J. Aquat. Plant Manage. 17: 12-19

British Columbia Aquatic Plant Management Program

PETER R. NEWROTH

Project Manager
Aquatic Plant Management Program
Environmental Studies Division
Water Investigations Branch
Ministry of Environment
Parliament Buildings
Victoria, British Columbia
Canada V8V 1X5

ABSTRACT

A substantial and concerted effort has been made since 1972 by the Water Investigations Branch, British Columbia Ministry of Environment, to investigate the ecology, impacts and management of Eurasian watermilfoil (*Myriophyllum spicatum* L.). By 1977, this plant had spread to occupy about 580 ha of littoral zone in the Okanagan Valley mainstem lakes in British Columbia. The main elements of the British Columbia Aquatic Plant Management Program have included: surveys, mapping and documentation of Eurasian watermilfoil, research on its ecology, evaluations of mechanical and chemical control technologies, and attempts at containment and quarantine. Historical perspectives of the organization and functional components of the present program are presented.

INTRODUCTION

Aquatic plant management in British Columbia has become increasingly important since about 1970. The Water Investigations Branch (W.I.B.) of the British Columbia Ministry of Environment has been instructed to investigate, advise, and report on nuisance aquatic plant populations. This work has been performed as part of the general W.I.B. responsibility for studies on water quality and possible conflicts with multi-purpose uses, and to provide environmental protection of waters within the Province. The Aquatic Plant Management Program (A.P.M.P.) is the largest of a number of water quality-related studies currently being performed by the Environmental Studies Division, one of four divisions of the W.I.B. (see Figure 1). The Federal Government of Canada has supported some research on aquatic plant removal technology but has designated weed removal as a Provincial responsibility.

The water resources of British Columbia have been subject to growing exploitation and development for hydroelectric generation, navigation, flood control, irrigation supply, and the tourism industry. Tourism, which was in 1977 British Columbia's third largest industry, and the related increasing demand for improved aquatic recreational facilities, are important factors which stimulate concern about nuisance aquatic plants.

Public interest in the protection of traditional patterns

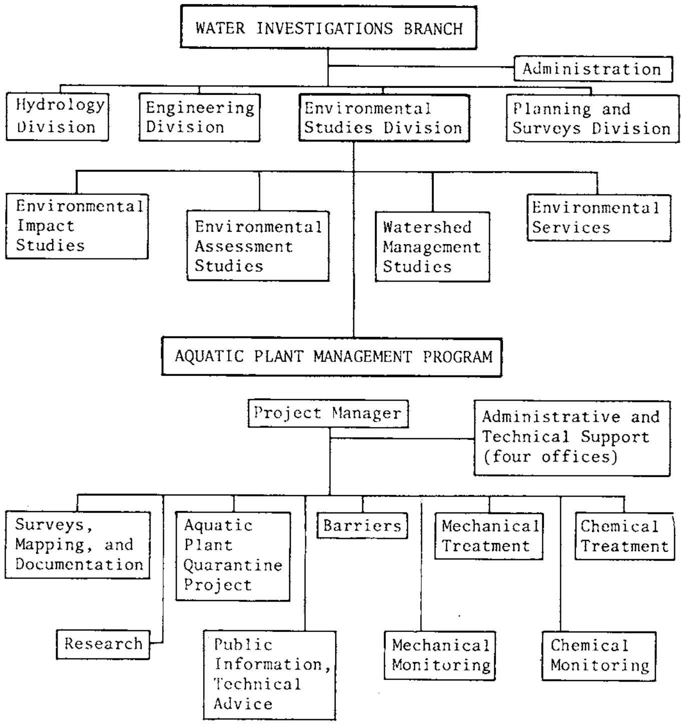

Figure 1. British Columbia Aquatic Plant Management Program—Administrative Structure.

of water usage has resulted in the requests for W.I.B. involvement in aquatic plant control. Since 1970, many lakes have been studied, including: Elk, Beaver, and Langford lakes on Vancouver Island; Magic Lake on Pender Island; and in addition to the six mainstem Okanagan lakes, Kathlyn, Windermere, Christina, Cultus and Paul lakes on the mainland. General water quality factors and a variety of aquatic plants in addition to Eurasian watermilfoil (including *Elodea canadensis* Rich. in Michx., *Potamogeton* spp., *Ceratophyllum demersum* L. and *Chara* spp.) have been studied. The joint Federal-Provincial Okanagan Basin Study (2) recognized the importance of rooted aquatic plants, and the sub-basin study on the Kalamalka-Wood lakes watershed reiterated need for aquatic plant management (3).

About 1971, Eurasian watermilfoil (misidentified as *M. exalbescens* Fernald) was observed in the Vernon Arm of Okanagan Lake and the W.I.B. involvement increased, as described here.

ORGANIZATION

Other Agencies

Because of the need to consider the input of the client groups and other concerned management agencies, the W.I.B. has made a substantial effort to communicate with outside groups. The Okanagan Basin Water Board (O.B.W.B.) is comprised of elected members and is recognized as the local body with responsibility for coordination of water-related matters in the Okanagan Valley watershed. It was the concern of the O.B.W.B. and local citizens that initiated the W.I.B. studies on Eurasian watermilfoil. Continued involvement of this local board and the Province of British Columbia have led to a number of cost-sharing arrangements for weed removal activities. The latest agreement, signed in May 1977, facilitated the establishment of the present A.P.M.P. Under the terms of this agreement, which remains in effect until 1980, the Province is responsible for funding, implementation, and supervision of a major program to control Eurasian watermilfoil in the Okanagan Valley, with administrative assistance from the O.B.W.B. The input of local representatives to help give direction to the Program is solicited through the Steering Committee appointed under the terms of the agreement.

The B.C. Aquatic Weed Committee was established in 1973 by the W.I.B. Technical representation from other Provincial and Federal agencies have continued to review and advise all levels of government in matters relating to aquatic plant management.

In October 1976, the Minister of Environment appointed an Advisory Committee, comprised of three University of British Columbia professors with expertise in medicine, engineering, and food science. This committee has reviewed all available information on management of Eurasian watermilfoil and has worked closely with the A.P.M.P. and the B.C. Aquatic Weed Committee. Their reports have provided guidelines for the implementation of the program in 1977 and 1978 (15).

AQUATIC PLANT MANAGEMENT PROGRAM

Figure 1 shows the present relationship of the A.P.M.P. to other sections of the Environmental Studies Division and within the W.I.B. During the 1978 operational season nearly 200 employees (including summer seasonal and Quarantine Project staff) were involved in the A.P.M.P. components shown in Figure 1. Although the central base for the W.I.B. is located in the Provincial capital, Victoria, the main operational office for the A.P.M.P. is centrally located in Penticton, with smaller offices in Vernon and Osoyoos, all in the Okanagan Valley.

SURVEYS, MAPPING AND DOCUMENTATION

Identification and documentation of the problem are prerequisites for planning and implementation of control activities and assessment of effectiveness. Knowledge of aquatic flora, field surveys and collections, and preservation of voucher specimens are all essential elements of good management. In 1972, a survey of all macrophytes was made in the mainstem Okanagan Valley lakes. The observations and the plant collections made in 1972 and subsequent years have become the basis for documentation of the spread of Eurasian watermilfoil.

Since 1975, detailed mapping of Eurasian watermilfoil populations has been performed (24). In 1977, several hundred lakes in British Columbia were surveyed for Eurasian watermilfoil; Figure 2 illustrates the distribution as recorded from those surveys. Table 1 provides details on populations in the six mainstem lakes of the Okanagan Valley and shows that the total area affected in this region increased 41% from 1975 to 1976 and 75% from 1976 to 1977. Based on surveys of littoral area available to support macrophyte growth, over 2000 ha are subject to potential infestation in these lakes.

TABLE 1. AREAS OF LAKE BOTTOM AFFECTED BY EURASIAN WATERMILFOIL IN THE OKANAGAN VALLEY, B.C. 1975-1977.

Lake	Hectares Affected By Watermilfoil		
	1975	1976	1977
Okanagan	233	288	405
Skaha	4	14	71
Vaseux	.1	28	75
Kalamalka	0.3	3	10
Osoyoos	0	0.8	25
Wood	<0.8	<0.8	<0.8
Total	238	335	586

By 1978, eight known species of *Myriophyllum* were recorded in British Columbia waters (*M. brasiliense* Camb., *M. elatinoides* Gaud., *M. exalbescens* Fern., *M. heterophyllum* Michx., *M. farwellii* Morong., *M. spicatum* L., *M. ussuriense* (Regel) Maxim., *M. verticillatum* L.). Research is continuing on phytochemical methods to separate species (11) and in preparation of a handbook for aquatic plants of British Columbia.

In the 1978 program, efforts were made to survey southern British Columbia for Eurasian watermilfoil. These extensive surveys resulted in the documentation of nearly 400 ha of Eurasian watermilfoil in the Lower Fraser Valley, distributed in about 40 locations.

RESEARCH

The research component of the A.P.M.P. has been investigating the literature (12) and reviewing data in the following major areas:

(1) Studies on aquatic macrophyte composition and abundance.
(2) Ecological studies on Eurasian watermilfoil, including seasonal growth, fragmentation, flowering and seed germination, and downstream drift.
(3) Evaluations of hundreds of sediment samples to relate sediment quality to factors which could encourage growth of Eurasian watermilfoil; studies of nutrient limitation possibilities.
(4) Investigations of interstitial water chemistry and possible treatments with NaCl and lime to discourage macrophyte growth.
(5) Reviews of biological control agents for Eurasian watermilfoil control in British Columbia (6).
(6) Reviews of technologies for utilization of Eurasian watermilfoil in British Columbia.
(7) Studies of repetive harvesting and evaluation of total plant stress.

PUBLIC INFORMATION AND TECHNICAL ADVICE

Because of concern for the problems created by Eurasian watermilfoil and interest in the technologies proposed for its control, public requests for information about the Program have increased. Reports prepared by W.I.B. staff about aquatic plant management are often too technical or lengthy for mass distribution to the general public, so pamphlets, information bulletins (4, 5) and posters have been prepared in the last several years. Efforts have been made to deposit appropriate literature in regional libraries and a motion picture on Eurasian watermilfoil was also released in 1978.

In 1977, a biologist employed on the program assumed the full-time task of responding to the media and to public requests for lectures and other information on the Aquatic Plant Management Program. Also, senior staff on the program are called upon to act as resource persons, and there have been increasing requests by agencies outside British Columbia for information. Because of international ramifications of the expansion of Eurasian watermilfoil in British Columbia (downstream spread could affect the Columbia River drainage), there has been need for continuing liaison with the State of Washington.

AQUATIC PLANT QUARANTINE PROJECT

In their Interim Reports, the Advisory Committee recommended that efforts should be made to reduce the chance of spread of Eurasian watermilfoil by boating activity (15). Special funds were requested from the B.C. Ministry of Labour to hire about 80 staff (mainly high school students) for a special quarantine project in summer, 1978. The objectives of this project were to assess the potential for transport of Eurasian watermilfoil from infested to non-infested lakes, to prevent transportation of this plant between major boat launching areas, and to encourage the public to help minimize spread.

In order to assist the quarantine workers, all boat launching areas in the Okanagan Valley were posted with signs, explaining the main objectives of the project. Larger notices advised motorists entering the affected areas. In addition to the Okanagan Valley, the Shuswap Lake area to the north and the Cultus Lake area of the Lower Mainland (see Figure 2) were staffed with a small number of quarantine workers. No Eurasian watermilfoil has been reported in the Shuswap region, but local agencies are concerned and have pressed for preventative action to avoid the introduction of this aquatic weed.

This project indicated that substantial numbers of boats and trailers transported Eurasian watermilfoil from affected areas and has provided valuable information to guide future preventative activities. Also, it provided an excellent opportunity for public education about this plant.

CHEMICAL TREATMENT AND MONITORING

In British Columbia, there has been no historical widespread use of or apparent need for herbicides for aquatic plant management. It was with reluctance that the W.I.B. was forced to consider the practical use of herbicides as a control technology. Major literature reviews of herbicide use of aquatic weed control were performed (9, 16) and partly because of the controversial nature of herbicide use, the Aquatic Weed Committee was formed.

Detailed monitoring of all proposed chemical trials was recommended and has been expanded over the past four years. Research trials with the bipyridyl herbicides (6,7-dihydrodipyrido (1,2-α:2′,1′-c) pyrazinediium ion (diquat) and 1,1′-dimethyl-4,4′-bipyridinium ion (paraquat) in 1974 and 1975 did not indicate that these materials gave promise for widespread use to control Eurasian watermilfoil. The

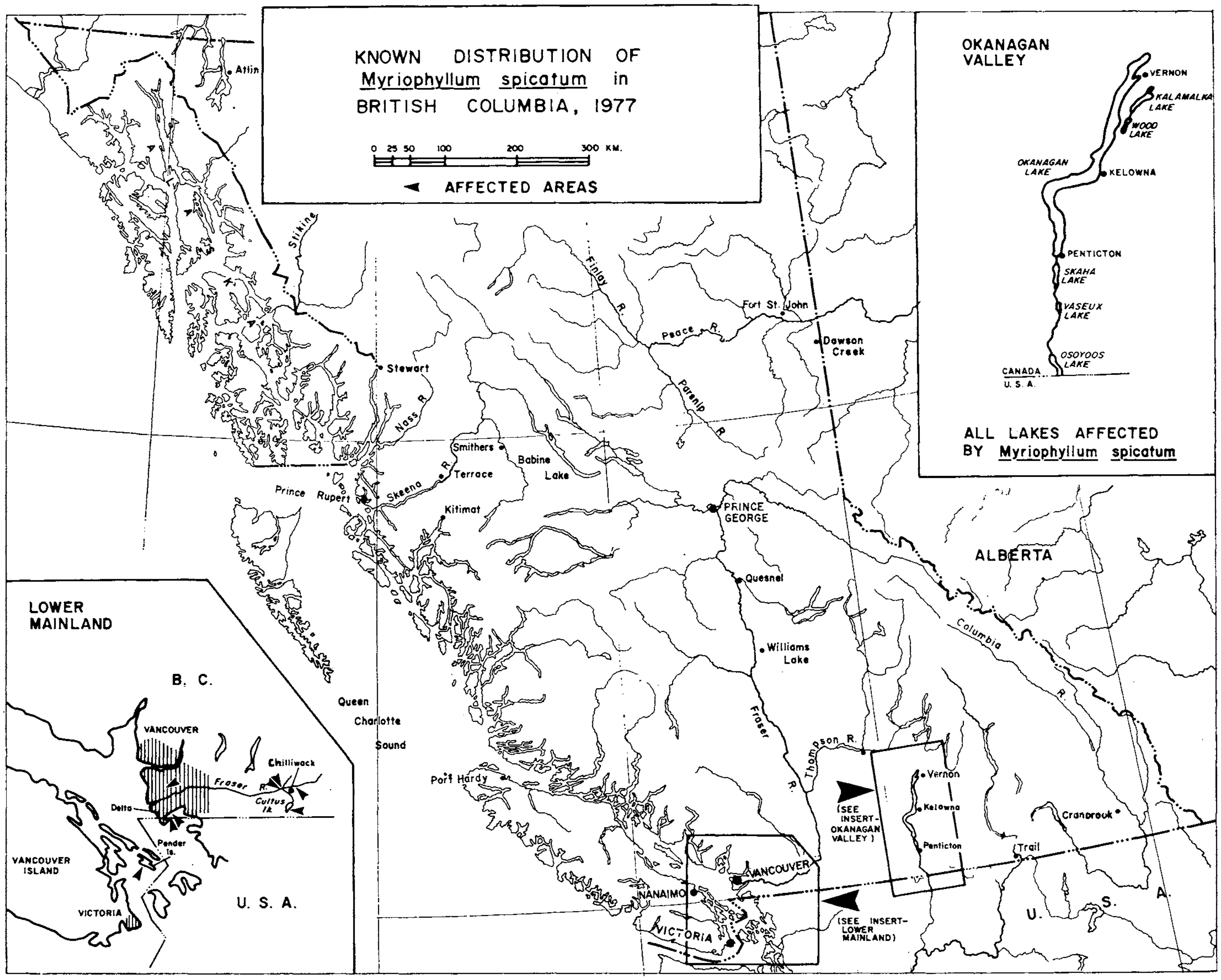

Figure 2. Map of British Columbia showing distribution of Eurasian Watermilfoil in 1977.

relatively high cost of liquid herbicides, difficulty in making applications to large, slowly-moving bodies of water, and the failure of diquat and paraquat to kill watermilfoil roots were recognized as major disadvantages (7, 23).

During the winter of 1975-1976 laboratory trials were performed with the butoxyethanol ester of 2,4-dichlorophenoxyacetic acid (2,4-D: "Aqua-Kleen 20") (13). This research showed that root and shoot kill of Eurasian watermilfoil could be achieved and encouraged a large scale field trial in the North Arm of Okanagan Lake in spring and summer, 1976. Applications of "Aqua-Kleen 20" in two adjacent areas (each approximately 0.6 ha) at the 22.5 kg/ha a.e. rate were carefully monitored for herbicide persistence, drift, effects on Eurasian watermilfoil, non-target vegetation, and water quality. Good control was achieved in the test areas, and no major or persistent environmental changes were recorded (14).

The results of these trials were reviewed by the Advisory Committee and additional trials were recommended for 1977. Four areas were selected for a variety of trials (including some combinations with mechanical methods) in Okanagan and Skaha lakes (see Figure 3), and a total of 9.5 ha were treated with rates between 22 and 45 kg/ha a.e. These applications were monitored to determine effectiveness, persistence and drift of 2,4-D, effects on non-target organisms, and water quality. Funds have been provided by the W.I.B. to the B.C. Fish and Wildlife Branch during fiscal years 1977-1978 and 1978-1979 to support detailed studies on (1) the impacts of Eurasian watermilfoil on fisheries and waterfowl and (2) the impacts of the control technologies on wildlife.

A total of 2,300 samples of water, sediment and plant tissues were analyzed for 2,4-D levels after applications in 1977. Summaries of the results of the studies of concentrations in water are shown in Tables 2 and 3. Following the treatments, qualitative and quantitative evaluations of effectiveness in controlling Eurasian watermilfoil were recorded. Observations on experimental areas were continued in the 1978 growing season; a summary of the results has been published as an Information Bulletin (5).

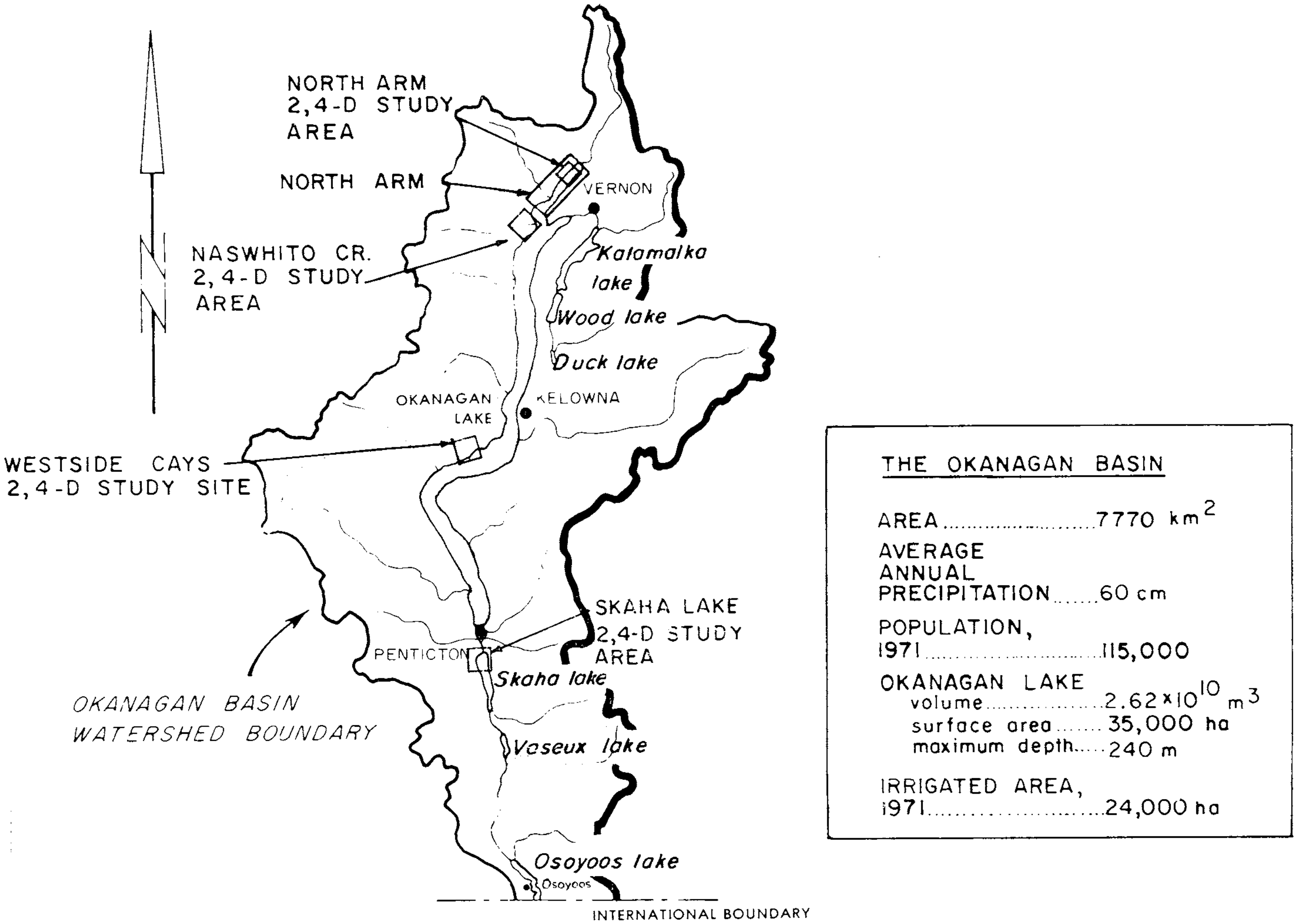

Figure 3. Map of the Okanagan Valley, B.C., showing 2,4-D application sites in 1977.

In summary, 2,4-D was shown to be effective in controlling Eurasian watermilfoil and killed the plant roots in most treatments. The main factors affecting the success of treatments include: weather conditions, time of year, water depth, the configuration and density of the target vegetation, and the uniformity of the application of granules. Because the policy adopted by the Ministry of Environment is aimed to prevent exposure of the public to levels of 2,4-D above the detectable level in water (0.001 ppm), thorough surveys have been made of all water intake systems in the Okanagan Valley lakes. The information gathered was used in the design of permit requests for 2,4-D applications. Buffer zones of between 200 and 1500 m between treatment areas and active water intakes were recommended (15).

In British Columbia, pesticide use is closely regulated by Provincial legislation (Pesticide Control Act) and permits are required for use on public lands or waters. The W.I.B. applied in 1978 for 28 permits to treat a total of about 500 ha of littoral area affected by Eurasian watermilfoil. Permits were received for approximately 200 ha, and all permits were subject to an appeal process. These procedures, illegal protest demonstrations, and legal manoeuvres by environmental groups caused irreparable delays in execution of the permits, so the 1978 herbicide treatment program was severely curtailed and only about 13 ha were treated.

Table 2. Summary of 2,4-D concentrations (ppm) in water sampled from treatment areas (1977).

Application Site	Maximum 2,4-D Concn.		Detectable 2,4-D (days)	No. Samples
	Surface	Bottom		
Open Sites				
Skaha Lake	0.063	0.14	6	97
Naswhito Cr.[1] (45 kg/ha a.e.)	0.19	0.23	9	153
North Arm[1] (22 kg/ha a.e. Retreatment)	0.056	0.36	10	68
North Arm[1] (33 kg/ha a.e.)	0.060	3.25	6	68
North Arm[1] (22/45 kg/ha a.e.)	ND[2]	0.67	6	74
Enclosed Site				
Westside Cays[1] (11-33 kg/ha a.e)	1.26	4.0	59	198

[1] Okanagan Lake sites.
[2] ND—no detectable level recorded.

TABLE 3. SUMMARY OF 2,4-D CONCENTRATIONS (PPM) IN WATER AT DRIFT STATIONS AFTER TREATMENTS (1977).

Application Site	Maximum Detected 2,4-D	Maximum Distance 2,4-D (m)	Concn. At Maximum Distance	Detectable 2,4-D (days)	No. Samples
Skaha Lake	0.017	140	0.017	1	40
Naswhito Cr.	0.038	39	0.026	3	207
North Arm (22 kg/ha a.e. Retreatment)	0.059	67	0.013	10	160
North Arm (33 kg/ha a.e.)	0.055	15	0.013	2	176
North Arm (22/45 kg/ha a.e.)	0.074	27	0.074	2	110

MECHANICAL TREATMENT AND MONITORING

A wide variety of mechanical treatment technologies and their effectiveness have been examined by the W.I.B. since 1972. Also, the possible use of lake drawdown has been studied. Experiences with mechanical options are summarized below, in chronological order:

1972:

An Aquamarine harvester was leased and extensively tested in studies sponsored jointly by the W.I.B. and the O.B.W.B.

1973:

This used harvester was purchased under joint funding from the Province and the O.B.W.B. and a major report was prepared (17).

1974:

Continued use of the harvester did not provide lasting control, and since it tended to encourage further spread of Eurasian watermilfoil, reviews of other mechanical removal options were continued.

1975:

A contractor was hired to perform experimental trials with a "Mud Cat" suction dredge, which treated approximately 4 ha of Eurasian watermilfoil infestation on Vernon Arm of Okanagan Lake. Extensive monitoring of this trial indicated that this method was slow, expensive and limited to areas where there were no obstacles (8, 9).

1976:

The Aquamarine harvester was converted into a floating rotovator and extensive trials with tractor-mounted, amphibious, and floating rotovators were performed; about 80 ha were treated. Initial evaluations indicated that root removal by this method provided good seasonal control of Eurasian watermilfoil (9). The use of bottom barriers and hydraulic washing devices also was examined.

1977:

Three basic types of mechanical treatment were performed in 1977. The old rotovator, a new Aquamarine harvester, and a contracted diver-operated suction dredge were used as outlined in Table 4. A new rotovator was constructed late in 1977, and between November and December, 1977, an additional 6 ha of plants were treated in Kalamalka Lake. A summary of the 1977 mechanical program has been outlined in an Information Bulletin (4).

In 1977, the Ministry of Environment sponsored a national Design Contest (with $17,500 of prize money) to encourage the development and submission of new concepts for Eurasian watermilfoil control. About 220 parties showed interest in details of this competition and 22 entries were received at the close of the contest. An independent panel of judges awarded prizes to the three "best" designs, and the First Prize winner has been encouraged to construct his machine for trials in 1979.

1978:

For the 1978 operating season, 10 large machines were deployed for Eurasian watermilfoil control in Okanagan, Skaha, and Kalamalka lakes. Two new Aquamarine harvesters were delivered during fall and winter (1977-1978). These machines were equipped with special cutter heads which harvest to a depth of 2.5 m instead of the 1.5 m depth on standard models. Approximately 205 ha was treated by all mechanical methods in 1978.

Two rotovators (one a modified Aquamarine harvester and the other a new design fabricated in a local machine shop) were also deployed early in the spring. Since rotovators can operate effectively before Eurasian watermilfoil plants are in a stage of active growth, they have a much longer practical operating season. However, their speed is slow, with a relatively high operating cost as compared to harvesting (see Table 4).

TABLE 4. APPROXIMATE RATES AND COSTS OF MACHINE OPERATION (1977) FOR CONTROL OF EURASIAN WATERMILFOIL.

Machine Type	Area Operated (ha)	Approximate Rate of Operation (ha/day)	Approximate Cost of Operation[1] ($ per ha)
Floating Rotovator (modified Aquamarine Harvester)	10	0.08-0.28	741- 2965
Aquamarine Harvester (new in 1977)	45	0.73-1.05	213- 262
SCUBA diver operated dredges (2 types)	4	0.03-0.05	4942-18,532

[1] Estimates are based on 1977 operations and include operating and maintenance costs, and depreciation, but do not include costs of weed fragment collection or disposal (Canadian dollars).

Following the 1977 experiences with small diver-operated suction dredges, five larger units were constructed for operation during the 1978 season. Because of the high pay rates for the divers and the slowness of the operation, these units are practical only in areas of small new infestations. The diver dredges were particularly valuable in removal of plants adjacent to water intakes, around docks, breakwaters and other obstacles and as a follow-up procedure following rotovation. Diver-operated suction dredges may be nearly 100% effective and have been used to attempt to contain small infestations in Kalamalka Lake.

Combinations of treatments have been tested; for instance, harvesters were used to pre-treat dense colonies by removing top growth and stimulating new growth which may enhance subsequent herbicide treatment. Also, rotovators may provide a beneficial pre-treatment to 2,4-D applications.

Monitoring of all mechanical operations was given a high priority in 1978 in order to assess and improve machine effectiveness. This is particularly important since rotovating and diving dredges are relatively new technologies. Rotovators have been shown to be up to 95% effective in removal of Eurasian watermilfoil roots and stems, depending on the substrate type and other bottom characteristics. Rapid recolonization or regrowth from root crowns remaining after rotovator treatment has resulted in regrowth to approximately 50% of pretreatment density within one growing season and 100% of pretreatment density by the end of the second growing season following treatment (4).

BARRIERS

Three types of barrier systems have been utilized in the A.P.M.P. to control spread of Eurasian watermilfoil fragments, since natural fragmentation, and the action of winds, waves, and boaters tend to disperse buoyant, viable segments of this plant. Fragments generated by harvesters and rotovators are contained by floating barriers deployed around the machine operation. The barriers are constructed in sections with a flotation portion (expanded polyethylene cylinders, dimensions 15 cm by 2.5 m) suspending anchovy netting (1.2 cm square mesh and about 2 m deep with lead line). Although the labour of installation is high, the barriers are invaluable to prevent undue spread of fragments, especially in areas where Eurasian watermilfoil has potential for further expansion.

Downstream drift of floating fragments is believed to have been the main cause of the rapid infestation of lakes downstream from the initial populations in Okanagan Lake. Barrier systems were deployed across the main channels of the Okanagan River at Penticton, at the outlet of Skaha Lake, the outlet of Vaseux Lake and at the inlet of Osoyoos Lake (see inset map in Figure 2). These barriers are supported across the channels on flotation similar to the floating barriers described earlier, but the weed fragments are caught by 1 or 5 cm wire mesh attached to a wire rope. Maintenance crews remove the plant material collected on these barriers and record information on the material removed. These data will be useful to help evaluate the effectiveness of the barrier systems and to establish the desirability of annual maintenance of similar systems. If the present systems prove effective, they could be used to help prevent the massive reinfestation of downstream areas following systematic removal activity.

The third type of barrier system has been placed at two locations on Osoyoos Lake, which straddles the International Boundary between British Columbia and the State of Washington (see Figure 3). Osoyoos Lake is comprised of three sub-basins, and steel mesh barriers (1.2 cm galvanized weld-mesh) were installed at the two narrowest (maximum distance approximately 450 m) and shallowest places. Openings to permit the passage of recreational boating traffic and appropriate navigation and hazard markings were provided.

The installation of these lake barriers, in effect, isolated the northern basin on Osoyoos Lake from the central and south basins. Considerable quantities of Eurasian watermilfoil have collected on the northern, upstream lake barrier since the northern basin has the largest infestations. The central and southern basins only have small populations of Eurasian watermilfoil because of intensive mechanical removal operations (diver-operated dredges) on the Canadian shorelines and spot applications of 2,4-D by the Washington State Department of Ecology on the American shorelines. Since the outlet of Osoyoos Lake (Okanogan River) flows into the Columbia River, these efforts may delay the introduction of Eurasian watermilfoil to other waters.

STRATEGIES OF AQUATIC PLANT MANAGEMENT PROGRAM

Proposals for the 1978 A.P.M.P. were outlined late in 1977 (22) and were supported by the Advisory Committee (15). Although eradication of Eurasian watermilfoil is desirable wherever possible, it was recognized that this was an unrealistic goal for most of the Okanagan Basin mainstem lakes. Previous W.I.B. reports had recommended earlier and more timely action to prevent expansion and to encourage more active removal and containment measures (10, 18, 19, 20, 21). The experience of other agencies, such as the Tennessee Valley Authority, clearly demonstrated the need for prompt and effective action (1).

The control programs for 1978 were designed to make major reductions in Eurasian watermilfoil populations in Okanagan, Skaha, and Vaseux lakes and to attempt eradication in Kalamalka and Osoyoos lakes. The priorities for 1978 included:

(1) Maximum cosmetic benefits to be provided to areas which requested weed removal (using the lowest cost option, harvesting).
(2) Concentration of machines with longer-term effectiveness in areas where this more costly removal would be of maximum benefit.
(3) Improvements in knowledge of all technologies through continued documentation and completion of detailed reports.
(4) Documentation of expansion of Eurasian watermilfoil throughout British Columbia.
(5) Early preparation for the 1979 operational season.

The implementation and integration of *all* elements of the proposed program was essential to achieve the desired goals. The funding provided for the 1978 program was adequate to acquire the staff and equipment necessary for implementation. Unfortunately, permits required for large scale "Aqua-Kleen 20" applications were not received, and subsequent appeals and public protest demonstrations prevented the selective and timely use of herbicides.

Because of the continued expansion of Eurasian watermilfoil and loss of valuable time in 1978, the A.P.M.P. now must be modified, using information gathered in the 1978 operating season to design new objectives for 1979. At this time, continued efforts at containment of Eurasian watermilfoil throughout British Columbia and strenuous efforts to achieve maximum control in Kalamalka and Wood lakes appear to offer the best long-term management value. Because large areas of other water bodies are now populated by Eurasian watermilfoil, successful control requires containment and the reduction of the size of these infestations at an affordable cost, on a lake-by-lake basis. The best program would lead to a reduction of the control efforts, over time, until only a small maintenance operation is required. Unless mechanical control devices are developed with greater effectiveness than those now available or the use of herbicides (2,4-D) is permitted as a large part of the program, Eurasian watermilfoil colonies will continue to spread to other water bodies in British Columbia and into the State of Washington.

LITERATURE CITED

1. Anon. 1972. Environmental Statement. Control of Eurasian watermilfoil (*Myriophyllum spicatum* L.) in TVA Reservoirs. Tennessee Valley Authority, Office of Health and Environmental Science, Chattanooga, Tennessee. 22 pp.
2. Anon. 1974. Summary Report of the Consultative Board including the Comprehensive Framework Plan, prepared under the Canada-British Columbia Okanagan Basin Agreement, March, 1974. i-v, 43 pp.
3. Anon. 1974. Kalamalka-Wood Lake Basin Water Resource Management Study. Water Investigations Branch, Department of Lands, Forests and Water Resources, Parliament Buildings, Victoria, British Columbia. December, 1974. i-xxvi, 208 pp.
4. Anon. 1978. Information Bulletin, Aquatic Plant Management Program, Okanagan Lakes. Volume II: Summary of Program Results for 1977. Water Investigations Branch. 11 pp.
5. Anon. 1978. Information Bulletin, Aquatic Plant Management Program, Okanagan Lakes. Volume III: Special Edition on Results of 1977 Herbicide Application for Water Milfoil Control. Water Investigations Branch. 12 pp.
6. Baillie, B. R., D. L. Bissell and N. M. F. Kirk. 1973. Crayfish as a biological control measure for aquatic macrophytes. Water Investigations Branch Report No. 2049. 17 pp.
7. Bryan, A. D. (Editor). 1977. Studies on aquatic macrophytes. Part IX. Experimental herbicide treatment for aquatic weed control, Kelowna Boat Basin, Okanagan Lake, 1975. Water Investigations Branch Report No. 2627. 55 pp.
8. Bryan, A. D. (Editor). 1978. Studies on aquatic macrophytes. Part VIII. Experimental hydraulic dredging for aquatic weed control in Vernon Arm, Okanagan Lake, 1975. Water Investigations Branch Report No. 2727. 158 pp.
9. Bryan, A., K. Marsden, and S. Hanna. 1975. A summary of observations on aquatic weed control methods. Water Investigations Branch Report No. 2351. 23 pp.
10. Buchanan, R. J. 1976. Briefing Paper on Eurasian Water Milfoil (*Myriophyllum spicatum* L.). Water Investigations Branch Report No. 2471. 16 pp. + 10 accompanying documents. (Summary only, Water Investigations Branch Report No. 2463. 16 pp.).
11. Ceska, O. 1977. Studies on aquatic macrophytes. Part XVII. Phytochemical Differentiation on *Myriophyllum* Taxa Collected in British Columbia. Water Investigations Branch Report No. 2614. 33 pp.
12. Kangasniemi, B. 1975. Lake sediments and rooted macrophytes with particular reference to *Myriophyllum spicatum* in Okanagan Lake. Water Investigations Branch Report No. 2350. 19 pp.
13. Lim, P. G. 1978. Studies on aquatic macrophytes. Part XVI. A laboratory experiment with granular 2,4-D for control of Eurasian water milfoil, 1976-1977. Water Investigations Branch Report No. 2726. vi, 25 pp.
14. Lim. P. G. and K. R. Lozoway. 1977. Studies on aquatic macrophytes. Part X. A field experiment with granular 2,4-D for control of Eurasian water milfoil, 1976. Water Investigations Branch Report No. 2613. 105 pp.
15. MacKenzie, C. J. G., W. D. Powrie and W. K. Oldham. 1978. Interim Reports of the Advisory Committee on the Control of Eurasian Water Milfoil in the Okanagan Lake System of British Columbia, March, 1978. B. C. Ministry of Environment, Map Production Division. 19, 21, 4, 19 pp.
16. Newroth, P. R. 1974. Studies on aquatic macrophytes. Part IV. A review of the ecology and control of some aquatic macrophytes. Water Investigations Branch Report No. 2169. 64 pp.
17. Newroth, P. R. 1974. Studies on aquatic macrophytes. Part V. Aspects of aquatic weed control by mechanical harvester. Water Investigations Branch Report No. 2170. 54 pp.
18. Newroth, P. R. 1974. A discussion of some aspects of aquatic weed growth in Okanagan Lake. Water Investigations Branch Report No. 2182. 8 pp.
19. Newroth, P. R. 1975. Management of nuisance aquatic plants. Water Investigations Branch Report No. 2337. 15, 5, 9 pp.
20. Newroth, P. R. 1975. Aquatic plant management, Okanagan Basin, British Columbia. Water Investigations Branch Report No. 2371. 24 + 5 pp.
21. Newroth, P. R. 1976. An outline of aquatic plant management options considered in British Columbia. Water Investigations Branch Report No. 2462. 6 pp.
22. Newroth, P. R. 1977. Proposals for the 1978 Aquatic Plant Management Program. Water Investigations Branch Report No. 2628. 19 pp.
23. Newroth, P. R. and P. G. 1979. Studies on aquatic macrophytes. Part VI. Experiments with herbicides for aquatic plant management, Okanagan Lake, 1974. (Water Investigations Branch report in preparation).
24. Nijman, R. A. 1976. Studies on aquatic macrophytes. Part VII. Aquatic plant documentation, Okanagan Basin, 1975. Water Investigations Branch Report No. 2424. 31 pp. + 9 maps.

J. Aquat. Plant Manage. 17: 19-21