plumosus*, and bluegill *Lepomis macrochirus*. Test methods similar to EPA (1975) were used. Seven to nine concentrations were tested. Solvent and water controls were used for amphipods and midges. No controls were used for bluegills. Concentrations of methomyl were not measured during the test. The temperature averaged 17°C (bluegill and amphipod) and 22°C (midge). Hardness was 320 mg/L for the bluegill. Other water quality parameters were not measured. Control survival was 100% for amphipod test and 85% for midge test. The LC_{50} value for amphipod was 920 µg/L. This value was not accepted because the mortality range was unacceptable. For a valid LC_{50} value, one treatment other that the control must kill <37% of the test organisms and one treatment must kill >63% of the test organisms. The EC_{50} value for midge was 88 µg/L. This value was not used because control survival was <90%. The LC_{50} value for bluegill was 840 µg/L. This value was not accepted because controls were not used.

Roberts et al. (1982) - In 1982, 96-h static toxicity tests were performed by Virginia Institute of Marine Science, the Chesapeake Biological Laboratory, and the Chesapeake Research Consortium on methomyl (24%) with mysids *Neomysis americana* and *Mysidopsis bahia*, copepods *Eurytemora affinis* and *Acartia tonsa*, silverside *Menidia menidia*, and sheepshead minnow *Cyprinodon vareigatus* (life stages not given). ASTM (1980) and APHA (1975) testing standards were used. Five concentrations were tested with one or two replicates. No controls were mentioned. Concentrations were not measured. Water quality parameters during the tests were: temperature of 22^{o}C, pH of 7.3 to 7.8 (mysid); dissolved oxygen of 3.3 to 6.4 (fish and mysid); and salinity of 20$^{o}/_{oo}$ (mysids) and 10$^{o}/_{oo}$ (copepods and fish). Control survival was not given. The LC_{50} values were 32 µg/L (*Neomysis americana*), 56 µg/L (*Mysidopsis bahia*), 290 µg/L (*Eurytemora affinis*), 410 µg/L (*Acartia tonsa*), 340 µg/L (silverside) and 960 µg/L (sheepshead minnow). These values were not used because the formulation was too low in active ingredient.

Summers (1982) - In 1982, a 96-h flow-through toxicity test was performed by Haskell Laboratory in Newark, Delaware on technical grade methomyl (99%) with larval fathead minnows *Pimephales promelas*. No test standards were mentioned. Five concentrations were tested in replicate. A water control was used. Water quality parameters during the test were: temperature of 25^{o}C; pH of 7.0 to 7.3; dissolved oxygen of 8.3 to 8.5; and hardness of 84 mg/L. Control survival was 100%. The LC_{50} for fathead minnows was >972 μg/L. This value was not used because the mortality range was unacceptable. For a valid LC_{50} value, one treatment other than the control must kill <37% of the test organisms and one treatment must kill >63% of the test organisms.

Ward and Boeri (1991) - In 1991, a 96-h flow-through toxicity test was performed by EnviroSystems Laboratories in Hampton, New Hampshire on technical grade methomyl (98%) with juvenile eastern oysters *Crassostrea virginica*. EPA (1985b, 1988) test guidelines were used. One concentration was tested with no replicates. A water control was used. Water quality parameters during the test were: temperature of 21.2 to 23.7°C; pH of 7.4 to 7.9; dissolved oxygen of 6.5 to 7.6; and salinity of $30^{o}/_{oo}$. Control survival was 100%. No effects were given. This test was not accepted because too few concentrations were tested and no LC_{50} value was determined.

Table B-1. Values (μg/L) from accepted tests on the acute toxicity of methomyl to aquatic animals.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Amphipod *Gammarus pseudolimnaeus*	adult	S,U	Technical (95-98%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	920 (660-1300)	Sanders et al. 1983
Atlantic salmon *Salmo salar*	N/A[c]	S,U	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1120 (930-1350)	Mayer and Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	S,U	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	560 (460-690)	Mayer and Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	S,U	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	640 (500-830)	Mayer and Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	S,U	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	700 (570-870)	Mayer and Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	S,U	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1220 (1080-1380)	Mayer and Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	S,U	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1050 (950-1160)	Mayer and Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	S,U	Technical (99%)	12 mg/L as $CaCO_3$	96-h	LC_{50}	1000 (830-1200)	Mayer and Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	S,U	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1150 (980-1360)	Mayer and Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1050 (860-1300)	Mayer and Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as CaCO3	96-h	LC_{50}	2000 (1430-2800)	Mayer and Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as CaCO3	96-h	LC_{50}	1150 (930-1420)	Mayer and Ellersieck 1986
Bluegill	N/A	S,U	Technical	40 mg/L	96-h	LC_{50}	860	Mayer and

Lepomis macrochirus			(95%)	as $CaCO_3$			(640-1150)	Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	480 (320-710)	Mayer and Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1200 (820-1760)	Mayer and Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	940 (650-1360)	Mayer and Ellersieck 1986

Table B-1. Continued -2-

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.)	Reference
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	600 (420-860)	Mayer and Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	620 (370-1040)	Mayer and Ellersieck 1986
Brook trout *Salvelinus namaycush*	N/A	S,U	Technical (95%)	40 mg/L as CaCO*3*	96-h	LC_{50}	1500 (1230-1830)	Mayer and Ellersieck 1986
Brook trout *Salvelinus namaycush*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	2200 (1600-3010)	Mayer and Ellersieck 1986
Channel catfish *Ictalurus punctatus*	N/A	S,U	Technical (98%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	530 (380-750)	Mayer and Ellersieck 1986
Cladoceran *Daphnia magna*	1st instar	S,U	Technical (95-98%)	40 mg/L as $CaCO_3$	48-h	EC_{50}	8.8 (4.1-19)	Sanders et al 1983
Cladoceran *Daphnia magna*	<24-h	S,U	Technical (99%)	N/A	48-h	LC_{50}	31.7 (29.5-34.1)	Summers 1978
Cladoceran *Daphnia magna*	<24-h	S,U	Technical (99%)	101 mg/L as $CaCO_3$	48-h	LC_{50}	38.1 (35.6-40.8)	Summers 1981
Fathead minnow *Pimephales promelas*	N/A	S,U	Technical (98%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	2800 (1820-4310)	Mayer and Ellersieck 1986
Fathead minnow *Pimephales promelas*	juv.	F,M	Technical (99%)	50.5 mg/L as $CaCO_3$	96-h	LC_{50}	2110 (1840-2420)	Geiger et al. 1988
Fiddler crab *Uca pugilator*	N/A	S,U	Technical (100%)	$25^{0}/_{00}$	96-h	LC_{50}	2380 (1970-2880)	Bentley 1973
Grass shrimp *Palaemonetes vulgaris*	N/A	S,U	Technical	$25^{0}/_{00}$ (100%)	96-h	LC_{50}	130	Bentley 1973 (90-180)

Grass shrimp *Palaemonetes vulgaris*	N/A	S,U	Technical	25°/oo (100%)	96-h	LC_{50}	49	Bionomics 1973 (30-81)
Largemouth bass *Micropterus salmoides* Ellersieck 1986	N/A	S,U	Technical	40 mg/L (95%)	96-h as $CaCO_3$	LC_{50}	1250	Mayer and (970-1610)
Midge *Chironomus plumosus*	4th instar	S,U	Technical (95-98%)	40 mg/L as $CaCO_3$	48-h	EC_{50}	88 (47-160)	Sanders et al. 1983
Mud crab *Neopanope texana*	N/A	S,U	Technical (100%)	25°/oo	96-h	LC_{50}	410 (221-759)	Bionomics 1973

Table B-1. Continued -3-

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.)	Reference
Mysid *Mysidopsis bahia*	juv.	S,M	Technical (98%)	16-17$^{o}/_{oo}$	96-h	LC_{50}	220 (200-250)	Ward and Boeri 1989
Pink shrimp *Penaeus duorarum*	N/A	S,U	Technical (100%)	25$^{o}/_{oo}$	96-h	LC_{50}	19 (12-30)	Bionomics 1973
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (90%)	N/A	96-h	LC_{50}	3400 (2640-4390)	McCain 1971
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO^3$	96-h	LC_{50}	1600 (1190-2150)	Mayer and Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1700 (1180-2440)	Mayer and Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%) Ellersieck 1986	320 mg/L as $CaCO_3$	96-h	LC_{50}	1400 (950-2000)	Mayer and
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO^3$	96-h	LC_{50}	2000 (1430-2790)	Mayer and Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	1050 (670-1630)	Mayer and Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	860 (590-1260)	Mayer and Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%) Ellersieck 1986	40 mg/L as $CaCO_3$	96-h	LC_{50}	1500 (1100-2000)	Mayer and
Rainbow trout *Oncorhynchus mykiss*	N/A	S,U	Technical (95%)	40 mg/L as $CaCO^3$	96-h	LC_{50}	1100 (760-1600)	Mayer and Ellersieck 1986
Rainbow trout	N/A	S,U	Technical	40 mg/L	96-h	LC_{50}	1200	Mayer and

Oncorhynchus mykiss			(95%)	as $CaCO_3$			(780-1860)	Ellersieck 1986
Sheepshead minnow *Cyprinodon variegatus*	juv. 1989	S,M	Technical	$162^{o}/_{oo}$ (98%)	96-h	LC_{50}	1160	Boeri and Ward (1020-1300)
Stonefly *Isogenus* sp.	1st-yr	S,U	Technical (95%)	42 mg/L as $CaCO_3$	96-h	LC_{50}	343 (270-440)	Mayer and Ellersieck 1986

[a] S = Static F = Flow through M = Measured concentrations U = Unmeasured concentrations

[b] Confidence limits

[c] N/A = Not available

Table B-2. Values (µg/L) from unaccepted tests on the acute toxicity of methomyl to aquatic animals.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference	Test[c] Deficiencies
Amphipod *Gammarus pseudolimnaeus*	mature	S,U	Technical (95-98%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	920 (680-1240)	Mayer and Ellersieck 1986	1
Bluegill *Lepomis macrochirus*	N/A[d]	S,U	Technical (95-98%)	320 mg/L as $CaCO_3$	96-h	LC_{50}	840 (530-1340)	Mayer and Ellersieck 1986	2
Carp *Cyprinus carpio*	N/A	S,U	Lannate (24%)	116 mg/L as $CaCO_3$	48-h	LC_{50}	2.7 (2.33-2.89)	El Refai et al. 1976	3,4
Carp *Cyprinus carpio*	N/A	S,U	Lannate (24%)	116 mg/L as $CaCO_3$	48-h	LC_{50}	1.35 (1.16-1.57)	El Refai et al. 1976	3,4
Cladoceran *Daphnia magna*	1st instar	S,U	Technical (95-98%)	40 mg/L as $CaCO_3$	48-h	LC_{50}	8.8 (4.1-19)	Mayer and Ellersieck 1986	1
Copepod *Acartia tonsa*	N/A	S,U	Lannate (24%)	$10^{o}/_{oo}$	96-h	LC_{50}	410 (260-620)	Roberts et al. 1982	4
Copepod *Eurytemora affinis*	N/A	S,U	Lannate (24%)	$10^{o}/_{oo}$	96-h	LC_{50}	290 (90-500)	Roberts et al. 1982	4
Cutthroat trout *Salmo clarkii*	N/A	S,U	Technical (95-98%)	162 mg/L as $CaCO_3$	96-h	LC_{50}	6800 (2180-7530)	Mayer and Ellersieck 1986	1
Eastern oyster *Crassostrea virginica*	juv.	F,M	Technical (98%)	$30^{o}/_{oo}$	96-h	EC_{50}	>140,000	Dupont 1991	1
Eastern oyster *Crassostrea virginica*	juv.	F,M	Technical (98%)	$30^{o}/_{oo}$	96-h			Ward and Boeri 1991	5,6
Fathead minnow *Pimephales promelas*	larv.	F,U	Technical (99%)	84 mg/L as $CaCO_3$	96-h	LC_{50}	>972	Summers 1982	1
Midge *Chironomus plumosus*	3rd instar	S,U	Technical (95-98%)	40 mg/L as $CaCO_3$	48-h	LC_{50}	88 (60-129)	Mayer and Ellersieck 1986	7
Mysid *Mysidopsis bahia*	N/A	S,U	Lannate (24%)	$20^{o}/_{oo}$	96-h	LC_{50}	56 (36-66)	Roberts et al. 1982	4
Mysid *Neomysis americana*	N/A	S,U	Lannate (24%)	$20^{o}/_{oo}$	96-h	LC_{50}	32 (14-53)	Roberts et al. 1982	4
Sheepshead minnow *Cyprinodon variegatus*	N/A	S,U	Lannate (24%)	$10^{o}/_{oo}$	96-h	LC_{50}	960 (820-1260)	Roberts et al. 1982	4

Silverside *Menidia menidia*	N/A	S,U	Lannate (24%)	10°/oo	96-h	LC_{50}	340 (290-390)	Roberts et al. 1982	4

Table B-2 Continued -2-

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference	Test[c] Deficiencies
Tilapia *Tilapia nilotica*	N/A	S,U	Lannate (24%)	116 mg/L as $CaCO_3$	48-h	LC_{50}	2.6 (2.33-2.89)	El Refai et al. 1976	3,4
Tilapia *Tilapia nilotica*	N/A	S,U	Lannate (24%)	117 mg/L as $CaCO_3$	48-h	LC_{50}	1.4 (1.14-1.70)	El Refai et al. 1976	3,4

[a] S = Static F = Flow through M = Measured concentrations U = Unmeasured concentrations

[b] Confidence limits

[c] 1 = Unacceptable mortality range
2 = No controls used
3 = Test duration too short
4 = Formulation too low in active ingredient
5 = Inadequate number of concentrations tested
6 = No pertinent values given
7 = Unacceptable control survival

[d] N/A = Not available

APPENDIX C. Abstracts of accepted and unaccepted chronic toxicity tests reviewed for hazard assessment.

Accepted chronic toxicity tests - The following tests used accepted test methods.

Dupont (1993) - In 1993, a 193-d flow-through toxicity test was performed by DuPont laboratories on technical grade methomyl (98%) with fathead minnow *Pimephales promelas*. No testing standards were mentioned. Five concentrations were tested with water controls. Concentrations were measured and averaged 93 to 107% of nominal concentrations. Water quality parameters during the test were: temperature of 25^{o}C; pH of 7.6 to 8.4; dissolved oxygen of 4.8 to 7.9 mg/L; and hardness of 136 to 154 mg/L. Control survival was 100%. The NOEC, LOEC, and MATC values, based on egg hatchability and survival, growth, and reproductive activity, were 76.0 µg/L, 142 µg/L, and 104 µg/L, respectively.

Summers (1981) - In 1981, a 21-d static toxicity test was performed by Haskell Laboratory in Newark, Delaware on technical grade methomyl (99%) with <24-h cladocerans *Daphnia magna*. ASTM (1981) testing standards were used. Six concentrations were tested with ten replicates and a water control was used. Concentrations were not measured. Water quality parameters during the test were: temperature of 20^{o}C; pH of 6.2 to 7.5; dissolved oxygen of 4.2 to 7.4 mg/L; and hardness of 93 mg/L. Control survival was 100%. The NOEC, LOEC and MATC values, based on reproduction, survival, and growth, were 1.6 µg/L, 3.1 µg/L, and 2.23 µg/L, respectively.

Summers (1982) - In 1982, a 28-d flow-through toxicity test was performed by Haskell Laboratory in Newark, Delaware on technical grade methomyl (99%) with larval fathead minnows *Pimephales promelas*. ASTM (1981) testing standards were used. Five concentrations were tested and a water control was used. Concentrations were measured every six days and measured concentrations averaged 87 to 98% of nominal concentrations. Water quality parameters during the test were: temperature of 25°C; pH of 7.6 to 7.8; hardness of 91.3 mg/L; and dissolved oxygen of 8.5 to 8.6 mg/L. Control survival was 100%. The NOEC, LOEC, and MATC values, based on embryo hatch and larval survival and growth, were 57 µg/L, 117 µg/L, and 81.7 µg/L, respectively.

Unaccepted chronic toxicity tests - The following tests did not use accepted test methods and/or produce acceptable results

Bionomics (1971) - In 1971, a 28-d flow-through toxicity test was performed by Bionomics, Whareham, Massachusetts on Lannate (percent active ingredient not given) with rainbow trout *Oncorhynchus mykiss* (life stage not given). No test standards were mentioned. Two concentrations were tested with two replicates and solvent controls were used. Concentrations were measured every three to seven days during the test. Water quality parameters during the test were: temperature of 18°C; pH of 7.3; dissolved oxygen of 5.0 mg/L, and hardness of 25 mg/L. Control survival was 100%. Effects were not given. This test was not used because no pertinent values were determined, and an inadequate number of concentrations were tested.

Clare et al. (1992) In 1991, a 14-d static toxicity tests was performed by Duke University on technical grade methomyl (percent active ingredient not given) with megalopa stage mud crabs *Rhithropanopeus harrisii* Gould. No test standards were mentioned. Four concentrations were tested with three to five replicates. A water control was used. Concentrations were not measured. The temperature averaged 25°C. Other water quality parameters were not measured. Control survival was 100%. Effects were not given. This test was not used because no pertinent values were determined.

Clare and Costlow (1989) - In 1989, a static toxicity test (duration not given) was performed by Duke University Marine Laboratory on technical grade methomyl (98%) with megalopa and juvenile mud crabs *Rhithropanopeus harrisii*. No test standards were mentioned. Four concentrations were tested with five replicates. A water control was used. Concentrations were not measured. Water quality parameters were not given. Control survival was >90%. Effects were not given. This test was not used because no pertinent values were determined.

Table C-1. Values (μg/L) from accepted tests on the chronic toxicity of methomyl to aquatic animals.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values	MATC	Reference
Cladoceran *Daphnia magna*	<24-h	S,U	Technical (99%)	93 mg/L as $CaCO_3$	21-d	LOEC NOEC	3.1 1.6	2.2	Summers 1981
Fathead minnow *Pimephales promelas*	larval	F,M	Technical (99%)	91.3 mg/L as $CaCO_3$	28-d	LOEC NOEC	117 57	82	Summers 1982
Fathead minnow *Pimephales promelas*	embryo	F,M	Technical (98%)	136 mg/L as $CaCO_3$	193-d	LOEC NOEC	142 76	104	DuPont 1993

[a] S = Static   F = Flow through   M = Measures concentrations   U = Unmeasured concentrations

Table C-2. Values (μg/L) from unaccepted tests on the chronic toxicity of methomyl to aquatic animals.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values	Reference	Test[b] Deficiencies
Mud crabs *Rhithropanopeus harrisii*	megalopa	S,U	Technical (% N/A)	N/A[c]	14-d	N/A	N/A	Clare et al. 1992	1
Mud crabs *Rhithropanopeus harrisii*	juv.	S,U	Technical (98%)	N/A	N/A	N/A	N/A	Clare and Costlow 1989	1
Rainbow trout *Oncorhynchus mykiss*	N/A	F,M	Lannate (% N/A)	25 mg/L as $CaCO_3$	28-d	N/A	N/A	Bionomics 1971	1,2

[a] S = Static F = Flow through M = Measured concentrations U = Unmeasured concentrations

[b] 1 = No pertinent values determined
2 = Inadequate number of concentrations tested

[c] N/A = Not available

APPENDIX D. Abstracts of aquatic plant toxicity tests reviewed for hazard assessment.

Kobbia et al. (1991) - In 1991, 7-d static toxicity tests were performed by Cairo University, Egypt on technical grade methomyl (percent active ingredient not given) with cyanobacteria *Nostoc muscorum* and *Tolypothrix tenuis*. No test standards were mentioned. Five concentrations were tested and a control was used. No replicates were mentioned. Water temperature ranged from 25 to 27^{o}C; no other water quality parameters were given. Control survival was not given. Growth was inhibited even at the lowest concentration of 100 mg/L.

Khalil and Mostafa (1986) - In 1986, 7-d static toxicity tests were performed by Cairo University, Egypt on technical grade methomyl (percent active ingredient not given) with freshwater algae *Phormidium fragile*. No test standards were mentioned. Five concentrations were tested with three replicates and a control. No water quality parameters were given. Control survival was 100%. Growth was inhibited at 225 mg/L.

Roberts (1982) - In 1982, 96-h static toxicity tests were performed by Virginia Institute of Marine Science, the Chesapeake Biological Laboratory, and Chesapeake Research Consortium on methomyl (24%) with algae *Pseudoisochrysis paradoxa*, diatom *Skeletonema costatum*, and dinoflagellate *Procentrum minimum*. ASTM (1980) and APHA (1975) testing standards were used. Five concentrations were tested with one to two replicates. No controls were mentioned. Concentrations were not measured. Water quality parameters during the tests were: temperature of 22^{o}C and salinity of 20$^{o}/_{oo}$. Control survival was not given. The LC_{50} values were 580 mg/L (algae), 524 mg/L (diatom), and 338 mg/L (dinoflagellate).

Table D-1. Values (μg/L) from tests on the toxicity of methomyl to aquatic plants.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% c.l.[b])	Reference
Algae *Pseudoisochrysis paradoxa*	N/A[c]	S,U	Lannate (24%)	20°/oo	96-h	LC_{50}	580,000 (210,000-1,780,000)	Roberts 1982
Cyanobacteria *Nostoc muscorum*	N/A	S,U	Technical (N/A)	N/A	7-d	N/A	N/A	Kobbia et al. 1991
Cyanobacteria *Tolypothrix tenuis*	N/A	S,U	Technical (N/A)	N/A	7-d	N/A	N/A	Kobbia et al. 1991
Diatom *Skeletonema costatum*	N/A	S,U	Lannate (24%)	20°/oo	96-h	LC_{50}	524,000 N/A	Roberts 1982
Dinoflagellate *Procentrum minimum*	N/A	S,U	Lannate (24%)	20°/oo	96-h	LC_{50}	388,000 N/A	Roberts 1982
Freshwater algae *Phormidium fragile*	N/A	S,U	Technical (N/A)	N/A	7-d	N/A	N/A	Khalil and Mostafa 1986

[a] S = Static F = Flow through M = Measured concentrations U = Unmeasured concentrations

[b] Confidence limits

[c] N/A = Not available