EVALUATION OF THE USE OF SONAR®
IN MICHIGAN

(A Science Report to Governor John Engler)

Prepared by
Michigan Environmental Science Board
Sonar Investigation Panel

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OCTOBER 1999

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(Appendices 4 and 5 are not available electronically. They are available by securing a printed copy of this report from the Michigan Environmental Science Board)**

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PREFACE

Michigan Environmental Science Board

The Michigan Environmental Science Board (MESB) was created by Governor John Engler by Executive Order 1992-19 on August 6, 1992. The MESB is charged with advising the Governor, the Natural Resources Commission, the Michigan Department of Natural Resources and other state agencies, as directed by the Governor, on matters affecting the protection and management of Michigan's environment and natural resources. The MESB consists of nine members and an executive director, appointed by the Governor, who have expertise in one or more of the following areas: engineering, ecological sciences, economics, chemistry, physics, biological sciences, human medicine, statistics, risk assessment, geology and other disciplines as necessary. Upon the request of the Governor to review a particular issue, a panel, consisting of MESB members with relevant expertise, is convened to evaluate and provide recommendations on the issue.

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Evaluation of the Use of Sonar® in Michigan

Major Conclusions and Recommendations

The Michigan Department of Environmental Quality (MDEQ) has regulatory authority over the use of herbicides to control nuisance aquatic plants pursuant to the Public Health Code, 1978 PA 368, as amended and Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. The MDEQ issues permits for the use of chemicals to control specific plants in specific areas of a lake or pond.

The liquid formulation of the aquatic herbicide fluridone (Sonar®) is used to control the submersed exotic weed, Eurasian watermilfoil (*Myriophyllum spicatum* L.), in natural lakes and reservoirs across the northern tier states. Within Michigan, treatments have been limited to using the liquid aqueous suspension of Sonar®. Close to 10 years of research has taken place in Michigan and other states on the impact of Sonar® on aquatic plant communities. On October 14, 1998, the Michigan Environmental Science Board (MESB) was requested by Governor John Engler to review the research and evaluate seven preliminary conclusions reached by the MDEQ regarding the efficacy of the herbicide, Sonar®.

A Panel of scientists was formed to address the Governor's charge to the MESB. Dr. Bette J. Premo (aquatic ecology, White Water Associates, Inc.) chaired the Panel, which consisted of Dr. Ted R. Batterson (aquatic ecology, Michigan State University); Dr. John A. Gracki (chemistry, Grand Valley State University); Dr. Clarence D. McNabb (aquatic ecology, Michigan State University); and Mr. Keith G. Harrison (ecology, Michigan Environmental Science Board).

The investigation consisted of the accumulation and evaluation of peer-reviewed and some non-peer-reviewed literature and data on the subject. In addition, oral and written testimony from experts, industry specialists, state regulatory agencies, environmental organizations, and concerned citizens was also considered. The report was prepared by the MESB Panel with each member assigned a specific topic or topics to address.

The following conclusions and recommendations were reached by the MESB Panel regarding the seven MDEQ conclusions:

> MDEQ Conclusion 1. A balanced, diverse aquatic plant community should be maintained in all water bodies for the maintenance of healthy fish and wildlife populations.

In general, the MESB Panel concurs with MDEQ Conclusion 1; however, history has demonstrated that aquatic ecosystems that are managed by humans using Sonar® or other means are likely to be never in balance. Given this, the MESB Panel recommends that Conclusion 1 be modified by omission of the word, *balance*.

> MDEQ Conclusion 2. Sonar® should not be used in Michigan at or near the labeled rate to eliminate all or the majority of aquatic plants in a water body.

The purpose of the use of Sonar® is to rehabilitate water bodies that have become overpopulated with Eurasian watermilfoil. The process necessarily entails that such removal be accomplished in a manner that will not negatively impact the more desirable native species but, rather, encourage their proliferation and resurgence of dominance within the water body. Based on the available research, Sonar® application rates at or near the label rate will remove Eurasian watermilfoil; however, at these rates, it will also impact significantly the native species. Removal of all or the majority of the aquatic species (Eurasian watermilfoil and the native species) from a water body would be a component of a comprehensive lake restoration project, which is not the purpose of the MDEQ program. Therefore, the MESB Panel concurs with MDEQ Conclusion 2.

> MDEQ Conclusion 3. When Sonar® is used to control Eurasian watermilfoil, negative impacts on native aquatic plants should be minimal in the year of treatment and in subsequent years.

The MESB Panel concurs with MDEQ Conclusion 3 but suggests that the option for rehabilitation of a given water body may be not only to control, but also totally eliminate Eurasian watermilfoil by the application of Sonar®. Implementing this option may, in the year of treatment, have a greater than minimum negative impact on native aquatic plants. Eliminating by administrative rule the option to eradicate Eurasian watermilfoil when conclusive data to condemn or promote this particular approach are not yet available, may be premature. Because of this, the MESB Panel suggests that Conclusion 3 be qualified to allow the option to use Sonar® in Eurasian watermilfoil elimination and water body rehabilitation programs, and that such use be allowed at the MDEQ's discretion on a case by case basis with decisions based on its review of the available scientific field studies and specific physical, limnological, and biological data for the particular water body in question.

> MDEQ Conclusion 4. The Sonar® concentration that effectively controls Eurasian watermilfoil with minimal impacts on native species is between five and eight parts per billion (ppb).

> MDEQ Conclusion 5. Boosting the concentration of Sonar® 10 - 14 days after the treatment (i.e., bringing the concentration of Sonar® in lake water back up to the target concentration) enhances the effectiveness and timeliness of the treatment without additional negative impacts on native species.

In general, the scientific literature supports and the MESB Panel concurs with both MDEQ Conclusions 4 and 5; however, several suggested changes regarding the current MDEQ methodology for calculating lake volume and a more precise application rate are offered by the MESB in the report. In particular, the MESB Panel recommends that the application rate of Sonar® for selective control of Eurasian watermilfoil be six ppb followed by the potential of retreatment boosting the concentration back to six ppb two to three weeks after the initial treatment based on results of a FasTEST® for water column concentrations of the compound. Under this protocol, impact to non-target native plant species would be minimal in the year of treatment and beyond, and the amount of native vegetation habitat remaining would be adequate for fish and wildlife.

> MDEQ Conclusion 6. Sonar® is one tool for controlling Eurasian watermilfoil on a whole-lake basis.

The MESB Panel concurs with MDEQ Conclusion 6 since each lake has unique aquatic plant populations and distributions. When exotic species, such as Eurasian watermilfoil, grow in numbers that are considered nuisance then all control options must be considered including mechanical harvest, chemical control, and nutrient source reduction. Currently, the MDEQ requires that only a minimum of information be provided with a permit application. In order to better understand the dynamics of the interrelated natural ecological processes that operate within a lake and, therefore, the potential impacts that may take place due to manipulation of these processes, a greater level of information would be useful. There currently exist several lake information-gathering models that may be used to supplement the information currently required by the MDEQ. The MESB Panel suggests that the MDEQ evaluate the use of these and other similar models and encourage the use of such tools in conjunction with its permit program.

> MDEQ Conclusion 7. Sonar® does not have any direct negative impacts on fish or wildlife populations, or pose any human health concerns when used according to the product label.

The MESB Panel concurs with MDEQ Conclusion 7 but recommends that it be modified by adding the words, "*and its permitted use by the MDEQ*" to the end of the sentence.

EVALUATION OF THE

USE OF SONAR® IN MICHIGAN

(A Science Report to Governor John Engler)

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Issue

The Michigan Department of Environmental Quality (MDEQ) has regulatory authority over the use of herbicides to control nuisance aquatic plants pursuant to the Public Health Code, 1978 PA 368, as amended and Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. The MDEQ issues permits for the use of chemicals to control specific plants in specific areas of a lake or pond.

The liquid formulation of the aquatic herbicide fluridone {1-methyl-3-phenyl-5-[3-(trifluromethyl)phenyl]-4(1H)-pyridinone} is used to control the submersed exotic weed, Eurasian watermilfoil (*Myriophyllum spicatum* L.), in natural lakes and reservoirs across the northern tier states. Within Michigan, treatments have been limited to using the liquid aqueous suspension of fluridone (Sonar®). The MDEQ intends to initiate the administrative rules process to define allowable uses of Sonar® in Michigan. However, there is little agreement on appropriate Sonar® uses and application rates in Michigan despite nearly a decade of evaluation and attempts to reach consensus among the various stakeholders. Opinions on Sonar® use range from allowing it at rates up to 60 parts per billion (ppb) under certain circumstances to not allowing its use at all. Proponents of high Sonar® concentrations in Michigan believe that long-term results would include eradication of the nuisance exotic plant, Eurasian watermilfoil, with lower costs to the customer and that these benefits outweigh the relatively short-term adverse impacts on the native plant community. Opponents of Sonar® use in Michigan point to the variable effects on native plants, even at low concentrations, and that long-term impacts on the plant, fish, and wildlife communities are relatively unknown. The MDEQ and other stakeholders have held that Sonar®, when used responsibly at low concentrations (5 ppb to 8 ppb range), may be an effective tool for selectively controlling some nuisance populations of Eurasian watermilfoil.

Governor's Charge to the Michigan Environmental Science Board

On October 14, 1998, the Michigan Environmental Science Board (MESB) was requested by Governor John Engler (Engler, 1998) to review the available research and evaluate the MDEQ preliminary conclusions regarding the efficacy of the herbicide, Sonar® (see Appendix 1).

The report evaluates the following seven MDEQ conclusions:

1. A balanced, diverse aquatic plant community should be maintained in all water bodies for the maintenance of healthy fish and wildlife populations;

2. Sonar® should not be used in Michigan at or near the labeled rate to eliminate all or the majority of aquatic plants in a water body;

3. When Sonar® is used to control Eurasian watermilfoil, negative impacts on native aquatic plants should be minimal in the year of treatment and in subsequent years;

4. The Sonar® concentration that effectively controls Eurasian watermilfoil with minimal impacts on native species is between five and eight ppm;

5. Boosting the concentration of Sonar® 10 - 14 days after the treatment (i.e., bringing the concentration of Sonar® in lake water back up to the target concentration) enhances the effectiveness and timeliness of the treatment without additional negative impacts on native species;

6. Sonar® is one tool for controlling Eurasian watermilfoil on a whole-lake basis; and

7. Sonar® does not have any direct negative impacts on fish or wildlife populations, or pose any human health concerns when used according to the product label.

Michigan Environmental Science Board Response

A Panel of scientists was formed to address the Governor's charge to the MESB. Dr. Bette J. Premo (aquatic ecology, White Water Associates, Inc.) chaired the Panel, which consisted of Dr. Ted R. Batterson (aquatic ecology, Michigan State University); Dr. John A. Gracki (chemistry, Grand Valley State University); Dr. Clarence D. McNabb (aquatic ecology, Michigan State University); and Mr. Keith G. Harrison (ecology, Michigan Environmental Science Board).

The investigation consisted of the accumulation and evaluation of peer-reviewed and some non-peer-reviewed literature and data on the subject. In addition, oral and written testimony from experts, industry specialists, state regulatory agencies, environmental organizations, and concerned citizens was also considered. The report was prepared by the MESB Panel with each member assigned a specific topic or topics to address.

Summary of Sonar® Use in Michigan

Sonar® was introduced for use in Michigan to control aquatic weeds in 1987. It is a broad spectrum, systemic herbicide. The liquid formulation (the only formulation currently used in Michigan) disperses with efficacy throughout an entire lake. Early treatments in Michigan revealed that Sonar® effectively controlled most aquatic plants when used at the labeled application rate (Kenaga, 1995; 1993). Sonar® has been found also to pose negligible direct risk to humans, fish, and wildlife since it neither

bioaccumulates nor bioconcentrates, and plants die slowly so dissolved oxygen levels in the water are maintained (Rathbun, 1999; Klemans, 1998).

In 1991, the MDEQ began to evaluate the effectiveness and adverse impacts of Sonar® when used in Michigan at application rates from five ppb to 46 ppb. Results of the Sonar® treatments were highly variable in terms of percentage of plant cover affected, the number of native species lost, and plant response following treatments. Based on these evaluations; however, it appeared that Sonar® might be used to selectively control Eurasian watermilfoil (Rathbun, 1999; Klemans, 1998).

In 1994, the Michigan Department of Natural Resources (MDNR) established a Quality Action Team (QAT) to bring together the stakeholders to recommend acceptable Sonar® uses and application rates. The QAT agreed, based on information collected prior to 1995, that Sonar® treatments at concentrations greater than 12 ppb removed too much aquatic vegetation. The QAT evaluated treatments at eight ppb and five ppb Sonar®, but was unable to reach a consensus on which treatment option provided the most desirable results. The QAT recommended further evaluation of Sonar® treatments at five ppb with a supplemental treatment 10 to 14 days later to bring the Sonar® concentration in the lake back to five ppb *(*5-bump-5 treatment) (O'Neal, 1999; Rathbun, 1999; Klemans, 1998; LWMD, 1997b).

The MDEQ began a two-year cooperative evaluation in 1997 with SePro Corporation, the U.S. Army Corps of Engineers, Michigan State University, consultants, and licensed commercial herbicide applicators to test the 5-bump-5 treatment protocol. The development of a new enzyme-linked immunosorbent assay (FasTEST®) (SePro, 1997) for fluridone enabled the MDEQ to correlate plant community response to Sonar® concentrations in the lakes. This was used in the 5-bump-5 treatments, as well as in five ppb treatments. Based on the preliminary results of the 1997 evaluation, an evaluation of a 6-bump-6 treatment was initiated in 1998 to improve upon the efficacy of the 1997 treatments. The MDEQ is also evaluating the use of Sonar® for the control of nuisance duckweed (*Lemna spp.*) in ponds, and the possibility of using it as a restoration treatment for a lake infested almost exclusively with curlyleaf pondweed (*Potamogeton crispus* L.) (Rathbun, 1999; Klemans, 1998; LWMD, 1997b).

Current Permitting Process and Requirements for Sonar® Use in Michigan

Appendix 2 presents the MDEQ's 1999 strategy for the use of Sonar® in Michigan. The strategy outlines the requirements for obtaining a Sonar® permit and includes sampling protocols to be used for fluridone residue analyses, two alternative procedures for calculating water volumes and application rates, and a Vegetation Management Plan to be completed and submitted to the MDEQ as part of the permit process. The Vegetation Management Plan requests information on the physical and hydrological characteristics of the water body, current and proposed uses of the water body, completion of an aquatic plant species (targeted and non-targeted) surveys, delineation of areas to be treated, indication of the goal to be reached as a result of the treatment, and proof of public participation (LWMD, 1999).

The 1999 strategy allows for the application of Sonar® at different concentrations depending upon the size and hydrology of the water body, degree of weed infestation, adjacent land use, time of year, etc. For example, and depending upon supporting permit information, up to five ppb of Sonar® may be applied to lakes, up to 15 ppb may be applied to ponds up to 10 acres in size with no outflow and up to eight ppb with subsequent re-treatments to maintain a maximum concentration of five ppb for 30 days may be permitted in commercial marinas where adjacent wetlands and water bodies will not be affected. In addition, permits may be obtained to conduct evaluation treatments of Sonar® consistent with current research needs. Some of the types of research mentioned include evaluations of 6-bump-6 and 8-bump-5 treatment protocols to selectively control Eurasian watermilfoil and long term impact evaluations of lakes subject to repeated treatments of Sonar® (LWMD, 1999).

Recent Research on Sonar®

Madsen *et al.* (In press) investigated the impact of low-dose Sonar® treatments on aquatic plants in eight southern Michigan lakes in 1997. The main objective of the study was to determine whether submersed plant species diversity and frequency were impacted by low-dose Sonar® applications in the year of treatment when targeting for Eurasian watermilfoil control. Secondary objectives included: (1) determining Sonar® effectiveness on the exotic submersed species curlyleaf pondweed; (2) evaluating shifts in plant species diversity at one year post-treatment; (3) measuring the effect of thermal stratification on water column distribution of Sonar® residues; and (4) verifying laboratory-derived results of Sonar® concentration and exposure time relationships with respect to efficacy against Eurasian watermilfoil.

Study lakes were 136 to 544 acres in size and contained an average of nine species of submersed plants, including Eurasian watermilfoil and curlyleaf pondweed. Four lakes (Big Crooked, Camp, Lobdell, and Wolverine) were treated in mid-May 1997, with Sonar® to yield a target concentration of five ppb Sonar® in the upper 10 feet of each lake. A boost application of Sonar® was conducted on each lake at 16 to 21 days after initial treatment. This whole-lake boost or “bump up” application was intended to re-establish the target concentration of Sonar® (5 ppb) in the upper 10 feet of each lake. Four other water bodies (Bass, Big Seven, Clear, and Heron Lakes) did not receive any Sonar® applications and served as untreated reference lakes.

Water residue samples were collected on prescribed intervals on each of the Sonar® treated lakes from pretreatment to approximately 75 days after initial treatment. Samples were collected from six littoral zone stations and from two deep locations throughout the lakes. Water temperature profiles were measured at the deep stations at each water sampling event. Sonar® residues were analyzed using two separate techniques; (1) FasTEST® and (2) the standard high performance liquid chromatography method.

Quantitative sampling of vegetation was performed using point-based frequency of species occurrence to evaluate whole-lake distribution and diversity of the submersed plant community of all eight study lakes. The technique was implemented using global positioning and geographic information systems, with a minimum grid resolution of approximately 151 feet by 151 feet. Plant surveys were conducted in early- to mid-May and in mid-August in 1997 (year of treatment) and 1998 (one year post-treatment).

According to Madsen *et al.* (In press), Sonar® levels on three of the treated lakes met the laboratory-derived criteria for achieving good control of Eurasian watermilfoil by providing a peak concentration of approximately five ppb during the first two weeks post-treatment, and by maintaining a concentration greater than two ppb through 60 days after initial treatment. This Sonar® concentration and exposure time relationship resulted in good control of Eurasian watermilfoil through one year post-treatment on these lakes. On a fourth lake, however, the required concentration and exposure time relationship was not maintained and poor control of Eurasian watermilfoil was observed. There was no strong evidence of curlyleaf pondweed control in any of the Sonar® treated lakes.

In 1998, two lakes in southern Michigan (Eagle and Lower Scott) were treated to yield a target concentration of six ppb Sonar® in the upper 10 feet of each lake. A boost application was conducted on each lake 21 to 22 days later to re-establish the target concentration (6 ppb). Two additional lakes (Clear Lake and Bass Lake) did not receive any Sonar treatments and served as untreated reference lakes. During the year of treatment, Eurasian watermilfoil was reduced by 35 percent in Eagle Lake and 75 percent in Lower Scott Lake. Collection of data for one year post-treatment evaluation was completed in August 1999. Although still preliminary, the data indicate that one year post-treatment, the 6-bump-6 treatment protocol resulted in an equal to or greater than 85 percent reduction of the target species in Eagle Lake and a equal to or greater than 95 percent reduction in Lower Scott Lake (Madsen and Getsinger, In press).

The herbicide application strategy used in both studies did not significantly impact the native plant species diversity or cover in the year of treatment, or through one year post-treatment, in any of the Sonar® treated lakes. Native plant cover was maintained at levels greater than 70 percent in the 1997 study and greater than 75 percent in the 1998 study in the year of treatment and at one year post-treatment (Madsen *et al.*, In press; Madsen and Getsinger, In press).

Sonar® residues became well mixed in the water column under isothermal conditions and thermal stratification prevented mixing of fluridone into deeper and colder waters. Thermal stratification, or the lack thereof, at the time of herbicide application can impact target concentrations of Sonar®. Using the volume of pre-selected depth zones to calculate the amount of Sonar® needed to achieve a particular target concentration can result in an over- or under-dosing of a water body, leading to poor or non-selective control of Eurasian watermilfoil (Madsen *et al.*, In press).

Conclusions and Recommendations for Sonar®

Sonar® and Balanced Aquatic Communities. Historically, balanced and diverse plant communities of many different kinds have existed in the wide array of water bodies that are scattered throughout the state. Eurasian watermilfoil has had profound effects on many of these aquatic communities since it was introduced into Michigan about 1965 (Coffey and McNabb, 1974). Over the past three decades, this aquatic plant has produced successful and lasting generations, and has become naturalized and integrated into Michigan's aquatic flora. Because of this, a new balance and diversity now exists among aquatic plants that co-occupy water bodies with Eurasian watermilfoil. Such introductions of non-native species, and subsequent interactions and reorganization of impacted plant and animal populations, are dynamic and on-going processes. In recent decades, the frequency at which successful introductions have occurred has accelerated in North America and elsewhere as intercontinental travel and commerce among human populations has increased. In treating this topic, Bright (1998) draws attention to the severe threat that successful invasions of non-native species pose to regional biodiversity. Intense human intervention is often needed to minimize impacts of invaders on native plant and animal communities. In the case under consideration by the MESB Panel, Sonar® is a tool being considered by the MDEQ for use to minimize the impact of Eurasian watermilfoil on native aquatic plant and animal communities. The first MDEQ Conclusion recognizes the importance of aquatic plant diversity on the overall health of the aquatic ecosystem.

> "*A balanced, diverse plant community should be maintained in all water bodies for the maintenance of healthy fish and wildlife populations*."

The rationale for this conclusion is strongly supported in the literature. For example, a diverse community of aquatic plants, as compared to nearly monotypic stands of Eurasian watermilfoil, is known to support productive and diverse periphyton communities on surfaces of submersed vegetation (Pullman, 1995; Hutchinson, 1975; Wetzel, 1983; Ruttner, 1953). Items in these periphyton communities are important sources of food for fish (O'Neal, 1999). Monotypic stands of Eurasian watermilfoil have a simplistic three-dimensional underwater architecture in comparison to diverse native plant communities (Coffey and McNabb, 1974). Native species of fish are adapted to use of the complex architecture of native species for spawning, and utilize the cover that these plants provide to escape predators (Keast, 1984; Savino and Stein, 1982). Waterfowl use items in the periphyton for food, as well as tubers that various native plants produce. Compared to diverse stands of native aquatic plants, nearly monotypic stands of Eurasian watermilfoil have few characteristics that benefit amphibians and those mammals that use freshwater habitats.

The Panel concurs with the MDEQ Conclusion as it relates to diversity. However, it is the opinion of the Panel that history has demonstrated that aquatic ecosystems that are managed by humans using Sonar® or other means are likely to be never in balance. Given this, the MESB Panel recommends that Conclusion 1 be modified by omission of the word, *balance*.

Water Body Rehabilitation. The MDEQ's aquatic plant management program under consideration by the Panel has rehabilitation of water bodies as its goal. The concept of *rehabilitation* is used here in the sense of Cooke (1999). It implies an effort to repair essential ecosystem structures and functions in order to move altered or impaired water bodies in the direction of improvement. As an aside, this differs from the notion of *restoration* that is occasionally used in lake management literature to imply a return of habitats to pristine or early historical pre-disturbance conditions. Restoration is seldom, if ever, attainable in aquatic habitats in Michigan; particularly those that are surrounded by landscapes that are extensively occupied and modified by people.

Within the literature, there are several papers that suggest that Sonar® can be an effective tool for rehabilitating water bodies in which Eurasian watermilfoil has become objectionable; for example in the case of Long Lake in the state of Washington (TCWWM, 1995). However, evaluations of early (1987 - 1994) Sonar® applications in Michigan showed that the product could also have undesirable anti-rehabilitation effects if used at high concentrations (Kenaga, 1995). Given these results, the MDEQ has subsequently taken a cautious approach to the use of Sonar® in water bodies in the state. Such caution is evident in MDEQ's Conclusions 2 and 3, which state:

> "*Sonar® should not be used in Michigan at or near the labeled rate to eliminate all or the majority of aquatic plants in a water body,*" and
>
> *"When Sonar® is used to control Eurasian watermilfoil, negative impacts on native aquatic plants should be minimal in the year of treatment and in subsequent years."*

The purpose for the use of Sonar® is to rehabilitate water bodies that have become overpopulated with Eurasian watermilfoil. The process necessarily entails that such removal be accomplished in a manner that will not negatively impact the more desirable native species but, rather, encourage their proliferation and resurgence of dominance within the water body. Based on the available research, Sonar® application rates at or near the label rate will remove Eurasian watermilfoil; however, at these rates, it will also impact significantly the native species. Removal of all or the majority of the aquatic species (Eurasian watermilfoil and the native species) from a water body would be a component of a comprehensive lake restoration project, which is not the purpose of the MDEQ program. Therefore, the MESB Panel concurs with MDEQ Conclusion 2.

Recent work with Sonar® by Madsen *et al*. (In press) has demonstrated that Sonar® can be used to control Eurasian watermilfoil without significant negative impacts on native aquatic plants. However, Conclusion 3 appears to preclude cases where, for example, the best option for rehabilitation of a water body may be not only to control, but also totally eliminate Eurasian watermilfoil by the application of Sonar®. Implementing this option may, in the year of treatment, have a greater than minimum negative impact on native aquatic plants (TCWWM, 1995). Eliminating by administrative rule the option to eradicate Eurasian watermilfoil when conclusive data to condemn or promote this particular approach are not yet fully available, may be premature. Because of this, the MESB Panel suggests that MDEQ Conclusion 3 be qualified to allow the option to use Sonar® in Eurasian watermilfoil elimination and

water body rehabilitation programs, and that such use be allowed at the MDEQ's discretion on a case by case basis with decisions based on its review of the available scientific field studies and specific physical, limnological, and biological data for the particular water body in question.

Sonar® Application Rate to Control Eurasian Watermilfoil. MDEQ Conclusions 4 and 5 address application rate and method of application of Sonar® to control Eurasian watermilfoil. Specifically, Conclusions 4 and 5 state:

> *"The* Sonar® *concentration that effectively controls Eurasian watermilfoil with minimal impacts on native species is between five and eight ppb,"*
> and
>
> *"Boosting the concentration of* Sonar® *10 - 14 days after the treatment (i.e., bringing the concentration of* Sonar® *in lake water back up to the target concentration) enhances the effectiveness and timeliness of the treatment without additional negative impacts on native species."*

In general, available literature supports and the MESB Panel concurs with both of the MDEQ conclusions; however, several suggested recommendations regarding the current MDEQ methodology for calculating lake volume and a more precise application rate are in order.

Lake Volume Calculations

As part of its 1999 program, the MDEQ provided guidance to lake managers to assist them in the development of Sonar® permit applications for the control of Eurasian watermilfoil. Contained in that package are procedures for calculating lake volumes (LWMD, 1999). The procedure calculates the amount of Sonar® that is needed to meet the targeted concentration in the upper 10 feet of the water body and partitions the water column and the amount of Sonar® to be applied into two compartments, the near shore zero to five foot *donut* and the five to 10 foot *donut hole*. The targeted amount of Sonar® should be based on the entire lake if the lake is shallower than 10 feet. In addition, it should be based on calculations for appropriate *donut* and *donut hole* volumes, based on the bathymetry of the lake.

Appendix 3 presents changes to the current MDEQ procedures for calculating lake volume for Sonar® treatment. The Panel's proposed revision incorporates several assumptions. First, it assumes that the bathymetry of the lake is known and that the area of the various surface areas for the zero, five, and 10-foot depth contours are correct. However, if those mapped areas are greater than the actual area, too much Sonar® will be applied to the lake. It also assumes that the lake does not have a well-established thermocline, or if it has, that it is below a depth of 10 feet. In order to address this, a temperature profile must be determined for the lake at the time of any treatment, and if a thermocline is present that is shallower than 10 feet (whether well established or not), appropriate adjustments need to be made in the amount of Sonar® to be applied. This will necessitate interpolation of the data to determine the surface area of the resultant upper bound of the thermocline since most depth contour maps

are in five foot increments. Making corrections for a thermocline will lessen the potential for applying too much herbicide. It is also assumes that the product rapidly disperses throughout the water column (at least within the epilimnion), which might not always be the case depending upon the morphometry of the lake basin and how well it is protected from the wind. In most other situations, the actual water column concentration of Sonar® will be less than the calculated amount since most lakes will contain water that is deeper than 10 feet and, if not stratified, will result in a dilution of the herbicide.

Selective Control and Recommended Application Rate

There have been no conclusive field data published in the literature to date that purports a specific effective Sonar® treatment rate for the control of Eurasian watermilfoil that will have *no* impact on non-target aquatic plant species. Studies on Michigan lakes prior to 1997 have indicated an array of responses in regard to control of Eurasian watermilfoil and impact on non-targeted species at various rates of Sonar®. (Kenaga, 1999; 1995; 1993; O'Neil, 1999; LWMD, 1997a; MDEQ, 1997). However, these results are anecdotal since actual lake concentrations of the herbicide were not measured in any of the evaluations.

Laboratory and mesocosm studies conducted by the U.S. Army Engineer Waterways Experiment Station (Netherland, Getsinger and Skogerboe, 1997; Netherland and Getsinger 1995a; 1995b) indicated that an application of five ppb Sonar® followed by an exposure period of 45 to 60 days at levels exceeding one ppb Sonar® was very near the threshold concentration required to selectively control Eurasian watermilfoil. Recent (post 1997) field studies reported on by Madsen *et al.* (In press) on four Michigan lakes following a 5-bump-5 Sonar® treatment protocol and by Madsen and Getsinger (In press) on two Michigan lakes following a 6-bump-6 Sonar® treatment protocol resulted in good to excellent control of Eurasian watermilfoil with minimal impact on whole lake native plant species.

Because of its mode of action and its distribution throughout the water column, the following three factors need to be considered in making a recommended Sonar® field application rate for selective control of Eurasian watermilfoil: (1) initial concentration, (2) extended exposure period, and (3) calculated versus actual application rates. First, field experience of the U.S. Army Engineer Waterways Experiment Station has shown that biological activity, physical absorption, and various degradation processes can reduce Sonar® availability for plant uptake by as much as 20 percent soon after application (Getsinger, Netherland and Madsen, 1998). Second, Netherland and Getsinger (1995a) found in mesocosm studies that to obtain effective selective control of Eurasian watermilfoil requires an extended exposure time beyond the initial dose of five ppb or greater. Third, calculated concentrations can be significantly influenced by errors in volume calculations based on erroneous depth-contour maps as well as the establishment of a persistent thermocline at the time of treatment. In addition, field data collected by the U.S. Army Engineer Waterways Experiment Station during the Michigan lakes project indicated that detectable levels of Sonar® are restricted to the epilimnion (Getsinger, 1999). Given these factors and, in particular, the results from the newer field studies (Madsen *et al*, In press; Madsen and Getsinger, In press), the

MESB Panel recommends that the application rate of Sonar® for selective control of Eurasian watermilfoil be six ppb followed by the potential of retreatment, boosting the concentration back to six ppb two to three weeks after the initial treatment based on results of a FasTEST® for water column concentrations of the compound.

Data Requirements for Sound Decision Making. MDEQ Conclusion 6 states:

> *"Sonar® is one tool for controlling Eurasian watermilfoil on a whole-lake basis*."

The MESB Panel concurs with this conclusion since each lake has unique aquatic plant populations and distributions. When exotic species, such as Eurasian watermilfoil, grow in numbers that are considered nuisance then all control options must be considered including mechanical harvest, chemical control, and nutrient source reduction.

There can be many reasons, both natural and man-induced, why a lake becomes a candidate for the use of Sonar® and/or other chemical and mechanical means of controlling nuisance aquatic weeds. However, prior to any action that seeks to "manage" natural lake resources, it is important that there exists a thorough understanding of the natural resource to be managed and of the goals, options, and effects of that management. Currently, the MDEQ requires that a Lake Vegetation Plan be prepared as part of the permit application process. However, only a minimum of information is requested. In order to more fully understand the dynamics of the interrelated natural ecological processes that operate within a lake and, therefore, the potential impacts that may take place due to manipulation of these processes, the Panel suggests that a greater level of information is needed.

There are several ways to achieve this greater level of detail. The most common is through the development of a lake plan. A lake plan establishes baseline information about the lake, assesses the problems of the lake, considers management options, sets timelines, and outlines a strategy for evaluating management alternatives and monitoring selected management efforts. In addition, it also can gain information about stakeholders' (property owners, lake planners, weed harvesters, environmental engineering services, and state regulators) goals. In the process of creating a plan, lake property owners become more aware of the unique characteristics of their lake and how their activities can impact the lake.

Appendix 4 presents one of several examples on how to create a lake plan (Klessig *et al.*, 1997) and Appendix 5 presents a tool to assist lake property owners in better understanding lake data (Shaw, Mechenich and Klessig, 1996). Both types of documents can be useful to lake property owners in helping them to better evaluate and manage their lake. The MESB Panel suggests that the MDEQ evaluate these and other similar lake information-gathering models and encourage the use of such tools in conjunction with its permit program.

Direct Impacts on Aquatic Animals and Humans. MDEQ Conclusion 7 states:

> *"*Sonar® *does not have any direct negative impacts on fish or wildlife populations, or pose any human health concerns when used according to the product label*."

Bremigan *et al*. (1999) prepared an annotated bibliography on the current and past research on the effects of Sonar® on fish, macroinvertebrates, and zooplankton. Based on the research summarized, and at levels recommended for application by this report, Sonar® will not accumulate in fish (West *et al.*, 1983); shows no indication of increased mortality, decreased body condition, or modified behavior in carp (Kamarianos *et al*., 1989); is well below lethal levels to fish (Hamelink *et al*., 1986); has no observable adverse effects of toxicity, growth, or survival to larval fish (Paul*,* Simonin and Symula, 1994); shows no effects on benthic and epiphytic macroinvertebrates such as accumulation or acute and chronic toxicity (Haag and Buckingham, 1991; Muir *et al.,* 1982); and shows no acute or chronic toxicity to zooplankton (Hamelink *et al.,* 1986).

Based on work completed by Probst (1982) and the material safety data sheet for Sonar® (SePro, 1996), there appears to be little risk at levels recommended by this report of carcinogenic, mutagenic, or teratogenic effects to animals including humans. Consequently, the MESB Panel concurs with MDEQ Conclusion 7 but recommends that it be modified by adding the words, "*and its permitted use by the MDEQ*" to the end of the sentence.

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Appendix 1

October 14, 1998 Correspondence to the Michigan Environmental Science Board from Governor John Engler

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STATE OF MICHIGAN
OFFICE OF THE GOVERNOR
LANSING

JOHN ENGLER
GOVERNOR

October 14, 1998

Dr. Lawrence Fischer, Chair
Michigan Environmental Science Board
Knapps Centre, Suite 340
P.O. Box 30680
Lansing, Michigan 48909-8180

Dear Dr. Fischer:

The Department of Environmental Quality (DEQ) has regulatory authority over the use of herbicides to control nuisance aquatic plants pursuant to the Public Health Code, 1978 PA 368, as amended, and Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. The DEQ issues permits for the use of chemicals to control specific plants in specific areas of a lake or pond. The primary challenge is to identify a plant control strategy that balances the needs of various uses (i.e., swimming, boating, fishing) with the need to protect the lake resources for fish and wildlife under current statutory authority. The challenge becomes greater, often to the point of controversy, when a new herbicide, for which there is limited information on its effectiveness and adverse impacts in Michigan, is introduced for use in the state. I am, therefore, requesting the Michigan Environmental Science Board's (MESB) assistance in reviewing the DEQ's preliminary conclusions regarding the use of one such herbicide, fluridone, whose registered trade name is Sonar.

The DEQ expects to begin the administrative rules process in the fall of 1998 to specify conditions under which Sonar may be used in Michigan. I seek the MESB's advice on the scientific principles that will form the basis of those rules. Specifically, I request that the MESB review and provide recommendations regarding the DEQ's preliminary conclusions on the use of Sonar and the range of appropriate rates of application, based on a review of available scientific information. Recommendations regarding additional long-term environmental and resource protection considerations related to the use of Sonar in Michigan lakes are also welcome.

The DEQ's preliminary conclusions regarding Sonar use are:

1. A balanced, diverse aquatic plant community should be maintained in all waterbodies for the maintenance of healthy fish and wildlife populations.

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2. Sonar should not be used in Michigan at or near the labeled rate to eliminate all or the majority of aquatic plants in a waterbody.

3. When Sonar is used to control Eurasian watermilfoil, negative impacts on native aquatic plants should be minimal in the year of treatment and in subsequent years.

4. The Sonar concentration that effectively controls Eurasian watermilfoil with minimal impacts on native species is between 5 and 8 parts per billion.

5. Boosting the concentration of Sonar 10-14 days after the treatment (i.e., bringing the concentration of Sonar in lake water back up to the target concentration) enhances the effectiveness and timeliness of the treatment without additional negative impacts on native species.

6. Sonar A.S. is one tool for controlling Eurasian watermilfoil on a whole-lake basis.

7. Sonar does not have any direct negative impacts on fish or wildlife populations, or pose any human health concerns, when used according to the product label.

I encourage the MESB to seek assistance from appropriate state and federal agencies, particularly the DEQ and the U.S. Army Corps of Engineers' Waterways Experiment Station, your peers in the academic and scientific communities, and those who are familiar with the use and effects of Sonar in Michigan. It would be most helpful if you could provide the results of your evaluation as soon as possible to the DEQ so they may begin the administrative rules process.

Thank you for your continuing service to the State of Michigan.

Sincerely,

John Engler
Governor

JE/pc

cc: Mr. Russell J. Harding, Director, DEQ
Mr. Keith G. Harrison, Executive Director, MESB

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Appendix 2

Interim Strategy, Sonar Use in Michigan in 1999

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MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
LAND AND WATER MANAGEMENT DIVISION

--- INTERIM STRATEGY ---
SONAR USE IN MICHIGAN IN 1999

February 1999

The Department of Environmental Quality (DEQ) intends to develop rules for Sonar use in Michigan based on the information obtained from field evaluations and other research, and the ongoing review of Sonar by the Michigan Environmental Science Board. The public and all other interested stakeholders, including other state agencies, will have an opportunity to provide input and to participate in the rules-making process.

The DEQ staff may issue permits for the use of Sonar under certain conditions as outlined in this interim strategy while the rules are being developed. Each permit application will be considered on a case-by-case basis, using site-specific information.

NOTE: It is generally recognized that early treatment with Sonar (usually in early May depending on weather conditions) to control Eurasian watermilfoil produces the most positive results. Therefore, complete permit applications, including all supporting documentation for these treatments should be submitted to the DEQ no later than March 15, 1999, to ensure that permits are issued for optimally-timed treatment.

General Sonar Treatments

1. Lakes

Sonar may be permitted at concentrations up to 5 parts per billion (ppb) in lakes with significant Eurasian watermilfoil infestations. The goal of this treatment is to selectively control Eurasian watermilfoil. The applicant will provide the following information with the permit application:

- Documentation of significant Eurasian watermilfoil infestation (i.e. plant survey results and map);
- authorization from affected riparian property owners;
- accurate calculations of lake volume based on the 10-foot depth contour and the method provided by the DEQ;
- a Vegetation Management Plan, including community input to the plan's development, on a form provided by the DEQ; and
- a schedule and a map of sampling sites for Sonar concentration monitoring.

The DEQ will provide instructions for calculating lake volumes, the Vegetation Management Plan form and guidance for developing the schedule, and sampling sites for Sonar concentration monitoring upon request. All required information must be approved by the DEQ prior to issuing a permit.

The DEQ will consider amendments to permits issued for this Sonar treatment scenario to control nuisance plants other than Eurasian watermilfoil on a case-by-case basis. A site visit by the DEQ and/or a plant survey may be required prior to amending a permit.

2. Ponds

Sonar treatments may be permitted in selected ponds with limited public trust value, as determined by the DEQ upon review of a permit application. These ponds are regulated due to multiple ownership or discharges to other waters. The applicant will monitor and report Sonar concentrations based on a DEQ-approved plan. The following Sonar treatments may be permitted in selected ponds:

a) Initial Sonar treatment of up to 8 ppb and subsequent retreatments, if needed, to maintain a maximum concentration of 5 ppb for 30 days in ponds up to 10 acres. The goal of this treatment is to selectively control Eurasian watermilfoil.

b) Sonar treatments of up to 15 ppb for control of Eurasian watermilfoil in ponds up to 10 acres that have no outflow. Permit applicants will need to document the Eurasian watermilfoil problem and demonstrate how the pond volume was calculated using actual depth measurements in the absence of a bathymetric map. The DEQ can provide assistance on developing an appropriate method for volume calculations.

c) Sonar treatments of up to 45 ppb for the control of duckweed in ponds with a history of 100 percent coverage and with a developing problem in 1999. Treatments will be limited to 30 ppb in ponds where emergent vegetation is present. Permits for up to 45 ppb may be issued for the control of duckweed only when no emergent vegetation is present. Photographs of the pond verifying the absence of emergent vegetation must accompany the permit application. Permits for these treatments will be considered for ponds with a surface area of up to 5 acres and having only a seasonal outflow (i.e. corresponding to high flow events in the spring and fall). Permittees should take care to follow the precautions on the product label when treating irrigation ponds.

3. Marinas

Sonar treatments at an initial concentration of up to 8 ppb and subsequent retreatments to maintain a maximum concentration of 5 ppb for 30 days may be permitted in commercial marinas where adjacent wetlands and water bodies will not be affected. The applicant will monitor and report Sonar concentrations based on a DEQ-approved plan.

Evaluation Treatments

Additional evaluations are needed to resolve several issues related to Sonar. These evaluations would ideally be conducted by independent agencies or public institutions that have the necessary facilities, resources, and knowledge, such as the U.S. Army Corps of Engineers and universities. However, in the absence of resources for such institutions, other interested participants may conduct the evaluations provided that they have demonstrated the ability and commitment necessary to collect, evaluate, and document plant and water quality data as outlined in the study plan.

The evaluation study plan will include detailed pre- and post-treatment plant surveys, including surveys the year following treatment and FasTESTs conducted at several different times and at several different locations, including depth profiles. An evaluation study plan that is agreeable to all participants, including the DEQ, and resources for conducting the evaluation must be in place before permits for the evaluation treatments will be issued. The DEQ can assist the investigators in developing evaluation strategies that will address remaining issues of concern. Permit applicants must also provide the information outlined under "General Sonar Treatments, Lakes" on page 1 with their permit applications.

Permits may be issued in the year following Sonar treatment for control of nuisance plants other than Eurasian watermilfoil based upon a case-specific evaluation**.**

Sonar treatments to evaluate the following will be considered:

1. Sonar should continue to be evaluated for selective control of Eurasian watermilfoil, building on the results obtained in the 1997 evaluation. Permits may be issued to treat lakes with Sonar at initial concentrations of up to 6 ppb, and amended to allow a retreatment back to the initial concentration (up to 6 ppb) approximately 2-3 weeks after the initial treatment. Permit amendments will not be approved if the initial concentration of Sonar in the lake exceeds 6 ppb, based on the average of all surface samples. The exact timing of the retreatments will be determined during development of the study plan**.**

2. Fall Sonar treatments should be evaluated to determine whether more selective, long-term control of Eurasian watermilfoil could be achieved with fall treatments than with spring treatments. Appropriate application rates will need to be determined.

3. Evaluation of 8-ppb Sonar treatments in lakes should continue to refine the predictability and manageability of this treatment scenario for selective control of Eurasian watermilfoil. If the results of the first FasTEST samples average less than 5 ppb, the permit may be amended for a retreatment to attain a concentration of 5 ppb Sonar. The great variability in results for this treatment concentration suggests that procedures for calculating the amount of Sonar to be applied may need to be refined.

4. Evaluate the long-term impacts on lake ecosystems of repeated Sonar treatments.

5. Evaluate the effectiveness of Sonar SRP treatments in marinas and for selective treatment of Eurasian watermilfoil in small areas of large water bodies. In addition to the application information listed on page 1, circulation patterns in the marinas and lakes must be presented with the permit application. The information will be needed to determine an appropriate Sonar application strategy. The DEQ will work with other interested parties to determine the Sonar application rates and an appropriate study plan(s).

Education and Training

It is clear from the 1997 evaluation that treatment objectives and public expectations may not always be consistent. Therefore, permittees and others involved in the Sonar treatments are encouraged to work with lake associations and lake boards to ensure that their plant control expectations can best be met by using Sonar as outlined in this strategy. The DEQ is interested in working cooperatively with the permittees, investigators, and others involved in the 1999 Sonar treatments to develop the needed educational materials and to meet with interested communities.

1999 GUIDANCE FOR FLURIDONE RESIDUE SAMPLING

Sampling Equipment

- Van Dorn-style water bottle
- Temperature probe
- Water bottles (125 ml) with labels/completion sheet
- Containers for shipping water samples to SePro
- Boat - one that has not been used to apply Sonar

Sample Kits and Handling

Sample kits are available from SePro Corporation. The kits contain the sample bottle and data sheets. Water samples and data sheets should be mailed to SePro Corporation immediately following sample collection. Results of the analyses will be provided to the permitee and to the Department of Environmental Quality.

Sampling Technique

Take care that sampling equipment, bottles, and your hands are not contaminated with Sonar or any other materials that may interfere with sample analysis. Samples should not be collected in water that is unnaturally turbid. Remove the bottle cap and submerge the bottle upside down until elbow deep (approximately one foot below the surface). Turn bottle over and allow filling, returning it to the surface, fastening cap and placing the bottle immediately into a dark cooler containing ice. Label samples with the lake name, site number, and the collection date and time. Also record the collection date and time on the data sheet.

Number and Locations of Sampling Sites

LAKES

Lakes less than or equal to 300 acres - five or more sampling sites.

- Three sites located near shore (at least 40 feet from shore in water greater than 5 feet deep) in a triangular pattern around the lake, and
- Two sites located over (different) deep spots off shore. *If there is only one deep spot, the last sample should be collected from the near shore,* OR
- One site located over the deepest spot off shore and one site in the center of each canal. If there are more than four canals, collect samples from only 25 percent of the canals.

Lakes between 300 and 500 acres - six or more sampling sites

- Four sites located near shore (at least 40 feet from shore in water greater than 5 feet deep) in a rectangular pattern around the lake, and

- Two sites located over (different) deep spots off shore. *If there is only one deep spot, the last sample should be collected from near shore,* OR

- One site located over the deepest spot off shore and one site in the center of each canal. If there are more than four canals, collect samples from only 25 percent of the canals.

Lakes greater than 500 acres - The number and location of sampling sites will be determined on a case-by-case basis

The number and location of sampling sites for fall treatments will be determined on a case-by-case basis.

PONDS

Each pond will have one sampling site in the center. Additional sites may be added on a case-by-case basis.

The permit applicant must provide a lake or pond map indicating the location of the sampling sites and their identification number. The approved sample location map will be attached to the permit.

Sampling Sites

Water samples for FasTest analysis will be collected as follows:

- Discrete surface samples throughout the near shore zone should be taken as described in Sampling Techniques.

- Discrete off shore sampling should be profile samples taken at:

    a. one foot below the surface (elbow depth),

    b. Lower epilimnion, and

    c. Upper hypolimnion.

- Water temperature readings are recorded at each one-meter depth at off shore sites.

- Sampling locations are identified on the approved identification map. Throughout the duration of the sampling period, the same locations must be used.

Sampling Frequency

LAKES

- General Sonar AS treatments.

    a. Application up to 5 ppb one time treatment.

        1. Sample all sites between 48 and 60 hours after initial treatment.

        2. Sample all sites at 30 days post-treatment.

- Evaluation Sonar AS Treatments.

    a. Application at 6 ppb with one time bump-up treatment to raise concentration back to 6 ppb.

        1. Sample all sites between 48 and 60 hours after the initial treatment.

        2. Sample all designated sites at 14 days post-treatment.

        3. Sample all sites between 24 and 48 hours after bump-up treatment.

        4. Sample all designated sites at 30 days post bump-up treatment.

        5. Sample all designated sites at 60 days post bump-up treatment.

    b. Application at 8 ppb.

        1. Sample all sites between 48 and 60 hours after the initial treatment.

        2. Sample all designated sites at 14 days post-treatment.

        3. Sample all designated sites at 30 days post bump-up treatment.

        4. Sample all designated sites at 60 days post bump-up treatment.

Note: If the permit is amended to allow a re-treatment under the 1999 Sonar Use Strategy, additional sampling requirements will be determined on a case-by-case basis and reflected in the amended permit.

    c. Applications for fall treatments.

        1. Sampling frequency will be determined on a case-by-case basis.

PONDS

    a. Application up to 8 ppb Eurasian watermilfoil.

        1. Sample designated site(s) between 48 and 60 hours of the initial treatment.

b. Application up to15 ppb one time treatment for Eurasian watermilfoil.

    1. Sample designated site(s) between 48 and 60 hours after the initial treatment.

c. Application up to 45 ppb one time treatment for duckweed.

    1. Sample designated site(s) between 48 and 60 hours after the initial treatment.

Note: If re-treatments are permitted under conditions outlined in the 1999 Sonar Strategy, additional sample requirements will be determined on a case-by-case basis and reflected in the amended permit.

PROCEDURE FOR CALCULATING LAKE VOLUMES FOR PROPOSED SONAR TREATMENTS

This is the standard procedure used to calculate the volume of water within the upper 10 feet of a lake and to determine the appropriate amount of Sonar to apply. The goal of this procedure is to achieve rapid and uniform distribution of a given concentration of Sonar by treating water within the 0-5 foot depth contour and within the 5-10 foot depth contours separately with different amounts of Sonar. This procedure determines the amount of Sonar necessary to treat an entire lake to a depth of 10 feet at a given concentration.

Volume Calculations

1. Determine the surface acres of the 0-, 5-, and 10-foot depth contours.
   Example: 0-,5-, and 10-foot depth contours are 239,189, and 71 acres respectively.

2. Use the following lake volume formula to calculate the volume of the lake between the surface and 5-foot depth.

   V(ac/ft) = h/3 (A1 + A2 +[sq. rt.(A1 x A2)]), where V volume, h = height of the water column, A1 = area of the lake surface, A2 = area of the 5 foot contour, A3 = area of the 10 foot contour. Results are in acre-feet. The volume of water to the 5-foot depth contour = 5/3 (239 + 189 [sq. rt. (239 x 189)] 1069 af.

3. Multiply the area of the 5-foot contour by 5 feet. 189a x 5f = 945 af.

4. Subtract Step 3 from Step 2. This equals the acre-feet in the 0- to 5-foot deep "donut" area. 1069 - 945 = 124 af.

5. Multiply Step 4 by 2.72. Then multiply that figure by the target concentration in parts per **million**. 124 x 2.72 x 0.005 = 1.7 pounds (or quarts) of Sonar. One quart of Sonar AS contains one pound of active ingredient. Distribute evenly in the 0- to 5-foot "donut" area.

6. Enter the 5- and 10-foot areas into the volume formula to find the volume of water between the 5- and 10-foot depths.
   Volume = 5/3 (189 + 71 + [sq. rt. of (189 x 71)]) = 628 af.

7. Add Steps 3 and 6 to get the volume of the "donut hole" area below the 5-foot depth contour to a depth of 10 feet (628 + 945 = 1573 af).

8. Multiply Step 7 by 2.72. Then multiply by the target concentration in parts per **million**. 1573 x 2.72 x 0.005 = 21.4 pounds or quarts of Sonar. Distribute this amount evenly in the 0- to 10-foot "donut hole" area.

9. Add Steps 5 and 8 to obtain the total amount of Sonar necessary to treat the lake to a depth of 10 feet at a depth of 10 feet at a concentration of 5 ppb (1.7 + 21.4 = 23.1 qts.).

Product Distribution

Distribute the Sonar in the 0- to 5-foot depth contour "donut" area by zigzagging the boat within the water that is 0 to 5 feet deep as evenly as possible. Distribute the Sonar in the water deeper than 5 feet (the "donut hole") in a crisscross pattern. Distributions are best when these areas are broken into smaller section areas and just the amount of Sonar used for that subsection is placed in the mixing tank.

ALTERNATIVE PROCEDURE FOR CALCULATING LAKE VOLUMES FOR PROPOSED SONAR TREATMENTS

This is an alternative procedure that can be used to calculate the volume of water within the upper 10 feet of a lake and to determine the appropriate amount of Sonar to apply. The goal of this procedure is to achieve rapid and uniform distribution of a given concentration of Sonar by treating water within the 0-5 foot depth contour and within the 5-foot and deeper depth contours separately with different amounts of Sonar. This alternative procedure uses fewer steps to determine the amount of Sonar necessary to treat an entire lake to a depth of 10 feet at a given concentration.

Volume Calculations

1. Determine the acres of the 0-, 5-, and 10-foot depth contours.
   Example: 0-, 5-, and 10-foot depth areas are 239,189 and 71 acres respectively.

2. Use the following formula to calculate the volume of water between the 0- to 5-foot depth contour "donut" area.

   V = (A1-A2) x 2.5 feet x 2.72 x Expected Sonar Concentration (in parts per million) where: V = volume, A1 = surface area of the entire lake, A2 = area of the 5-foot depth contour, A3 = area of the 10-foot depth contour.

   V = (239 – 189) x 2.5 feet x 2.72 x 0.005 = 1.7 pounds or 1.7 quarts of Sonar (1 quart of Sonar AS contains 1 pound of active ingredients)

3. Use the following formula to calculate the volume of water between 5- to 10-foot depth contour "donut" area.

   V = (A1 – A2) x 7.5 feet x 2.72 x Expected Sonar Concentration (in parts per million)

   V = (189 – 71) x 7.5 feet x 2.72 x 0.005 = 12.0 quarts of Sonar AS

4. Use the following formula to calculate the volume of water below the 10-foot depth contour "donut-hole" area.

   V = A3 x 10 feet x 2.72 x Expected Sonar Concentration (in parts per million)

   V = 71 x 10 feet x 2.72 x 0.005 = 9.7 quarts of Sonar AS

5. To Determine the total amount of Sonar AS for the entire lake, add Steps 2, 3, and 4
   (1.7 + 12.0 + 9.7) = 23.4 quarts.

Product Distribution

Distribute the Sonar in the 0- to 5-foot depth contour "donut" area by zigzagging the boat within the water that is 0 to 5 feet deep as evenly as possible. Distribute the Sonar in the water deeper than 5 feet (the "donut hole" area) in a crisscross pattern. Distributions are best when these areas are broken into smaller section areas and just the amount of Sonar used for that subsection is placed in the mixing tank.

LAND AND WATER MANAGEMENT DIVISION
MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

THREE YEAR
LAKE VEGETATION MANAGEMENT PLAN FOR SONAR USE

Lake: _____ County: _____ Years: _____ thru _____

LAKE CHARACTERISTICS

Lake size: _____ acres Source: _____

Littoral zone size: _____ acres _____ acre feet (Based on 0 feet to _____ feet)

Basis for littoral zone depth:

Vegetated littoral zone: _____ acres

See attached sheets for LAKE VOLUME CALCULATING PROCEDURES

Lake Volume: _____ acre feet (Based on 0 feet to 10 feet)
_____ acre feet (Based on whole lake)

Approximately Hydraulic Retention Time: _____ days

Source: _____

Outlet Flow: _____ Source: _____

NOTE: If any endangered or threatened species, or special plant communities (as defined by the Michigan Natural Features Inventory) are present, the use of herbicides may be limited.

ENVIRONMENTAL/RECREATIONAL VALUES

Lake Uses		Shoreline Uses	
Check appropriate box(es) and then indicate approximate level of use as identified by individuals and groups involved in the development of this plan.		(indicate approximate % of use)	
☐ Swimming	_____	Undeveloped	_____ %
☐ Boating	_____	Low Density Residential (Lot frontage > 100')	_____ %
☐ Water Skiing	_____	High Density Residential (Lot frontage < 100')	_____ %

Lake Uses (cont'd.)

- ☐ Fishing _____
- ☐ Hunting _____
- ☐ Wildlife/waterfowl habitat _____
- ☐ Irrigation _____
- ☐ Municipal drinking water water _____
- ☐ _____ Other

Shoreline Uses (cont'd.)

- Commercial _____ %
- Public Land/Park Areas _____ %

MANAGEMENT PLAN INPUT

Who has participated in developing the management strategy other than the herbicide applicator and/or consultant? Please attach a copy of the letter or other notification(s) requesting input to this plan, a list of groups invited to participate, and other supporting documentation, such as meeting agendas and summaries.

- ☐ Lake Board
- ☐ Sports Club
- ☐ Lake Association
- ☐ Back Lot Owner
- ☐ Townships/County
- ☐ Group of Individual Riparians
- ☐ Park Administrator/Board
- ☐ Single Owner
- ☐ Other (Specify) _____
- ____ Percent of total estimated lake users represented

____ Percent of Riparian Owners Participating or Responding

IDENTIFICATION/DESCRIPTION OF AQUATIC PLANT SPECIES

The following information and maps must be based on plant surveys conducted pursuant to DEQ's "Procedures for Aquatic Plant Surveys."

Check the targeted plant species and indicate their approximate percentage distribution in the littoral zone.

Survey dates (month/year): **,** **,**

☐ Eurasian Watermilfoil __ % ☐ Curlyleaf Pondweed _____ %

Native submersed plant species _____ %

List individual native plant species (present at > 1% coverage), percent coverage, and explain if and why they are a nuisance. Include submersed, floating leaf and emergent species. Include additional pages if necessary.

1. _____

2. _____

3. _____

4. _____

5. _____

Indicate the general distribution of the targeted plant species on separate TARGETED PLANT SPECIES MAP(S) as well as the overall approximate plant distribution and densities of all combined exotic and native plant species (taken from aquatic plant surveys) on a COMBINED PLANT SPECIES MAP.

The map should also include any other information as required in Section V (TREATMENT MAP) of the "DEPARTMENT OF ENVIRONMENTAL QUALITY (DEQ) APPLICATION FOR PERMIT FOR CHEMICAL TREATMENT TO CONTROL NUISANCE AQUATIC PLANT AND/OR ALGAE."

PLANT VEGETATION GOALS

Vegetation goal is to maintain _____% plant coverage in littoral zone.
Basis for goal _____.

Check the appropriate management goals that are to be achieved through this program.

☐ Create/maintain swimming areas

☐ Create/protect fish habitat

☐ Improve native plant diversity

☐ Protect endangered species

☐ Open up areas for recreational use (boating, water skiing, fishing, etc.)

☐ Remove exotics to improve fishery by allowing native plant communities to expand

☐ Create/protect wildlife habitat

☐ Other (specify) _____

Indicate on a single vegetation goal map the general locations (by species and densities) where plant communities are to be established or maintained as an achieved goal of the program.

PLAN TO ACHIEVE GOALS

AQUATIC VEGETATION MANAGEMENT PLAN

Propose a three-year aquatic vegetation management plan using integrated pest management concepts to achieve vegetation goals, by checking appropriate box(es) indicating the type of management concept(s) that is anticipated to be used each year. Write in the names of any herbicides to be used.

YEAR 1:	YEAR 2:	YEAR 3:
☐ Sonar	☐ Other systemic aquatic herbicides _____ _____	☐ Other systemic aquatic herbicides _____ _____
☐ Other systemic aquatic herbicides _____ _____	☐ Harvesting	☐ Harvesting
☐ Harvesting	☐ Contact herbicides _____ _____	☐ Contact herbicides _____ _____
☐ Contact herbicides _____ _____	☐ Other (specify) _____	☐ Other (specify) _____
☐ Other (specify) _____		

Indicate the areas of management for each year on ANNUAL VEGETATION MANAGEMENT MAP(S). Identical annual management plans can be presented on a single map indicating so.

Be sure to compare the vegetation goal map with the annual vegetation management maps to ensure that the proposed treatments are consistent with the stated goal.

LAKE MONITORING

Lakes to be treated with Sonar should be surveyed in late August/early September in the year prior to the Sonar application and at least twice during each subsequent year of the program. It is suggested that subsequent surveys be conducted in late May/early June and late August/early September (once prior to the treatment and after the treatment). Additional surveys should be conducted as needed to monitor plant response to the treatments. Results of pre- and post-treatment surveys should be mapped using DEQ's "Procedures for Aquatic Plant Surveys" and compared in order to predict or alter the management concepts so that the program goals can be achieved.

Make necessary adjustments in plant control strategies to achieve the goals of this plan with input from interested and involved parties including the Department of Environmental Quality and Department of Natural Resources.

APPLICANT'S REVIEW CHECKLIST

- ☐ All management plan information is completed to the best of your ability based on information currently available.
- ☐ Completed TARGETED SPECIES MAP(S)
- ☐ Completed COMBINED PLANT SPECIES MAP
- ☐ Completed VEGETATION GOAL MAP
- ☐ Completed ANNUAL VEGETATION MANAGEMENT MAP(S)

Appendix 3

Recommended Procedures for Calculating Lake Volumes for Proposed Sonar® Treatments

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Recommended Procedure for Calculating Lake Volumes for Proposed Sonar® Treatments.

As part of the 1999 program, the Michigan Department of Environmental Quality (MDEQ) provided guidance to lake managers to assist them in the development of Sonar® permit applications for the control of Eurasian watermilfoil. Contained in that package are procedures for calculating lake volumes. The procedure calculates the amount of Sonar® that is needed to meet the targeted concentration in the upper 10 feet of the water body and partitions the water column and the amount of Sonar® to be applied into two compartments, the near shore 0 to 5 foot *donut* and the five to 10 foot *donut hole*. The targeted amount of Sonar® should be based on the entire lake if the lake is shallower than 10 feet. In addition, it should be based on calculations for appropriate *donut* and *donut hole* volumes, based on the bathymetry of the lake.

It is important to recognize that this recommended procedure assumes that the bathymetry of the lake is known and that the area of the various surface areas for the 0, 5, and 10-foot depth contours are correct. It also assumes that the lake does not have a well-established thermocline, or if it has, that it is below a depth of 10 feet. In order to address this, a temperature profile must be determined for the lake at the time of any treatment, and if a thermocline is present that is shallower than 10 feet (whether well established or not), appropriate adjustments need to be made in the amount of Sonar® to be applied. This will necessitate interpolation of the data to determine the surface area of the resultant upper bound of the thermocline since most depth contour maps are in five-foot increments. Finally, it assumes that the product rapidly disperses throughout the water column (at least within the epilimnion), which might not always be the case depending upon the morphometry of the lake basin and how well it is protected from the wind. In most other situations, the actual water column concentration of Sonar® will be less than the calculated amount since most lakes will contain water that is deeper than 10 feet and, if not stratified, will result in a dilution of the herbicide.

Specific revisions to the MDEQ 1999 procedure include the following:

1. The equation for the volume of a frustum is correct as presented at the beginning of the second paragraph under Step 2; however, A_3 is not a part of that equation and the text referring to the area of the 10-foot contour was deleted. Also, in the example, a plus sign (+) was missing between the number *189* and the left square bracket before *sq. rt.*,

2. In Step 8, the last sentence was changed from *0- to 10-foot* to *5- to 10-foot*, and

3. An explanation is provided as to what *2.72* represents (see Steps 5 and 8); that is, the pounds of active ingredient that are in a one part per million solution in an acre-foot of water since one acre-foot equals 2,719,350 pounds of water.

This is the standard procedure used to calculate the volume of water within the upper 10 feet of a lake and to determine the appropriate amount of Sonar® to apply. The goal of this procedure is to achieve rapid and uniform distribution of a given concentration of Sonar® by treating water within the zero to five foot depth contour and within the five to 10 foot depth contours separately with different amounts of Sonar®. This procedure determines the amount of Sonar® necessary to treat an entire lake to a depth of 10 feet at a given concentration. An example is presented for calculating a concentration of six ppb Sonar® applied to a lake that has a surface area (0-foot) of 239 acres, and an area of 189 acres at the five foot depth contour and 71 acres at the 10-foot depth contour. The areas for those depth contours are represented by A_1, A_2, and A_3, respectively.

Volume Calculations Steps

1. *Determine the surface acres of the 0-, 5-, and 10-foot depth contours.*

2. *Use the following formula for calculating the volume of a frustum for the lake between the surface (0-foot) and 5-foot depth contours.*

V (acre-ft) = h/3 (A_1 + A_2 + [square root (A_1 x A_2)])

Where: V = volume, h = height of the water column in feet, A_1 = area of the lake surface in acres, and A_2 = area of the 5-foot contour in acres.

Example: The volume of water to the 5-foot depth contour = 5/3 (239 + 189 + [sq. rt. (239 x 189)]) = 1068 acre-ft

3. *Multiply the area of the 5-foot contour by 5 feet*

   Example: 189 acres x 5 ft = 945 acre-ft

4. *Subtract Step 3 from Step 2 to calculate the volume of water in the 0-5 foot donut area.*

   Example: 1068 acre-ft - 945 acre-ft = 123 acre-ft

5. *Multiply Step 4 by the number 2.72 (pounds of active ingredient in a one part per million solution in an acre-foot of water). Then multiply that value by the target concentration in parts per million, not parts per billion. One quart of Sonar® contains one pound of active ingredient. This quantity of product is then evenly distributed in the 0-5 foot donut area.*

   Example: At 6 ppb Sonar®; 123 x 2.72 x 0.006 = 2.0 pounds

6. *Enter the 5- and 10-foot depth contour areas into the formula for a frustum as presented in Step 2 to find the volume of water between the 5- to 10-foot depth contours.*

   Example: V = 5/3 (189 + 71 + [sq. rt. (189 x 71)]) = 626 acre-ft

7. *Add the values calculated for Steps 3 and 6 to determine the volume of the donut hole area from the 5-foot depth contour to a depth of 10 feet.*

   Example: 945 acre-ft + 626 acre-ft = 1571 acre-ft

8. *Multiply Step 7 by the number 2.72 (pounds of active ingredient in a one part per million solution in an acre-foot of water). Then multiply that value by the target concentration in parts per million, not parts per billion. One quart of Sonar® contains one pound of active ingredient. This quantity of product is then evenly distributed in the 5 - 10 foot donut hole area.*

   Example: At 6 ppb Sonar®; 1571 x 2.72 x 0.006 = 25.6 pounds

9. *Add the values in Steps 5 and 8 to determine the total amount of Sonar® necessary to the treat the lake to a depth of 10 feet at a given concentration.*

   Example: At 6 ppb Sonar®, 2.0 + 25.6 = 27.6 pounds (or quarts).

Product Distribution

Distribute the calculated amount of Sonar® for the 0 to 5-foot depth donut area by zigzagging the boat within the water that is 0 to 5 feet deep as evenly as possible. Distribute the calculated amount of Sonar® for the 5 to 10-foot donut hole in a criss-cross pattern.

Distributions are best when each of these areas are broken into smaller sectional areas and just the amount of Sonar® used for that subsection is placed in the mixing tank. However, this requires additional calculations for the respective subsections.

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Appendix 4

A Model Lake Plan for a Local Community

Klessig, L., B. Sorge, R. Korth, M. Dresen and J. Bode. 1996. *A Model Lake Plan for a Local Community*. Publication G3606, University of Wisconsin Extension, Madison. 28p.

This Appendix is not available electronically.

It is available by securing a printed copy of the complete MESB report:

Evaluation of the Use of Sonar in Michigan, October 1999.

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Appendix 5

Understanding Lake Data

Shaw, B., C. Mechenich and L. Klessig. 1996. *Understanding Lake Data*. Publication G3582, University of Wisconsin Extension, Madison. 20p.

This Appendix is not available electronically.

It is available by securing a printed copy of the complete MESB report:

Evaluation of the Use of Sonar in Michigan, October 1999.

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AVAILABLE REPORTS (1993 - 1999)

Premo, B.J., T.R. Batterson, J.A. Gracki, C.D. McNabb and K.G. Harrison. 1999**.** ***Evaluation of the Use of Sonar® in Michigan, October 1999.*** Michigan Environmental Science Board, Lansing. x + 97p.

Fischer, L.J., R.Y. Demers, R.H. Kummler, G.M. Swanson and K.G. Harrison. 1999. ***Evaluation of the Risk of Cancer among Fire Fighters, June 1999***. Michigan Environmental Science Board, Lansing, Michigan. 31p.

Fischer, L.J., P.M. Bolger, J.L. Jacobson, B.J. Premo, E.O. van Ravenswaay and K.G. Harrison. 1998. ***Evaluation of Michigan's Proposed 1998 Fish Advisory Program, January 1998***. Michigan Environmental Science Board, Lansing. vi + 67p.

Long, D.T., W.E. Cooper, W.B. Harrison III, R.H. Olsen, B.J. Premo and K.G. Harrison. 1997. ***Evaluation of Directional Drilling under the Great Lakes, October 1997***. Michigan Environmental Science Board, Lansing. 8p.

Fischer, L.J., R.Y. Demers, J. R. Harkema, R.H. Kummler, K.R. Rosenman, G.T. Wolff and K.G. Harrison. 1997. ***Evaluation of Air Quality and Human Health Issues involving Particulate Matter and Ozone, August 1997***. Michigan Environmental Science Board, Lansing. xii + 82p.

Fischer, L.J., P.M. Bolger, G.P. Carlson, J.L. Jacobson, M.A. Roberts, P.T. Thomas, K.B. Wallace and K.G. Harrison. 1997. **(*Impact of New PCB Information on 1995 MESB-Council of Great Lakes Governors Special Fish Advisory Report*), *Correspondence to Governor John Engler, January 21, 1997***. Michigan Environmental Science Board, Lansing, Michigan. 10p.

Premo, B.J., J.E. Carey, L.J. Fischer, D.T. Long, D.J. Morrissey, C.E. Nagle and K.G. Harrison. 1996***. Evaluation of Michigan's Low-Level Radioactive Waste Isolation Facility Siting Criteria, June 1996***. Michigan Environmental Science Board, Lansing. xiv + 94p.

Fischer, L.J., P.M. Bolger, G.P. Carlson, J.L. Jacobson, B.A. Knuth, M.J. Radike, M.A. Roberts, P.T. Thomas, K.B. Wallace and K.G. Harrison. 1995. ***Critical Review of a Proposed Uniform Great Lakes Fish Advisory Protocol, September 1995***. Michigan Environmental Science Board, Lansing. xii + 62p.

Bulkley, J.W., R.Y. Demers, D.T. Long, G.T. Wolff and K.G. Harrison. 1995. ***The Impacts of Lead in Michigan, March 1995***. Michigan Environmental Science Board, Lansing. xii + 48p.

Olsen, R.H., B.J. Premo and K.G. Harrison. 1994. ***(Report on Bacteriological and Macrophyte Contamination of Lake St. Clair), Correspondence to Governor John Engler, August 26, 1994***. Michigan Environmental Science Board, Lansing. 2p.

Fischer, L.J., R.J. Cook, R.Y. Demers, B.J. Premo, E.O. van Ravenswaay and K.G. Harrison. 1994. ***Impacts of Chlorine Use on Environmental and Public Health, June 1994***. Michigan Environmental Science Board, Lansing. x + 67p.

Fischer, L.J., J.W. Bulkley, R.J. Cook, R.Y. Demers, D.T. Long, R.H. Olsen, B.J. Premo, E.O. van Ravenswaay, G.T. Wolff and K.G. Harrison. 1993. ***Mercury in Michigan's Environment: Environmental and Human Health Concerns, April 1993***. Michigan Environmental Science Board, Lansing. xii + 144p.

Copies of the above reports may be obtained free of charge by either writing to:

Michigan Environmental Science Board
Knapps Centre, Suite 340, P.O. Box 30680, Lansing, Michigan 48909-8180

or downloading from the MESB Internet Home Page at
<http://www.mesb.org>