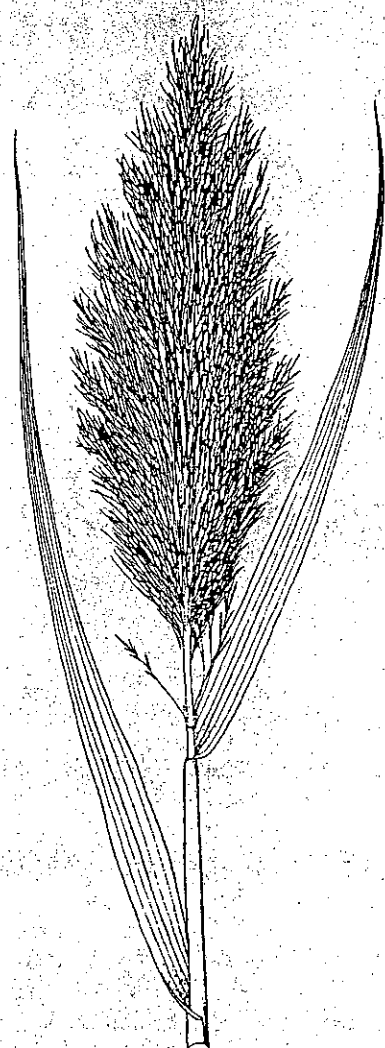
MANAGING COMMON REED (*Phragmites australis*) IN MASSACHUSETTS

An Introduction to the Species and Control Techniques



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Managing Common Reed (*Phragmites australis*) In Massachusetts

An Introduction to the Species and Control Techniques

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With Assistance from the Phragmites Working Group

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USE AND INTENT OF THIS REPORT

The Wetlands Restoration and Banking Program (WRBP) was established in the Massachusetts Executive Office of Environmental Affairs in 1994 to further address the State's goal of "no net loss of wetlands in the short term and a net gain in the long term." Proactive (voluntary) wetlands restoration is a primary function of the program. It soon became apparent that common reed (*Phragmites australis*) was present at a large number of potential wetland restoration sites in the State. Equally apparent was the general lack of knowledge about the plant and its management. Despite a predominant view that common reed is rapidly spreading and adversely altering many Massachusetts wetlands, little is known about its current distribution across the Commonwealth. Furthermore, the State has no particular policy regarding common reed. When it is present in wetlands, it is given the same protection as other wetland plants. This has hampered some attempts to control common reed and restore more diverse wetland plant communities. The regulatory process has also discouraged others from pursuing wetland restoration where common reed is a factor.

WRBP began to gather information on *Phragmites* and assembled a group of wetland scientists, land managers, and others who had experience with common reed (the Phragmites Working Group) to help WRBP sort through the many technical and policy issues surrounding this controversial species. In addition, WRBP distributed a *Phragmites* Survey Form to conservation commissions, watershed associations, and others in an attempt to discover the location of major *Phragmites* stands throughout the State.

This report includes: 1) a compilation of information about common reed and management strategies, 2) the results of the survey, and 3) a set of management and policy recommendations. The overall purpose of the report is to provide a broad overview of the ecology and management issues related to common reed in Massachusetts. It is not intended to be a comprehensive or exhaustive treatment of these subjects nor does the report provide detailed guidance on how to control *Phragmites* at specific sites. This report is a summary document that should acquaint readers with pertinent issues. Presentation of the material is designed for a non-technical audience. For more detailed technical information, readers are referred to the bibliography presented at the end of this report. The report should be useful to conservation commissions and their agents, public and private land managers, and others with an interest in this species, especially those considering control of this often-times invasive species. It should inform readers about the host of issues surrounding this controversial species. It is hoped that this report will help improve the decision-making process and will lead to more successful control of common reed where needed.

The report is arranged in six sections dealing with the following topics: 1) ecology, values, and uses, 2) the *Phragmites* issue (e.g., current problems, where common reed is not a problem, problem stand identification, and causes of invasion), 3) control and management (including basic strategies, specific control techniques, special considerations, baseline environmental conditions and monitoring), 4) regulatory issues (permit requirements), 5) results of case studies, and 6) recommendations of the Phragmites Working Group. An extensive list of references is provided at the end of the report. The list is more extensive than the articles used to prepare this report and should be a good source of additional information for interested readers. Two appendices provide copies of various forms that may be helpful in recording results of monitoring efforts: Appendix A - Phragmites Control Baseline Conditions Report Form and Appendix B - Phragmites Control Monitoring Form.

ACKNOWLEDGMENTS

The Massachusetts Restoration and Banking Program (WRBP) established a Phragmites Working Group to discuss issues related to restoring marshes dominated or threatened by common reed. The Group provided the benefit of their collective experiences in Massachusetts. Their help in putting this report together is gratefully acknowledged. Christy Foote-Smith, Director of WRBP, saw the need for this report and was responsible for organizing the Group.

The following individuals were members of the Group: Terry Bastian, Robert Blanchard, John Bolduc, Bruce Carlisle, Christy Foote-Smith, Aldo Ghirin, Mike Gildesgame, Wendi Goldsmith, Bob Hartzell, Janet Hutchins, Gwilym Jones, Barbara Keller, Dan McHugh, Walter Montgomery, Hugh Mulligan, Bonnie Nevel, Joseph Orzel, Mike Penko, Ed Reiner, Heidi Roddis, Gerry Smith, Pat Swain, Ralph Tiner, Rich Tomczyk, Michael Wheelwright, and Sally Zielinski.

Drafts of this report were reviewed by the Group and by others, including Bill Niering, Ron Rosza, and John Teal. Stephen Brown compiled the data from the survey on the distribution of common reed in Massachusetts towns, produced the figures and tables showing the distribution of Phragmites reports, and edited the report.

Other people providing assistance in the completion of this report were the following: Deborah Hadden, Michael Rotondi, and Cheryl Ferrone prepared case studies for two common reed control projects. Geoffrey Wilson and Charles Katuska provided comments on the final draft report. Jack Nawrot (South Illinois University at Carbondale) provided information on the University's work with common reed and a list of references. Heike Koppitz (Berlin, Germany) contributed current references on genetics and common reed ecotypes. Dennis Magee supplied county-based information on the distribution of common reed in New England. Numerous people completed the survey questionnaire including Elizabeth Bagdonas, Philip Barske, Derek Brown, Christopher Capone, Elizabeth Clark, Kevin Dawson, Liz Dolan, Joel Dumont, Shep Evans, Geralyn Falco, Mark Galkowski, Barbara Ganeau, Al Goetz, Joseph Grady, Shirley Griffin, Carol Gumbart, John Hartshorne, Barre Hellquist, John Keeley, Nelson Kessler, Cindy Kuhn, Marian Linden, Pike Messenger, Marilyn Nordby, the Norfolk Conservation Commission, Bob Prokup, Karen Riggert, Priscilla Ryder, Ginny Scarlet, Alex Strysky, Jane Varkonda, Elaine Vreeland, Robert Weidkmecht, Alan Weinberg, Christina Wordell, and Hazel Young. Beth Lapin, Tom Goettel, Ron Rosza, and Russ Cohen provided several useful references. Many references were used to compile this report and they are listed at the end of the report. Of particular interest to the reader should be an article that appeared in the Natural Areas Journal entitled "*Phragmites australis* (*P. communis*): threats, management, and monitoring" by M. Marks, B. Lapin, and J. Randall which is an excellent overview of these topics; readers are encouraged to read this paper.

Finally, the support of the U.S. Fish and Wildlife Service (Service) is recognized. The Service provided meeting space for the Phragmites Working Group on several occasions at Great Meadows National Wildlife Refuge. The help of the Refuge staff is greatly appreciated. The report was published by and developed with technical support from the Service.

SECTION 1. OVERVIEW OF ECOLOGY AND VALUES OF COMMON REED

1.1. Ecology of Common Reed

Common reed (*Phragmites australis*, formerly *P. communis*) is a tall grass (Family *Poaceae*) attaining a height of 16 feet or more, although it is commonly around 12 feet high (see cover). It flowers from late July to October in the Northeast. Seeds mature from August into November. Its terminal flower head (inflorescence) is typically a showy purplish plume that many people find attractive enough to collect for interior decorating or for use in dried flower arrangements. Specimens with light-colored inflorescences occur less commonly. The stolons of common reed are 1/4 to 3/4 inch wide and may be almost 40 feet long.

Common reed is nicknamed "Phrag" by many people. It is one of the most widespread plants in the world, occurring on every continent except Antarctica. Its North American distribution is from Nova Scotia and Quebec to British Columbia, south to Florida, Texas, and California. Common reed has been reported in every county in Massachusetts and Connecticut.

Phragmites grows under a wide range of environmental conditions from salt to fresh marshes to dry upland sites to shallow open water. This broad ecological amplitude has probably facilitated its nearly circumglobal occurrence. It grows in pristine wetlands as well as in altered wetlands, dredged material disposal sites (former wetlands), impoundment dikes, disturbed uplands, powerline right-of-ways, roadside ditches, railroad embankments, sandy soils, mine waste areas (refuse piles, acid spoil areas, and tipple areas), and in and around mine slurry impoundments. It even grows as a mat across shallow water and may be found in the shallows of lakes and ponds growing in water about 3 feet deep. Air-spaces in stems and roots (aerenchyma tissue) facilitate movement of air from above-ground parts to roots and permit growth in anaerobic conditions. Under dry conditions (xeric), *Phragmites* can extend its rhizomes almost 7 feet below the surface to tap underground water supplies. Common reed grows on soil with a wide range of organic content (1-97%). It obtains nutrients from the soil or dissolved solutes. Where common reed forms monotypic stands, shoot density is usually greater than 100 stems per square meter. Above ground biomass can be over 2,000 grams per square meter.

Phragmites is most common in the United States in tidal and nontidal marshes. It is perhaps most frequently found in Massachusetts along highways in roadside ditches and along the coast in brackish marshes and tidally restricted former salt marshes. Tidal flow in the latter marshes is limited either by undersized culverts, tide gates, or similar structures beneath roads and railroad embankments. *Phragmites* also occurs in some salt marshes at road drainage culverts where fresh water is discharging directly into the marshes without adequate creek or ditch connections to the ocean (to facilitate mixing) and where sediments washed from roadways are being deposited. It may also be found along the edges of salt marshes lacking any signs of disturbance. These areas may have high ground water tables and strong freshwater influence.

Common reed is a good competitor in most geographic regions, spreading mainly by vegetative reproduction. It is a clonal species whose rhizomes produce new shoots and roots at the nodes. Its stolons can grow across the ground at rates of up to 30 feet or more per year in nutrient-rich sites giving *Phragmites* the reputation of a fast-spreading species. In most cases, growth is slower, more on the order of a few feet annually. Near the mouth of the Connecticut River, colonies are increasing in size at one to two percent each year.

A thick layer of leaf and shoot litter typically forms in *Phragmites* stands. This organic matter build-up plus thick rhizome growth and adventitious roots create a thick mat that inhibits seed germination of other species. This gives common reed a definite competitive advantage over other species. The mat also raises the elevation of the marsh and may be responsible for somewhat drier surface conditions in *Phragmites* marshes when compared to other marshes. These conditions produce a monoculture of common reed in many places.

Common reed does not seem to produce many viable seeds. Studies indicate that less than 10 percent of the seeds are viable. The seeds are short-lived, unlike those of many wetland species. Seeds are shed and dispersed by wind and birds (on their feet) from the fall to February. *Phragmites* is reportedly shade-intolerant and seeds usually become established only after a water-level drawdown exposes the substrate. Perhaps this requirement for bare soil explains why common reed grows well on recently disturbed sites and in areas of recent and rapid sedimentation. Once established, *Phragmites* expands by vegetative growth--its stout rhizomes extend laterally to colonize new territory. Despite its general shade-intolerant nature, *Phragmites* has been observed growing beneath the canopy of deciduous trees, especially in lowland forests bordering existing reed stands.

Seed germination is affected by flooding, salinity, and temperature. A depth of two inches or more of water and salinities above 20 parts per thousand (sea strength = 35 ppt) prevent germination, whereas salinities below 10 ppt do not affect germination. Germination usually increases with temperature (e.g., from 16-25 degrees Celsius) and sprouting time decreases with rising temperatures (e.g., 25 to 10 days, respectively for that temperature range).

Optimal pH for common reed is circumneutral, from 5.5 to 7.5, with the most robust stands occurring in this range. *Phragmites* can tolerate acidic conditions down to a pH of 3.6 and alkaline conditions to a pH of 8.6.

Different ecotypes of common reed adapted to specific environmental conditions are likely to exist. Salt tolerances of *Phragmites* appear to differ geographically. Studies have reported the following maximum salinity levels: 12 parts per thousand (ppt) in Great Britain, 29 ppt in New York, and 40 ppt in the Red Sea. In the Northeast, salinities above 18 ppt tend to significantly restrict the growth of common reed. Where it does grow in higher salinities (i.e., salt marsh edges), its height is markedly stunted--3 to 4 feet tall compared to 12 feet or more in less saline sites. Also, its density decreases with increased salt stress.

Some people think that common reed is an invasive exotic introduced in the last 50 years. However, the species is a natural component of the New England flora. The buried rootstocks of *Phragmites* found in 3000-year old salt marsh peat in Connecticut provide evidence of this. In Colorado, Native American mats over 1000 years old contained common reed.

Although *Phragmites* has been in this country for thousands of years, it is clear that it has been spreading rapidly over the past half century in the Northeast. It is also spreading rapidly in disturbed habitats in mined areas such as southern Illinois. In our lifetimes, some salt marshes have been transformed into common reed marshes. This type of rapid invasion is characteristic of exotic species, leading some botanists to speculate that an aggressive genotype has been recently introduced into the United States or that an aggressive ecotype has evolved in the past 50 years. Studies in Louisiana and adjacent Gulf Coast states have shown that the invasive *Phragmites* is genetically different from natural populations of this species. Regardless of its genetic status, some populations of common reed are creating problems for many other plant species and plant communities. For example, along the lower Connecticut River, common reed occurs naturally in brackish marshes, but it is now expanding its distribution and replacing narrow-leaved cattail (*Typha angustifolia*) and other brackish species. Because of its invasive nature, its tendency to form monocultures, and other reasons, *Phragmites* is now regarded as a nuisance plant in many parts of the country.

It is important to note that common reed does not always form a monoculture. More open stands have a number of other plants as associates and continue to be diverse communities. These species are probably remnants of the previous plant community that occupied the site.

1.2. Values and Uses of Common Reed

Common reed marshes perform many of the functions typical of other marshes. They assimilate and recycle nutrients, promote the accumulation of water-borne sediments (under appropriate conditions), provide temporary water storage, and serve as wildlife habitat for some species. In some highly polluted wetland ecosystems in urban areas, *Phragmites* marshes probably serve as an important air filter (Bill Niering, pers. comm. 1996). They also produce a lot of oxygen that should benefit local ecosystems. Common reed has also been used by people in various ways throughout the world.

In the United States, there has been little study of the ecology of common reed marshes. There are descriptions of associated vegetation in coastal marsh studies, but little work has been done on fish and wildlife use of *Phragmites* marshes. Much has been written about the invasive nature of the plant. It replaces highly valued salt marshes, lowering species diversity and changing vegetation life-form from low grasses to tall grasses, with significant adverse consequences for estuarine animals. Although they do provide habitat for some species, the marshes taken over by *Phragmites* are generally less productive and less important fish and wildlife habitats than the marshes they replaced. This is also true for freshwater stands. Moreover, *Phragmites* marshes are not the preferred habitat for any vertebrate.

Professor Gwilym Jones and his students at Northeastern University have observed wildlife in Boston's Back Bay Fens and Victory Gardens for almost a decade. They have compiled an extensive list of species using this largely *Phragmites*-dominated area: 151 birds, 13 mammals, 5 reptiles, 2 amphibians, and 11 fish. Unfortunately, the list does not differentiate species using reed marshes from other habitats (e.g., upland grasslands, community gardens, and treed parklands). While most of the birds have been observed using reeds at one time or another (e.g., probably feeding along the water's edge or perched on reed stems), *Phragmites* is not the preferred habitat for any listed species. Some species seen in the reeds included Virginia rail, sora, common yellowthroat, great blue heron, green-backed heron, black-crowned night heron, and red-wing blackbirds. These birds would also use other vegetation of similar structure (e.g., cattail). Various waterfowl observed in the Fens would still frequent the area if *Phragmites* were eliminated and replaced by more desirable marsh plants. Muskrats, meadow voles, and white-footed mice observed would likewise use similar habitats as would turtles and amphibians. In many respects, the attractiveness of the Fens to wetland wildlife is not dependent on the occurrence of *Phragmites* as much as it is on the presence of a marsh and open water complex in the midst of an urban environment.

Reed marshes are well established in the Hackensack Meadowlands in northeastern New Jersey. Narrow bands of creekside *Phragmites* reportedly are used for nesting by ducks. Perhaps common reed provides dense cover important for keeping out predators like common crows and gulls. Ring-necked pheasant have been observed along the edges of a common reed marsh at Newark International Airport in New Jersey and an American bittern among the *Phragmites* reeds at Hammonasett State Park in Connecticut (observations by the author). A study in Illinois found least bitterns using the interior of reed marshes on mined lands. One nest was observed in these marshes compared to 6 nests found in cattail marshes in the study area.

Certain insects may find *Phragmites* an attractive plant. In a study of tidal fresh marshes along the Hudson River in New York, researchers found that common reed had more insects per square meter than cattail (*Typha* spp.) or purple loosestrife (*Lythrum salicaria*). These reed marshes also produced three times more insect biomass than cattails and ten times more than purple loosestrife, yet the significance of this is not known.

Only a few vertebrates seem to feed on *Phragmites*. Muskrat and geese may eat rootstocks, although common reed is not a preferred food. In marshes subject to frequent tidal flooding, detritus produced by leaves decomposing in water provides food for aquatic invertebrates (e.g., mollusks, crustaceans, and insects) and detritivore fishes (e.g., killifish) which serve as food for higher organisms (e.g., predaceous fish and birds). This contribution is similar to that of other marsh plants--the frequent contact with water facilitates detrital production, export, and utilization by detritus-feeding aquatic organisms. Most reed marshes unfortunately lack this condition because they are not frequently flooded.

Phragmites and other wetland plants provide important uptake of nutrients and other water pollutants that make them good candidates for treating wastewater. In other countries, especially in Europe, common reed is used for artificial wastewater treatment. The Max Planck Institute of Germany has a patented wastewater treatment system design that utilizes *Phragmites*. Given potential problems with the spread of common reed, it may be more prudent to use other marsh plants for these projects in the United States.

Like other marsh plants, *Phragmites* helps stabilize shorelines, prevent erosion, and temporarily store flood waters. These functions are not unique to this species and could be served by other wetland species, since these are rather generic functions that are determined more by landscape position and plant density than by plant species composition.

Early people throughout the world used common reed in a variety of ways. Uses included thatch roofs, canoes, mats, sandals, musical instruments (panpipes), brushes, and even as food or medicine for humans and animals. Some of these uses continue today. In southern Iraq, *Phragmites* marshes are grazed in winter by water buffalo and the new shoots in spring are harvested for fodder. Stems are used as windbreaks and mulch. Seeds of common reed can be ground into flour and the young shoots can be boiled or baked for eating. Even candy can be made from these tender shoots.

The European view of *Phragmites* is much different than ours. They generally have a more utilitarian perspective on natural resources and, given its many uses, common reed has economic significance in Europe. Common reed is used for roof thatch in Great Britain and the Netherlands. The high cellulose content of common reed has led to its commercial use by the paper industry in Romania and Russia which grows and harvests *Phragmites* commercially along the Volga delta. It is processed for making insulation or paper products (including paper, cardboard, cellophane, and synthetic fibers). Romanians also use it for cement reinforcement, fertilizer, and fuel alcohol production. *Phragmites* has been used to make writing pens and has been woven into sandals and mats. In Scandinavia, reeds are burned as fuel in homes. For years, the Dutch have used *Phragmites* for "coastal reclamation projects"--for drying out (dewatering) dredged material deposited in shallow waters behind dikes to build land from the sea. The plant takes up much water and its roots release oxygen into the soil (oxidized rhizosphere) which helps promote microbial breakdown of organic matter in the sludge. (Note: The U.S. Army Corps of Engineers imported this technique to the U.S. in the 1970s for dewatering dredged material sites along navigable waters.) The ability of *Phragmites* to regenerate after burial beneath dredged material has enhanced its use for this purpose. It can recover from burial by more than 6 feet of dredged material!

In addition to their clear economic value, certain reed marshes are considered by some Europeans to be valuable wildlife habitats. In southern Germany, for example, many wetlands designated as natural areas are *Phragmites* marshes. In many respects, this landscape is vastly different from our New England landscape as the reed marshes offer one of the last remnants of wetland wildlife habitat especially in agricultural areas. The wildlife value of these wetlands is somewhat similar to that of urban *Phragmites*-dominated wetlands in the Northeast such as the Hackensack Meadowlands in the Newark-New York City area, since these wetlands are nearly all that remain of a formerly more diverse and extensive ecosystem.

SECTION 2. THE *Phragmites* ISSUE

2.1. Current Concerns about Common Reed

Since the 1950s, common reed has been aggressively invading many tidal marshes, some inland wetlands, many disturbed soils, and filled lands. This increase seems to be coincident with expanded filling and hydrological modification of coastal wetlands, increased sedimentation from roadways and development, accelerated disturbance of uplands by development activities that have removed vegetative cover and exposed many soils, and increased water quality degradation in our waterways.

It is particularly interesting to note the frequent occurrence of *Phragmites* in ditches along major highways across the State. It may be possible that the spread of common reed is facilitated by this road network. Such plant dispersal has been reported for some Midwestern plants that have moved east along interstate highways and can today be found in roadside ditches in various locales in New England. Increased use of road salts in winter may have created conditions favoring *Phragmites* colonization along such roads.

Common reed spreads by rhizome sprouting and even by broken pieces that move downstream or are carried by birds, or relocated in fill material. *Phragmites* is so prolific that it is now the sole dominant plant in many wetlands. Its aggressive invasion displaces other flora and animals dependent on these more diverse habitats. *Phragmites* can create an almost impenetrable thicket. The dead canes provide a thick mulch which seems to effectively prevent other species from becoming established.

Although common reed provides habitat for some wildlife species, the changes in plant structure (from short grasses to dense tall grass), in biodiversity (from many species to a single species), and in wildlife food production have reduced the habitat value of these marshes for many fish and wildlife species and other plants. Wetland communities with native species have been disrupted and displaced by common reed. Lower plant diversity and a degradation of wildlife habitat are usually the end results of a *Phragmites* invasion. Many wildlife refuges are experiencing problems with common reed, including Parker River National Wildlife Refuge (NWR) in Newbury and Trustom Pond NWR in Rhode Island.

In addition to ecological concerns, there are other public issues, including fire hazards to homes and private property, visual intrusion, navigation restriction, and, in inland areas, invasion into agricultural lands. Stands of common reed may represent an increased fire hazard, especially where they occur contiguous to housing developments. In fall and winter, the dried stems of *Phragmites* are more easily ignited than the salt marsh vegetation they displaced. In 1981, *Phragmites* at the 250-acre Sagamore Marsh caught on fire. The marsh was completely burned and the fire spread to adjacent uplands. Several homes and structures were damaged. In the dry summer of 1995, *Phragmites* caught fire in the Neponset marshes of Boston, but no property was damaged. *Phragmites* fires are so intense that they are virtually impossible to control. Firefighters can only attempt to protect private property by hosing down the houses. Periodic burning of *Phragmites* marshes and local property damage has been a major reason for *Phragmites* control in some communities.

Adjacent property owners may have varying opinions on the common reed. In urban areas, common reed marshes are suspected of harboring Norway rats and are regarded by some citizens as sites of "vermin" that should be eradicated. Some people may feel that *Phragmites* is a nuisance and blocks their view and would prefer having a low-lying marsh or meadow there. Others appear to like the privacy afforded by a stand of common reed (a type of natural fence or wall) at the edge of their lawn, despite the potential fire hazard.

Healthy stands of *Phragmites* inhibit mosquito control operations. While other marshes are accessible for aerial spraying and other techniques, the dense foliage of common reed prevents spray from reaching isolated pools of water where mosquito larvae live.

Common reed can grow into water and cover small channels, thereby restricting boat passage and changing local hydrology. This may also have a negative effect on aesthetics as the tall reed may limit views from shore as well as from the water. When *Phragmites* overgrows small ditches and creeks, local drainage is altered. Along the edges of salt marshes, this process may inhibit the discharge of surface water runoff or stormwater runoff from storm drainage pipes and thereby decrease the soil salinity along the marsh perimeter, promoting the further spread of common reed at the expense of characteristic salt marsh species.

The adverse impact of *Phragmites* on historic and park landscapes can be tremendous if not controlled. For example, in Boston's Back Bay Fens and the Riverway, parks designed by Frederick Law Olmstead, common reed has taken over most waterbodies, destroying the specially designed vistas of the original parks. Moreover, the presence of common reed in parks is a deterrent to visitor use as people tend to avoid places with poor visibility. These reedy places are more likely to foster illegal and other activities that discourage park use by the general public.

2.2. Where Common Reed is Not a Problem

There are situations where *Phragmites* is non-threatening and some people regard it to be even useful. A few cases are presented below, but there are undoubtedly others.

Small stabilized stands of common reed at the upper edges of salt marshes or occurring in other wetlands should probably be of little concern, especially where there is adequate salinity to control its spread. These stands should be evaluated to insure that they are, in fact, stable and not spreading (see Problem Stand Identification section for tips on how to identify stable from invasive stands). Even if not spreading, they may be serving as sources for plant dispersal to other areas. It may, therefore, be worthwhile to consider this possible effect when contemplating control.

Phragmites has been used at constructed wetlands designed for wastewater treatment because of its nutrient assimilation capacity. This is especially true in Europe where many such facilities exist: 188 reed treatment beds in Germany, over 100 in Denmark, and over 20 in the United Kingdom. Common reed has also been used for similar systems to some extent in the United States. Due to its invasive nature, careful attention should be given to ensure that these stands do not produce seeds which could travel to and invade nearby areas. An effective management procedure might be to annually remove the flowering terminal inflorescence before it goes to seed. Yet, before utilizing *Phragmites* for wastewater treatment, facility planners should consider other species like cattails (*Typha* spp.), bulrushes (*Scirpus validus, S. pungens*, and others), reed canary grass (*Phalaris arundinacea*), sweet flag (*Acorus calamus*), arrowhead (*Sagittaria latifolia*), spatterdock (*Nuphar advena*), and bur-reeds (*Sparganium* spp.). These species have been successfully used in artificial wetlands constructed for wastewater treatment. Artificial cattail marshes have been successfully used to treat secondary sewage in Canada. Soft-stemmed bulrush (*S. validus*) has been shown to be better at removing nitrogen than both cattail and common reed. Arrowhead, common three-square (*S. pungens*), and cattail removed more biological oxygen demand (BOD) and nitrogen than *Phragmites* when grown on gravel substrates. The Emerald Square Mall in Attleboro uses constructed wetlands for handling stormwater runoff from the complex. Plants such as cattail, arrowhead, reed canary grass, millet

(*Echinochloa* sp.), and sweet flag (*Acorus calamus*) are among the more significant species in these wetlands.

Along highly polluted urban waterways, *Phragmites* might be the best species to control shoreline erosion through bioengineering techniques, provided other species are not as or more fit for this environment. Ideally, these stands should be managed to prevent common reed invasion to other areas, but this may not be practical. Perhaps sterile plants could be used for such projects, although vegetative propagation still poses a threat. There also are reports of common reed actually destabilizing banks in Delaware (John Teal, pers. comm. 1996). Apparently, the dense root mat caps the banks rather than stabilizing them. Over time, the banks are undercut by currents until the cap simply sloughs off into the creek or channel, exposing the bank soils to more erosion.

Some of the existing common reed stands may be native stands that were always part of the Massachusetts landscape. Yet, genetic studies have not been conducted to validate this notion or to separate stocks of a native genotype from a possible invasive genotype. It could be possible that the invasive form has effectively replaced the native stock and all that remains is the invasive genotype.

2.3. Problem Stand Identification

To determine whether a stand is aggressive and invasive or not, several steps may need to be taken. An initial analysis of historical aerial photography could be done to see how long the *Phragmites* has been in the subject marsh and to get an idea of how the conditions in and around the marsh may have changed to favor colonization by common reed, but this procedure requires the skills of a trained photointerpreter.

If photo analysis is not possible, an alternative method would be to set up some wooden stakes marking the outer edge of the *Phragmites* (extending into the subject marsh). Put in the stakes at the beginning of the growing season. Try to drive the stakes at least two feet in the ground. At the end of the growing season, re-examine the area to see if *Phragmites* has advanced further into the marsh. If it has, it is probably an invasive stand, as a stable stand would show essentially no expansion. Stands can be monitored over a period of a few years to determine where the spread is a slow one versus a rapidly expanding stand with clear evidence of expansion after just one growing season.

It may be of additional help to measure *Phragmites* stem density in a one-meter square plot, measure the areal cover of common reed and other species, and record the maximum and average heights of the stems as well. These measurements (taken annually over a few years) would reveal changes in plant density and vigor that would likely indicate an expanding stand. Another, but untested, indicator of an invasive stand may be the presence of long rhizomes spreading over the marsh surface to areas where *Phragmites* is not present. This might signify an expansion of the colony.

2.4. Causes of Common Reed Invasion

How has *Phragmites* been able to invade Massachusetts wetlands? Common reed has the ability to rapidly colonize areas in two ways: 1) by seed and 2) by rhizomatous and stoloniferous growth. Seed germination seems to be favored on exposed soils. Shade-sensitive seeds do well in disturbed sites, including dredged material disposal sites. Vegetative reproduction by spreading stolons and rhizomes (stolons = above ground or rhizomes = below ground) gives *Phragmites* the ability to rapidly cover a site once established. This capability may permit growth in adjacent deciduous forests.

The abundance of common reed usually indicates some type of disturbance or environmental stress, such as lowered salinity in salt marshes due to altered hydrology, bare soil from filling, bank erosion, sedimentation, or excavation, lower water quality and sedimentation from stormwater discharge, excessive nutrient enrichment, road salts, or other water pollution. Bare soils are prime places for colonization by *Phragmites*. It was the first plant to get established on dredged spoil at Nott Island in the lower Connecticut River.

The proliferation of common reed is most prevalent along the coast, where it has successfully invaded tidally restricted salt marshes. Here lower salinity resulting from less frequent tidal flooding has created a more brackish water environment that apparently favors the growth and spread of common reed over typical salt marsh species. *Phragmites* also can be found in smaller stands along the upland border of many salt marshes, especially in areas of recent fill, or where surface water runoff has increased.

In freshwater areas, common reed has colonized similarly disturbed sites and also has become well-established in some wetlands receiving stormwater discharge. Common reed is frequent along highways throughout the Commonwealth, usually in roadside ditches. Powerlines, gas lines, and railroad right-of-ways often provide similar opportunities for the spread of *Phragmites*.

Before considering *Phragmites* control techniques, it is vital to understand how environmental conditions changed to favor the growth of this species. This is somewhat akin to diagnosing and treating a disease, rather than simply trying to cure a symptom. To eliminate or control common reed effectively, we may first need to resolve or minimize the problem that created a favorable environment for the colonization and spread of this species. When the solution to the underlying problem is prohibitively expensive and/or politically infeasible, control of *Phragmites* and wetland restoration may still be desirable. Such projects will require annual or biannual maintenance strategies, such as herbicide treatment or frequent mowing and mulching, with additional costs for this periodic control. This approach may be the only feasible option for managing *Phragmites* and re-establishing a more diverse wetland plant community in many instances.

Three basic disturbances typically promote the invasion and spread of *Phragmites*:

1. <u>Tidal</u> <u>restrictions</u> - reduced tidal flooding and salinity of salt marshes;

2. Minor filling and sedimentation - increased elevation, reduced soil wetness, or decreased water depth (conditions which also reduce flooding and salinity in tidal areas);

3. Water quality degradation - stormwater discharges, increased nutrient inputs, introduction of road salts, and other forms of water pollution also seem to provide *Phragmites* with a competitive advantage over other plant species. Diluting salt water in coastal marshes by restricting the tidal flow, and increasing freshwater runoff into salt marshes, may also be considered as forms of water quality degradation, since the salt-fresh water balance of the soil and affected waters have been significantly altered.

A readily available supply of seeds and/or rhizomes of *Phragmites* allows the plant to take advantage of the above conditions. To design an effective restoration plan, sites dominated by common reed must be evaluated to determine the underlying cause(s). Without identifying and addressing the fundamental problem in some way, the control of common reed may be unsuccessful, temporary, or at best a costly annual or biannual maintenance (weed control) project. The goal of any restoration project related to *Phragmites* should ideally be to change the environmental conditions which favor it to conditions that will promote and sustain the establishment of more desirable wetland species.

2.5. Survey of Massachusetts Towns for *Phragmites* Locations

The Massachusetts Wetlands Restoration and Banking Program conducted a survey to begin the process of identifying significant stands of *Phragmites* in the State. A questionnaire was sent to the Conservation Commission in each of the 351 towns requesting information on significant stands. The questionnaire asked respondents to identify the location of each stand, the percent cover of *Phragmites* in the stand, the approximate acreage, and to indicate if the stand is expanding. In addition, the questionnaire asked the respondents to provide a map showing the location and approximate size of each stand that was reported. The distribution of towns that responded, and whether they reported *Phragmites* stands within their jurisdiction or not is shown in Figure 1. The list of towns that responded and the number of stands they reported, is listed in Table 1. Perhaps after distribution of this report, another survey should be conducted as the report may stimulate interest in the reporting on the distribution of this species in the remaining communities.

This survey provides only a first approximation of the distribution of *Phragmites* in some areas of the State. No field checking was done to verify the accurateness or completeness of the reports. Many towns did not respond to the survey, and no implication should be drawn about whether these towns have *Phragmites* stands or not. Over time, however, the State expects to refine and expand this listing and get a better picture of the statewide distribution of this species.

As an ongoing effort, the Wetlands Restoration and Banking Program (WRBP) would like to develop a more complete survey of *Phragmites* stands. Individuals with knowledge of such stands in towns not responding to the original survey are encouraged to complete the questionnaire and send it to the WRBP office.

Figure 1. Distribution of *Phragmites* in Massachusetts based on the results of a questionnaire survey, with input from conservation commissions and others. Note this is quite incomplete as only about 50 towns reported.

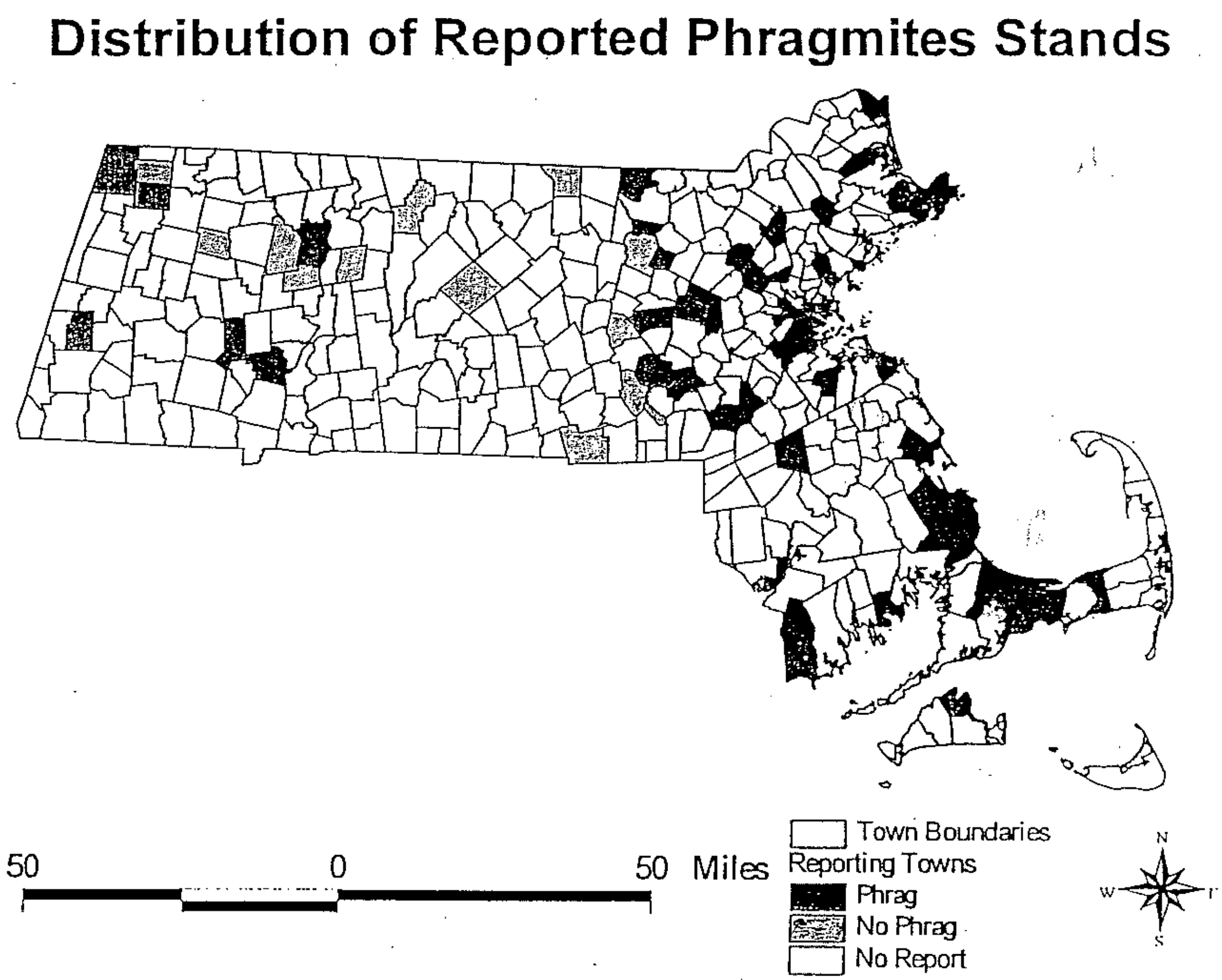

Table 1. Towns responding to *Phragmites* survey and the number of significant stands reported in each town.

Town	No. of Stands	Town	No. of Stands
Adams	2	Middleton	15
Ashby	0	Norfolk	3
Ayer	1	North Adams	0
Barnstable	1	Northborough	0
Barre	0	Oak Bluffs	6
Bedford	1	Orange	0
Boston	4	Pepperell	2
Boxborough	1	Plainfield	0
Braintree	9	Plymouth	11
Cambridge	3	Rockport	7
Cohasset	1	Rowley	6
Conway	0	Salisbury	16
Deerfield	1	Sandwich	5
Dennis	38	Saugus	5
Douglas	0	Somerset	2
Duxbury	8	Southampton	4
Easton	1	Stockbridge	18
Essex	9	Sudbury	3
Gloucester	2	Swampscott	8
Harvard	0	Tisbury	2
Holliston	1	Upton	0
Hopedale	0	Walpole	6
Hopkinton	3	Wayland	1
Huntington	2	Westport	6
Leverett	0	Whately	0
Lexington	1	Williamstown	2
Marlborough	1	Wilmington	1
Mattapoisett	19	Winchester	1

SECTION 3. CONTROLLING AND MANAGING *Phragmites*

3.1. Strategies for Managing Common Reed

Three main solutions to the basic underlying problems listed above are the following:

1. Restore tidal flooding through removing restrictions (e.g., expanding culverts and replacing standard flapper-type tide gates with state-of-the art self-regulating tide gates, automated sluice gates, or manually operated gates) and increasing salt water flow into various parts of the marsh (e.g., applying open marsh water management techniques, OMWM). OMWM involves plugging selected grid ditches and creating new ditches and tidal pools to improve salt water flow into portions of marshes that are high mosquito producing areas and/or *Phragmites*-dominated areas. For *Phragmites* control, in addition to increasing salt water flow, OMWM may create perimeter ditches around *Phragmites* colonies as a further deterrent to salt marsh invasion. OMWM also increases fish and wildlife use of the marsh and may reduce mosquito populations. The self-regulating and automated types of tide gates may be required where flood protection of adjacent properties (e.g., low-lying homes and development) is needed.

2. Restore original marsh elevations by removing fill/sediments and regrading. In some cases, it may be necessary to control a persistent source of sediments if sedimentation is still occurring. Removing fill and restoring original marsh elevations is a common technique to restore filled marshes that have been colonized by *Phragmites*. This approach may also be useful in freshwater marshes, but it will be more difficult to guarantee success since common reed favors bare soil. In freshwater environments, *Phragmites* management may have to be coupled with another control technique (e.g., herbiciding) and competitive plantings of other species.

3. Improve water quality by eliminating a pollution source, such as diverting stormwater discharge through a specially-designed constructed wetland for water treatment prior to releasing water into the wetland or employing best management techniques to control non-point source pollution.

Before considering control techniques, first evaluate whether the stand is creating a significant problem. Invasive stands should be controlled, while small stable stands at the edges of marshes may not be worth controlling. In the latter cases, no action may be the best management option.

Once a problem stand of *Phragmites* has been identified, one or a combination of control measures should be considered. Possible control measures include cutting (with or without mulching), burning, herbicides, hydrologic controls, and covering with sheets of plastic. The evaluation of control measures needs to include the overall effects of implementation (including, for example, the impacts to adjacent properties, effects upon private and public water supplies, and impacts to wildlife, especially rare and endangered species).

The following section is a brief review of *Phragmites* control and management techniques and their likelihood for success. Again, remember that it is best to address the underlying environmental conditions prior to attempting to control common reed by these techniques, but some of these conditions are not readily changed. Even rectifying the original problem, however, will not necessarily guarantee control of common reed because, once it is established, *Phragmites* is a good competitor. There may be a need for repeated chemical treatments to stress the stand and allow opportunities for native species to recolonize the site, especially in freshwater situations and in tidal marshes where salinities are less than 20 parts per thousand.

Local, state and federal permits may be needed for any of these methods. The local conservation commission, the Massachusetts Department of Environmental Protection, and the U.S. Army Corps of Engineers should be contacted before starting a *Phragmites* control project in wetlands and their buffer zones (see Regulatory Issues, Section 4).

3.2. Specific Management Techniques

Numerous techniques have been used in attempts to control the spread or to eliminate common reed. It should be recognized that in some or many cases, it may not be possible to completely eradicate the species as it is quite hardy and resilient, hence the reference to "management" of *Phragmites* rather than "control." Also, it is re-emphasized that if the underlying cause or causes that promoted the invasion and spread of *Phragmites* are not dealt with, the control project will most likely become an ongoing management project rather than a self-sustaining wetland restoration project. This fact, however, should not deter people from attempting to control this invasive species, since the reduction of fire hazards and the increase in wildlife habitat values, for example, should provide ample justification for most projects.

Fifteen different approaches to controlling *Phragmites* are briefly described below. In some cases, the reported effectiveness of a given technique has been variable. Unfortunately, people using these techniques have not documented their results very well. Such documentation is vital to increasing our understanding of the effectiveness of these techniques under a variety of environmental conditions. People involved in future *Phragmites* control projects are strongly encouraged to write up the results of their efforts so that we can all gain from these applications (see subsection 3.4). Remember that it is as important to write up the negative findings as it is to extoll the positive results. It is also vital that the documentation include a description of the baseline conditions and a general statement about the likely cause for the spread of *Phragmites*. Table 2 presents examples of control techniques for specific environmental conditions. Please note that some of the following techniques have been and may be used in combination to achieve better control results. Cost figures given in Table 2 are best estimates.

Table 2. Examples of application of *Phragmites* control techniques for selected site and environmental conditions.

Site Condition	Potential Control Techniques
Tidally Restricted Salt Marsh With No Low-lying Development	Increase Tidal Flow*
Tidally Restricted Salt Marsh With Low-lying Development	Increase Tidal Flow with Regulated Tide Gate* (Automatic or Self-regulating)
Brackish Marsh With No Hydrologic Restriction	Herbicide Application**
Small Fresh/Brackish Marsh (<10 a.)	Mowing, Burning, or Herbicide Application followed by Burning** (if possible; depends on adjacent land uses)
Large Fresh/Brackish Marsh	Burning or Herbicide Application (aerial spraying) followed by Burning**
Wet Meadow	Follow marsh control techniques; possibly heavy grazing
Small Stand in Shrub Swamp or in Understory of Forested Wetland	Selective Herbicide Application
Impoundment	Cutting and Flooding or Burning (during drawdown) and Flooding
Salt Pond, Lake, or Natural Pond	Hydroraking (for small stands), Cutting (below annual low water line), or Herbicide Application
Active or Abandoned Agricultural Field	Heavy Grazing (if possible) or Mowing, Burning, or Herbicide Application (with followup burning or mowing/mulching, if possible)
Roadside Ditch, Stormwater or Other Artificial Basin	Excavation or Herbicide Application
Wetland with Heavy Sedimentation or Filling	Remove sediments and restore original elevation

Table 2. (continued)

Site Condition	Potential Control Techniques
Dredged Material Disposal Sites and Filled Sites	Remove sediments and restore original elevations
Backyard	Mowing/Cutting combined with Disking or Tilling

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*May accelerate salt marsh recovery by cutting (with or without mulching), burning or applying chemicals (then burning or cutting/mulching), or initiating open marsh water management techniques (in areas where salinity is 18 ppt or greater). (Cutting or chemical application are the preferred methods when buildings are adjacent to the marsh.) Caution: Where low-lying developments exist adjacent to these marshes, *Phragmites* control techniques must not increase flooding of these properties.

**May accelerate regeneration of other plants by burning or mowing and mulching dead *Phragmites* stems.

1. Increase tidal flow and salinity (for controlling common reed in former salt marshes). This is a very successful technique in areas of salinities greater than 18-20 ppt and is the standard practice for most salt marsh restoration involving removal of *Phragmites*. It requires increasing size of culverts, installing self-regulating tide gates or automatic sluice gates, or otherwise removing the restriction to permit more tidal water exchange. It may be enhanced through open marsh water management which involves increasing salt water flooding through selective ditching and ponding. This technique has resulted in a significant die-back of common reed after four years (see Case Study 5.1). Installation of self-regulating tide gates, automatic sluice gates, or similar devices can both increase tidal flooding with salt water and protect low-lying developed areas from storm floods, thereby providing environmental, safety, and economic benefits. Costs for automatic sluice gates: Post Island Marsh, Quincy (10 acres) -- $95,300 or $9,530/acre; Third Marsh, Quincy (20 acres) -- $279,000 or $13,950/acre (for two automatic sluice gates and disposal of excavated material). Costs for self-regulating tide gates (from Nekton Inc., Fairfield, CT): variable depending on size, approximately $17,000 for a 36-inch diameter gate to $30,000 for a 60-inch gate. See case studies section for examples of the success of this technique.

2. Cutting or mowing. By itself, this technique is usually not successful in eradicating common reed, but is useful for annual control of this species and for eliminating the fire hazard potential. Cutting any grass at the wrong time may stimulate growth and increase stem density. Cutting at the end of the growing season or in winter can increase density, although stunting of *Phragmites* has been observed with a winter cut (more study is clearly needed here). Cutting after tasseling (e.g., before the end of July) may produce the most stress on the plants. Mowing with machines requires ground pressure-sensitive equipment (preferably 2 lbs/sq.in. or less) to minimize soil compaction. Cutting can be expensive, especially for large stands. Mowing should not be done during extremely wet conditions due to potential soil compaction problems. Small patches may be cut by hand and periodically mowed to help control *Phragmites*. While it may not eliminate common reed, cutting does provide an opportunity for other plants to grow. Although wildlife does not make wide use of dense *Phragmites* stands, if there are nesting birds or slow-moving animals (e.g., turtles) present, they may be harmed by summer mowing. The negative wildlife effects, however, should be short-term, while in the long-term, wildlife will greatly benefit from *Phragmites* control. Mulching the cuttings may be desirable, since this would better expose the marsh substrate to facilitate germination and colonization by other wetland species.

Costs for mowing are variable: $2,250/acre for 3-acre site (Boston Fens); $13,000/acre (1995 dollars for Boston Fens, includes trucking and disposal in Wrentham); $51,000/acre for 5-year treatment (one cut per year) - cutting with weedwacker; $30,000/acre for 5-year treatment (one cut/year) - cutting with ground pressure-sensitive equipment (excludes disposal costs). The costs of mowing by amphibious mulching mower in Connecticut is $190/acre (the cost of the machine is about $160K). This type of machinery may also be useful for clean-ups of oil spills on marsh vegetation. Mowing on the North Shore of Massachusetts should cost an estimated $105/acre with a minimum project area of 5 acres. A very small stand with rare plants required about two days of effort for cutting and disposal at a composting facility; the cost is less than $500 per year. Off-site disposal of cut stems can be very expensive especially in urban areas. On-site burning of the cut stems is a low-cost and effective alternative that should be considered.

3. Mowing and disking. The upper soil conditions are vital to the success of *Phragmites*, due to the presence of the rhizomes that help the plant spread. Disking of rhizomes may, therefore, enhance restoration, but it may be too expensive for large stands. This technique is probably ideal for controlling common reed in backyards. The value of this method may be further limited in some environments by the fact that disking to 12 inches is insufficient to destroy all of the rhizomes, since some rhizomes penetrate below this level. This is especially true in relatively dry wetlands, at upland sites, and on sideslopes where root penetration is deep. The estimated cost for mowing and disking *Phragmites* stands on the North Shore of Massachusetts is $210/acre with a minimum project size of 5 acres.

4. Plastic covers. This technique involves mowing the common reed stand, then covering it with plastic. Black plastic appears more effective than clear plastic. High temperatures can cause die-off in 3-4 days. Plastic deteriorates over time. Because this method is labor intensive, its utility may be limited to small sites. Results have been variable (favorable to minimal).

Estimated costs should be much less than the $60,000/acre cost of an experimental 8-week application demonstration project (two-1/4 acre plots) at Boston Fens which included heavy 20 mil black plastic, maintenance (twice weekly), off-site disposal of cut stems, and snow fence assembly/removal. The costs of operational application of black plastic should be far less in nonurban sites. It may be possible to reduce material and handling/installation costs if thinner plastic is used and if cut stems can simply be burned onsite.

5. Hydro-raking. This technique is used for controlling common reed in open waterbodies. It involves removal of living plants and rhizomes from water. Hydro-raking is accomplished with a York rake attached to a backhoe mounted on a pontoon boat. The rake can work in waters from 18 inches to 12 feet. It removes both stems and roots. The control is believed to last for 1-3 years. In Long Pond on Nantucket, only 10-15 percent regrowth occurred after one year. Raked material is disposed of at an appropriate upland site with incineration preferred to prevent colonization at the disposal site.

Costs will include transferring harvested materials to a landfill or other disposal such as incineration. While this technique may introduce pieces of rhizomes into the aquatic environment, experience to date does not suggest that this facilitates the spread of *Phragmites*. To further minimize this potential problem, a "fragment barrier" should be installed around the colony to prevent loss of fragments.

Unless all the *Phragmites* is removed, the benefits are probably short-lived and ongoing maintenance will be required. This technique is probably suitable only for new small stands of *Phragmites* growing in open water. Since the spreading mat is probably coming from a shoreline stand, other techniques will also be required to control this stand. Hydro-raking coupled with reintroduction of salt water has been successfully used to control *Phragmites* in Fairfield, CT (Bill Niering, pers. comm. 1996).

Costs vary, but a 1.3 acre site at Long Pond (Nantucket) cost $30,000 including trucking and landfill disposal. More typical costs are from $10,000-15,000 per acre to effectively control *Phragmites*.

6. Dredging and ditching. Dredging can eliminate common reed but it also changes a marsh to a pond. It also requires a place to deposit the dredged material. If soils are highly contaminated, special handling and disposal may be required, making the dredging costs extremely high. Also, one must be careful regarding disposal of plant material and soil to insure that rhizomes and seeds are not spread to another site. Environmental impacts of this type of dredging are similar to other dredging in open water and wetlands and appropriate safeguards should be taken to minimize water quality degradation and adverse fish and wildlife impacts.

This approach may be useful where pond restoration is desired. Ditching may also be used to stop the spread of a stand. This technique has been used in some open marsh water management (OMWM) projects.

The estimated cost for dredging of *Phragmites* marsh for the Muddy River project (Boston) was $150/cubic yard of excavated material for in-state disposal; costs would increase considerably for excavated material with significant contamination and out-of-state disposal.

7. Prescribed Burning. A root burn will have the greatest effect at reducing growth of common reed, but this is not possible in most cases due to soil wetness. Winter and spring burning may actually stimulate growth, whereas mid- to late summer burns may be effective. Europeans use burning to produce higher yields of common reed as a management technique. This allows plants to produce higher stem densities and to emerge earlier than competitor species. Late summer burns are more likely to penetrate roots and adversely affect plant survival, since the plant is quite vulnerable at this time (i.e., when it is moving nutrients from above ground to roots). Burning at this time has an added advantage, since most birds should have completed nesting by then, so adverse impacts to young birds should be minimal. Other animals, such as invertebrates and amphibians, may not be able to escape the fire, but such animals are not usually present nor particularly abundant in dense *Phragmites* stands.

Burning can only be done as long as there is enough fuel (*Phragmites* stems) to burn which means that it can only be done once a year. After a while, other means of control may be required. Also, this technique has essentially no application in developed areas due to concerns about the risks of fire spreading to adjacent areas and the amount of smoke emitted from *Phragmites* fires. One must be particularly careful with burning, since spot fires may develop some distance from the fire. Burning leaves carried by wind or air currents can start fires nearby.

The estimated cost for controlled burning a 375-acre site in a sparsely populated area of New Jersey was about $40/acre; also, an additional cost of $50,000 was given to mow *Phragmites* along the edges of the proposed burn area (presumably as a fire control measure). Estimated costs from the State of Virginia where volunteers were used: $66 for 216 acres.

8. Burning and tilling. Has produced at least one long-term reduction of *Phragmites*. Costs undetermined.

9. Burning or mowing and flooding with water. Burning or mowing can be used to remove vegetation and assist in natural salt marsh recovery where tidal flow of salt water has been restored. This should accelerate salt marsh restoration. The method has been successful for restoring salt marshes, but can be expensive depending on the water control devices needed. It may be useful for freshwater sites where water levels can be manipulated, e.g., in impounded marshes. This technique was successfully used in 1989 at Wertheim National Wildlife Refuge on Long Island, New York. The area remained free of *Phragmites* for a few years, but the long-term success is not known. In the Danube delta (Hungary), an August cutting coupled with poor aeration (flooded stubbles) led to a 60 percent loss in common reed yield. Poor aeration in late summer significantly lowers bud inception affecting future growth.

10. Flooding. In areas of similar salinity in the lower Connecticut River, marshes with longer hydroperiods had lower stem densities of common reed, suggesting that increased flooding could be a useful management technique. For freshwater systems, common reed may be controlled when rhizomes are covered with water for four months during the growing season. It is important to ensure that flooding reaches all affected marsh areas for this period. This technique was successfully used to control *Phragmites* in the pond at the Connecticut College Arboretum in New London, Connecticut. Flooding may create a floating mat (Bill Niering, pers. comm. 1996).

11. Herbicide application. Rodeo, a nonselective glyphosate herbicide, kills all grasses and broad-leaved emergents. It is absorbed through the leaves and moves through the plant to the roots. On its way, it inhibits the plant's ability to produce protein needed to live. Within a week or less from the time of Rodeo application, leaves yellow and wilt, eventually turning brown and deteriorating. Roots undergo a similar fate and begin decomposing fairly quickly. For quickest results, apply chemical during warm sunny weather when plants are growing rapidly and rain is not forecast for at least 24 hours--June through September are the best months.

Contact with soil neutralizes most of the plant toxicity of the glyphosate which binds to the soil, becomes immobilized, and then is degraded by soil microbes. This makes it degrade quickly into natural products--it does not bioaccumulate. Rodeo has no known adverse effects on birds and small mammals, and is virtually non-toxic to aquatic animals (fishes and invertebrates). It may have some effect on some algae whose photosynthesis may be impaired for a short time, but these impacts are not likely to be persistent. Based on existing information, little or no bioaccumulation of the glyphosate is expected. One should be especially careful applying Rodeo to control *Phragmites* in rare plant communities.

A combination of spraying and cutting may yield the best results. It may be best to cut the stems early in the growing season prior to herbiciding. The plants will then be about 2-3 feet tall at tasseling (vs. 10 feet or more), thereby facilitating hand spraying. It has also been suggested that stems be removed at the end of the growing season, well after the initial spraying. Follow-up treatment is usually required.

For optimum results in controlling *Phragmites*, apply Rodeo after common reed has tasseled. Since all plants do not tassel at the same time, more than one application is usually required. For small stands, follow-up treatments for individual plants may be required. In other cases, re-treatment may also be needed. For spraying a mixture of 4-6 pints of Rodeo and 100 gallons of water should cover an acre of common reed marsh.

Success is usually high, yet some repeated treatment may be needed in future years at much reduced costs. For controlling small stands along highways, application of herbicides may be the best option especially for hillslopes that cannot be mowed. Also, to control *Phragmites* where it is beginning to displace other species, hand application of Rodeo is necessary to prevent inadvertent killing of non-targeted species of special concern.

The technique may be expensive and costs vary widely depending on size of the project, method of application (e.g., aerial or manual spraying), and permit requirements. When spraying, it is important to avoid spray drift that could injure non-targeted areas. So avoid spraying on windy days. Also, heavy rainfall within two hours of application could necessitate re-spraying.

While chemical treatment may not eliminate the source of the problem, it is useful for controlling *Phragmites* and restoring or retaining a more diverse assemblage of native species. It may be required for controlling the species in freshwater and brackish tidal situations (salinities less than 20 ppt).

Examples of costs: $36,000/acre (Boston Fens; many permit/site-specific conditions; includes cutting/disposal, fencing, spraying, post-spray cut/disposal, and fence removal, with actual spraying costs being only a small portion of the total costs), $2,000/acre (small projects; estimated for a 1.2 acre site on Nantucket), $800/acre (a 1/10th acre site at Hodges Village Flood Control Project in Oxford) to $450/acre (8 acres; airboat application). Smaller applications (less than 1 acre) will generally range from $500-1000. A good rule of thumb for estimating project costs is: $1,000 for first acre and $400 for each additional acre for ground and/or boat applications. Aerial spraying is required for larger areas (10 acres or more) and starts with a minimum of $1,500. Estimated cost of aerial spraying for a 10-acre site is $250-350/acre. For a 50-acre site, it would be in the $150-200/acre range. The estimate for a 375-acre site on Delaware Bay in New Jersey worked out to $60/acre. The State of Virginia costs for treating a large site (Southern Watershed Common Reed Project) by aerial application was $62.17/acre, while ground application for a 3/4 acre site was $1,063. The $60/acre cost for aerial spraying is expected to be the same for Massachusetts, at least on the North Shore.

12. Aerial spraying with burning and/or flooding. Combined techniques seem to provide beneficial results. Should be cost-effective for large stands. Spraying followed by burning has been successfully used to control *Phragmites* at Forsythe National Wildlife Refuge in New Jersey.

13. Combination of control techniques with competitive planting. This combined approach would be expensive, but planting may give an edge to the more desirable species. Added costs for this alternative are due to the cost of the desired plant materials and labor costs for planting.

14. Heavy cattle grazing. There is a site in East Haven, Connecticut where the grazed meadow is free of *Phragmites* and just across the fence, tall *Phragmites* thrives. Disturbing the soil of common reed in patches can facilitate invasion by competing species. In Europe, this has led to the reduction and elimination of *Phragmites* in some areas. Damage to the upper rhizomes reduces bud density for a few years. If grazing is discontinued, the common reed stand may recover in four years.

15. Biological controls. Some insects and fungi that attack *Phragmites* may have potential for controlling this species, but have not been explored, so this technique is not available. Biological control is often useful for controlling non-native invasives.

3.3. Special Considerations for Project Planning

The following issues may need to be considered in deciding whether to attempt to control the spread of or eradicate common reed:

1. The presence and significance of rare and endangered species and/or rare and valuable natural habitats.
2. What effects will this activity have on wildlife presently using the area?
3. Is *Phragmites* performing a beneficial function that was not and cannot be accomplished by native species? (Does *Phragmites* improve water quality better than native species like *Typha*?)
4. Is the stand large or small?
5. Is *Phragmites* actively invading or is it stable?
6. What is the proximity of homes/buildings to the *Phragmites* stand?
7. Will the selected method cause adverse impacts to adjacent properties? If the selected methods are flooding or adjustment of tidal flow will there be an increase of flooding (either through storm events or by daily tides) to adjacent properties?
8. Will the selected method cause impacts to public or private water supplies, including but not limited to wells, reservoirs, or irrigation water?
9. What are the federal, state, and local permit requirements for controlling *Phragmites*?
10. Is *Phragmites* appropriate in an intensively managed area such as culturally significant landscapes (e.g., historic landscape parks and botanical gardens) or elsewhere?
11. Are there some *Phragmites* marshes where restoration may be too expensive (given present circumstances, technology, and budget constraints) and where it may be more advisable to simply tolerate the presence of common reed and receive the few benefits (e.g., water quality renovation) it provides until conditions change?

3.4. Baseline Data Collection and Monitoring

Recording the existing environmental conditions or baseline site conditions and monitoring results should be done for all projects. This is vital information that can help improve *Phragmites* control in the future. While everyone applying a control technique will certainly evaluate the results (how successful was the technique at eliminating or controlling common reed?), the findings often go unreported, so others do not benefit from the results of these undocumented applications. Reporting the results of *Phragmites* control projects is important. Two forms are provided in the Appendices to make it easier for people engaged in these projects to report the results of their efforts. Appendix A contains a baseline conditions report form which allows a general description of pre-existing conditions to be easily recorded. Appendix B provides a simple monitoring report form. The Wetlands Restoration and Banking Program is interested in maintaining a file of the results of such projects and plans to periodically summarize the results in its newsletter. People doing *Phragmites* control are encouraged to complete and submit these forms to WRBP.

Baseline environmental conditions should be recorded prior to initiating any *Phragmites* control project. Information to collect and record should include the type of wetland (estuarine or fresh, specify salinity regime of adjacent waterbody as appropriate), the nature of the condition that likely led to the invasion of *Phragmites* (e.g., tidal restriction, wetland drainage, or minor filling), and the proposed method of control or marsh restoration (Appendix B).

Permanent sampling plots should be established at numerous locations within the marsh or affected area. The number and location of plots will vary according to site conditions and the time available for monitoring, but it is useful to have some plots in the interior and some along the edges to get a sense of how the entire stand is responding to treatment. Mark each plot with a numbered stake (wooden or metal rebar). Metal rebar stakes with plastic caps may be preferred--they can be put flush to the ground and later located with a metal detector (you will need to prepare a good map to locate these markers). Wooden stakes above ground are prone to vandalism or removal in tidal areas by natural forces. Be sure to record the plot number and put the general location of each plot on a map or aerial photograph of the stand. Plot size should be either one square meter (1m x 1m) or 9-square feet (3 ft x 3 ft), whichever is more convenient. For plots, identify the number of living *Phragmites* stems (density) and the height of the tallest *Phragmites*, the height of an average plant in the plot, the areal cover of *Phragmites*, and the areal cover by other species (specify for each associated species) (see Appendix A).

After documenting baseline conditions and applying a specific management or control technique, annual assessments of the vegetation should be performed. Record the same parameters (see Appendix B). This evaluation will show any change in the height and density of *Phragmites* and any change in the abundance of other species over time. For the first three years, annual assessments are recommended. Afterwards, assessments at three-year intervals may be sufficient. More frequent sampling may be required if control is not proceeding as expected. This type of sampling regime will help identify the need for additional treatment and will provide information for judging the relative success or failure of the control project. It will also help others in their plans to control *Phragmites* at similar sites in the future.

For assistance in designing a monitoring program for a specific project, contact the Massachusetts Wetlands Restoration and Banking Program.

SECTION 4. REGULATORY ISSUES

Control of *Phragmites* may require permits from appropriate federal, state, and local government agencies. The following situations are the common cases where permits would be required. Contact the applicable regulatory agency for specific and up-to-date information on regulations as changes do occur.

4.1. Federal Permits

Phragmites control projects involving placement of fill into a wetland or waterway are regulated by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act. Most *Phragmites* areas will meet the Corps definition of wetland and will be regulated, requiring a permit for alteration. Under Section 10 of the Rivers and Harbors Act, the Corps regulates structures and work in or affecting navigable waters. In tidal areas, this jurisdiction extends from the deep water to the mean high water line, while inland, it reaches the ordinary high water mark.

In Massachusetts, to streamline the regulatory process, a Programmatic General Permit (PGP) has been issued. This lessens the Corps' involvement for minimal impact projects and relies on a comprehensive state/local review process (see below).

Under the PGP, activities impacting (directly or indirectly) less than 5,000 square feet of nontidal wetlands can generally proceed without reporting to the Corps. Projects with 5,000 square feet to one acre of wetland impact are subject to federal screening to determine PGP eligibility. Other projects require an individual permit from the Corps.

Before implementing a *Phragmites* control plan, you should review the PGP for eligibility. Contact the New England District of the U.S. Army Corps of Engineers (Concord, MA) directly regarding any questions about federal jurisdiction and permit requirements.

4.2. State/Local Permits

Several State regulations may apply to *Phragmites* control including the Massachusetts wetland regulations, the Water Quality Certification regulations, Chapter 91 Waterways regulations, License to Apply Chemicals, and groundwater protection regulations. Permits may be required depending on the control technique chosen.

State wetland regulations require that applicants secure a permit (Order of Conditions) before work can proceed in or near wetlands. Various conditions may be placed on permit approval. Water quality certification is required for projects that discharge into waters or wetlands and that need a federal permit to ensure that they are in compliance with the State's surface water quality standards.

The Chapter 91 Waterway regulations require licenses for work in tidal wetlands and waterbodies, great ponds, and many nontidal waterways. For those nontidal waterways in private ownership, only the public right to navigation is protected.

The License to Apply Chemicals is administered by the Department of Environmental Protection's Water Pollution Control Section. When chemicals are used to control or eradicate nuisance aquatic vegetation, licenses are required.

Ground water protection regulations are administered by the Department of Food and Agriculture. They control the types of chemicals that can be applied to Zone I and Zone II groundwater supply areas. Consult the Department for information on the location of these zones if intending to use herbicides to control *Phragmites.*

When applying for a permit to control *Phragmites*, it is important to fully describe the method of control, the purpose of the activity, and the impacts associated with the control. It is important to include information on the time of year when applying the technique, long-term management or maintenance, and any related work. Critical questions to answer include the following:

1. Will the control method result in flooding of land or property that is not presently flooded?

2. Will the control method adversely affect public or private water supplies? (Has the control method selected been based upon its proximity to surface and/or ground water drinking supplies?)

3. Will the control method alter a wetland resource area, other than the *Phragmites* marsh?

4. Will the control method cause long- or short-term impacts to rare and endangered species habitat? (If the subject marsh is in a designated habitat for rare species, you must send a copy of the Notice of Intent to the Natural Heritage and Endangered Species Program, Department of Environmental Management.)

5. Is the control method properly designed for the site?

6. Will the control method adversely affect public rights of access to the water or interfere with navigation?

7. Will the control method adversely affect shellfish or finfish habitat or will it interfere with an anadromous or catadromous fish run?

It is important to clearly state the goal of the *Phragmites* control project (e.g., improve wildlife habitat, increase biodiversity, and eliminate a fire hazard). Many projects will have multiple goals. A project that allows for the establishment or re-establishment of a better functioning wetland, then the project is more likely to be approved.

The local conservation commission or the DEP should be contacted for issues dealing with wetland regulations or if there is a question whether wetland regulations apply. The DEP should also be contacted with questions about water quality certification and Chapter 91 waterway regulations.

The following are the State agency points of contact:

Department of Environmental Protection, Division of Wetlands and Waterways Regulations and Water Quality Certification:

Northeast Regional Office	978-661-7677
Southeast Regional Office	508-946-2714
Central Regional Office	508-792-7683
Western Regional Office	413-784-1100 x214
Boston Office	617-292-5695
Water Pollution Control	617-292-5781

SECTION 5. CASE STUDIES IN MASSACHUSETTS AND SOUTHERN NEW ENGLAND

Listed below are several case histories for *Phragmites* control projects in Massachusetts and Connecticut. They provide examples of the real world effectiveness of some of the techniques outlined in Section 3. Most of the projects have involved *Phragmites* control in tidally restricted former salt marshes. These are typical salt marsh restoration projects in the region. Additional case studies may be reported in the future in the Wetland Restoration Newsletter. More up-to-date information may be available for specific projects, so contact the appropriate agency for current findings.

5.1. Restoration of Pine Creek Salt Marshes, Fairfield, Connecticut

Pre-existing Conditions/Problem: In 1914, there were 640 acres of viable salt marsh. The marshes have been ditched for mosquito control. They were mowed for salt hay until the late 1950s. The marshes have been used for a municipal dump and partly filled for development. By 1979, only about 17 acres remained. Summer cottages surrounding the marshes have been converted to year-round residences. Dikes were constructed to provide flood protection. Conventional flapper tidegates were installed on dike culverts to permit outflow of stormwater runoff from the watershed at low tide and to prevent the inflow of the tides. The plant community of the marsh changed from a mixture of short form smooth cordgrass (*Spartina alterniflora*) and salt hay (*Spartina patens*) to one dominated by seaside goldenrod (*Solidago sempervirens*), aster (*Aster* sp.), and common reed. The freshwater environment has facilitated people planting lawns and gardens on the former salt marsh. Common reed has caught fire on several occasions. These fires have burned a lumber company, cars, porches, fences, scorched homes, cracked windows, and melted vinyl siding from homes. In 1975, Fairfield averaged 100 fires/year on its diked marshes at a cost of $30,000 for fire suppression. The State abandoned mosquito control due to the lack of access through the common reed. By 1980, the marshes produced more mosquitoes than the original salt marshes.

Project Objectives: Restore tidal flow, while providing flood protection.

Treatment: In 1980, removed tide gates and dikes nearest the creek mouth to Long Island Sound and built a new 2500-foot dike around the lower marsh to maintain existing flood protection (cost $250,000). Restored tidal flow to a 10-acre lagoon and 25 acres of degraded salt marsh. Town also removed sediment, refuse, and debris from obstructed culverts, bridges, and channels. Used rotary ditcher to clean ditches that bred mosquitoes and utilized open marsh water management techniques for mosquito control. From 1980-86, installed self-regulating tide gates that were designed and patented by the Conservation Director (Thomas Steinke) (cost not given). These gates eliminated the highest tides from entering the marshes.

Monitoring: Installed *Phragmites* height gauges prior to restoring tidal flow to upper marshes. Annually inspect study sites and mark height of *Phragmites* with a painted line. Also measured density of stems per square meter.

Recent Results: Height of *Phragmites* was reduced from 12 feet to less than 4 feet after four growing seasons. Elimination of *Phragmites* is expected between years 10 and 12. Stem density has been reduced from several hundred to about 20 per square meter. Note: When combined with a growing season burn (July 4th), tidal flushing reduced *Phragmites* height 50% for each year, until they ran out of natural fuel in the fourth year. Increased tidal action also resulted in salt kills of lawns and gardens planted in former salt marsh. One homeowner made complaints of basement flooding, but the home had a long history of such problems. The combination of heavy rains, high groundwater, and high tides led to winter flooding problems. Resolved problem by closing tidegates during winter high water period, reopening them in March, and keeping them open until October. Town is monitoring the effect of this remedy and will help homeowner if problem continues.

Additional Comments: Sediment and debris accumulating at culverts and bridges are removed annually. Original plan for salt marsh restoration called for constructing a peripheral dike along the upland edge of the marsh. This proved infeasible--too many easements from unsupportive landowners and high construction costs were major obstacles. Instead opted for a self-regulating tide gate. As *Phragmites* is dying back, the marsh peat is losing some of its stability. Walking across the marsh has been likened to walking in knee-deep snow without snowshoes. It is undetermined what impact this may have on restoration. Some adjoining landowners are complaining of the rotten egg odor (hydrogen sulfide) emitted from one area of the restored marshes; this was first noticed 7 years after the restoration was done. Older residents say this is what the marsh smelled like decades ago. A fuel oil spill (300-500 gallons) in 1990 may be related to the problem. Over time, have eliminated upland runoff via storm sewers into the marsh; this has probably enhanced the restoration--this runoff is now piped into stormwater detention basins.

Preparer's Name: Ralph Tiner
Affiliation: Massachusetts Wetlands Restoration and Banking Program

Special Note: Prepared from materials provided by Thomas Steinke, Conservation Director, Conservation Department, Fairfield, Connecticut, especially "Restoration of degraded salt marshes in Pine Creek, Fairfield, Connecticut."

5.2. Hanscom Field *Phragmites* Study, Hanscom Field, Concord, Massachusetts

Pre-existing Condition/Problem: A small stand of common reed measuring approximately 100 feet long by 35 feet wide currently dominates a wetland area at the end of Runway 11 at Hanscom Field in Concord, MA. Prior to application of control techniques, the stand had an average height of approximately 10 feet and extended along a security fence in a seasonally wet drainage ditch. The Concord Natural Resources Commission required Massport to attempt to eliminate the patch of *Phragmites*, preferably using a non-chemical technique, as part of a 1995 vegetation removal project.

Project Objective: To eradicate the approximately 3,500 sq. ft. patch of Phragmites using a non-chemical control technique.

Treatment (1995): Massport is attempting to eradicate the *Phragmites* patch by covering it with black plastic. All above-ground growth of *Phragmites* was removed from the site on August 10, 1995, by hand pulling and the use of a weed whacker. All mature plants with seed heads were carefully removed from the site and disposed of in a sandy upland area where germination would not reoccur. The entire patch was covered with black 6 MIL thick plastic. Rocks, fence posts, and logs were placed on top of the plastic to hold it in place.

Treatment (1996): In the spring of 1996, the black plastic sheeting was reinstalled, but this time smaller overlapping sections were used in an effort to minimize tearing. Most of the vegetation had already been removed from the previous year's work, so minimal additional site clearing was required.

Monitoring: Site visits were conducted once every month from September 1995 through November 1995 to visually inspect the effects of the plastic on the *Phragmites*. Observations such as soil color, percent cover and average height of *Phragmites* growth, signs of root die off, and integrity of the plastic sheeting were recorded. In 1996, monitoring will occur approximately once a month until the end of November.

Recent Results: Site observations in 1995 indicated that *Phragmites* growth was suppressed by the plastic sheeting and no new growth occurred.

Over the winter and spring of 1996, the large plastic sheets deteriorated and tore, allowing sunlight to penetrate to much of the area and preventing heat buildup. Growth was suppressed in areas covered by the plastic remnants, but *Phragmites* shoots sprouted in the exposed areas and around the edges of the plastic. This new growth suggested that the *Phragmites* roots had not been significantly impacted by thermal heat during the previous late summer and fall.

Eventually the black plastic tore apart and was not replaced. The project was abandoned.

Additional Comments: If the plastic remains intact, it is expected that the thermal effect will eradicate *Phragmites* growth and kill the roots by the end of the 1996 growing season. Initiating this project in the early summer and utilizing a full season of intense sun should produce better results than was observed in 1995.

Preparer's Name: Deborah A. Hadden and Michael J. Rotondi
Affiliation: Massachusetts Port Authority

5.3. Restoration of Post Island Marsh, Houghs Neck, Quincy, Massachusetts

Pre-existing Condition/Problem: The subject 10-acre former salt marsh had been cut off from regular incursions of sea water for nearly six decades, resulting in an overgrowth of *Phragmites* that posed a serious fire hazard. Existing drainage ditches became clogged, creating pockets for heavy mosquito breeding. Wildlife habitat was also reduced by the dominance of common reed.

Project Objective: Re-establish tidal flow and increase soil salinity to stress common reed and allow return of salt marsh species.

Treatment: Constructed tide gate to restore tidal flowage. Supplemented this with vigorous mowing and interplanting of smooth cordgrass. Contingency strategy: use black plastic sheets to cover reed shoots after mowing (not employed to date). Cost of treatment was $95,200 or $9,510/acre ($47K construction, $18K headwall/pump station, $18K tidegate and chambers, $10K engineering services, and $2.7K strategy development).

Monitoring: No data available, but Harvard Graduate School of Design (Landscape Ecology) students have studied the changes in soil salinity.

Recent Results: Common reed is stunted and probably reduced in density; salt marsh vegetation is re-establishing.

Additional Comments: Site has served as an educational site for European and South American students studying hydrologic functioning of wetlands and ground water development at Harvard University's Applied Science Department.

Preparer's Name: Michael Wheelwright
Affiliation: City of Quincy, Public Works

5.4. Restoration of Third Marsh, Houghs Neck, Quincy, Massachusetts

Pre-existing Conditions: This 20-acre marsh is the remains of a larger marsh that was filled in the 1940s for houses. Flood protection and drainage facilities were built along with seawalls, street drains, and a one-way tidegate (to keep tides out) to mitigate mosquito and flood hazards for abutters. The tide gate created internal drainage problems for residents. These changes led to a change in the marsh from salt marsh to fresh marsh.

Project Objective: To re-establish tidal flushing for promoting salt marsh vegetation.

Treatment: Installed automatic tide gate to allow tidal flooding to levels that would not create a flood hazard for residents. Planted salt marsh species to accelerate salt marsh recovery. A 500-foot dike was constructed at Rock Island Road to protect properties to the east. Project costs were $279,000 or $13,950/acre ($159K construction, $42K headwall, $30.6K engineering, $29.4K two tidegates, $16K chambers, and $2K study).

Project Results: Internal drainage has been improved and salt marsh is re-establishing.

Prepared By: Michael Wheelwright
Affiliation: City of Quincy, Public Works

5.5. *Phragmites* Control at Hodges Village Dam Floating Bog, Oxford, Massachusetts

Pre-existing Conditions/Problem: *Phragmites* was rapidly colonizing a 4-acre floating bog at the Army Corps of Engineers Hodges Village flood control project. The bog is located in an isolated depression within woodland. No other *Phragmites* stands are nearby. Common reed had colonized about 1/4 acre at one end of the bog and was rapidly spreading through growth of rhizomes (stolons). Based on growth of new shoots, the expansion rate is about 7-10 feet (2-3 meters) per year. Shoot density ranged from about 50 stems/square meter in the center of the stand to less than 1 shoot/square meter at the leading edge of the *Phragmites*.
Project Objectives: Eradicate the *Phragmites* to preserve the floating bog community.

Treatment: An herbicide (5% Rodeo with 0.5% Arbochem as a surfactant) was applied to the stand using a backpack mist blower in early September 1995. The temperature was in the mid-70s and winds were calm. The 1/4 acre treatment took 1/2 hour at a cost of $200. Care was taken not to spray adjacent areas. Follow-up treatment may be needed.

Monitoring: Once eradication is achieved, the area will be monitored annually.

Recent Results: Two weeks after herbicide treatment, more than 90% of the reed shoots were brown and appeared to be dying. Damage to adjacent vegetation was minimal.

Preparer's Name: Mike Penko
Affiliation: U.S. Army Corps of Engineers, New England District

Special Note: Prepared from information provided by Dave Stidham, Park Manager, Buffumville Lake/Hodges Village Dam, Oxford, MA and by Harry Williston, Vegetation Control Services, Athol, MA.

5.6. Lewis Lake Salt Marsh Restoration Project, Winthrop, Massachusetts

Pre-existing Conditions/Problem: Lewis Lake consists of two basins--a 3.88 acre upper basin and a 3.93 lower basin, which both drain into Crystal Cove and then into Boston Harbor. The lake, originally part of the Crystal Cove salt marsh-estuary system, was partially cut off from tidal flow by a tide gate constructed in the 1960s to alleviate flooding concerns. Since then, the structure has fallen into disrepair, isolating the lake from the ocean. Salinity levels have dropped, water quality has declined, and common reed has replaced much of the original salt marsh vegetation. Nuisance algal blooms have discolored the water and caused localized odor problems for residents.

Project Objectives: To restore tidal flow and increase salinity for improving the water quality of Lake Lewis and re-establishing salt marsh vegetation. Also to create a more productive habitat for fish, waterfowl, and other biota and to provide flood protection to Winthrop residents. In addition, the restoration project seeks to inform the public that Lewis Lake is a resource that needs to be preserved.

Treatment: Through the efforts of the Winthrop Conservation Commission, in the spring of 1996, the town has repaired and automated the tide gate at the southern end of the lower basin to restore tidal flow to Lewis Lake. The bottom of the tide gate is 4.29 feet below mean sea level (MSL), which should allow for maximum flushing. The upper elevation is set at 0.7 feet below MSL, but will be eventually set at MSL.

Monitoring: Massport has prepared a base map identifying the topography and existing vegetation zones from field surveys, developed a vegetation monitoring program that was initially conducted by Massport but will be taken over by local volunteers, created a water quality monitoring program for local volunteers (training provided by Massport), and assessed existing and proposed tidal elevations to ensure no adverse flooding of adjacent properties. Water quality monitoring will involve salinity, dissolved oxygen, turbidity, pH, and temperature plus observing water color and odors, among other things. Vegetation monitoring will involve examining permanent plots: 4 in salt marsh, 4 in freshwater vegetation, 3 in transition areas, 3 in adjacent uplands, 1 in a spurrey flat, and 1 in a mud flat. The following parameters will be examined:

plant species composition, percent cover, stem height, stem density, root zone salinity, debris accumulation, plus a soil profile description. Additional observations on wildlife, disturbance, erosion, and sedimentation will be made.

Recent Results: Salinity in Lake Lewis has increased from 20-25 ppt in late March 1995 to 23-27 ppt in July 1996. Root zone salinity has increased, especially in the sand spurrey zone (24.8 ppt to 39.2 ppt). Percent cover increased in most sample plots. Mud and sand spurrey flats increased in size, the percent cover of smooth cordgrass (*Spartina alterniflora*) increased, while the percent cover of common reed decreased in most plots. Stem heights of common reed decreased in all plots.

Preparer's Name: Deborah A. Hadden and Cheryl A. Ferrone
Affiliation: Massachusetts Port Authority

5.7. Central County Ditch Wetlands Restoration, Revere, Massachusetts

Pre-existing Conditions/Problem: Approximately 24-acres of *Phragmites*-dominated wetland developed as a result of the installation of a standard flapper type tidegate for flood control. *Phragmites* contributes to drainage impairment by blocking trash wrack at the culvert. Inadequate maintenance of the tidegate led to its disrepair and subsequent salt water leakage since 1992. There has been a corresponding die-back in the *Phragmites* and a stunting of some of the remaining reeds. In October 1996, a northeaster flood tide caused the tidegate to fall off its hinge. The wetland is part of the Rumney Marsh complex.

Project Objectives: To restore tidal flow to the former salt marsh, increase soil salinities to favor salt marsh species and reduce or eliminate *Phragmites*, and to protect local properties from flooding. Project sponsors were the Corps of Engineers, U.S. EPA, City of Revere Planning Office and Department of Public Works, and the Syratech Corporation.

Treatment: In the fall of 1997, a self-regulating tidegate (SRT) was installed -- this is the first such tidegate installed in Massachusetts. Project costs were about $125,000 which included cofferdam construction and dewatering. The tidegate was constructed above a 24-acre section of marsh that previously had restricted tidal flow due to a malfunctioning tidegate. The SRT was constructed in a location to protect low-lying properties from tidal flooding by storm tides.
Recent Results: In January 1998 the tidegate was adjusted and in the spring of 1998, it was adjusted to the desired summer tide level. There was a noticeable 12-acre die-off of common reed in the area where tidal flow was restored (no tide gate). An intertidal mud zone is now being colonized by salt marsh species. Some *Phragmites* remains, but it is now stunted and probably less dense.

Monitoring: Unknown.

Preparer's Name: Edward Reiner

Affiliation: U.S. Environmental Protection Agency

5.8. Lower Connecticut River *Phragmites* Control in Old Lyme, Old Saybrook, and East Haddam, Connecticut

Pre-existing Conditions/Problem: *Phragmites* stands in coastal wetlands of variable salinities. At the Saybrook Point site in Old Saybrook, a main channel was blocked with about 3,000 cubic yards of woody debris.

Project Objectives: To eliminate or reduce *Phragmites* and promote the growth of other coastal wetland plant species.

Treatment: For the 10-acre Saybrook Point site, removed woody debris, cleaned main channel and constructed four Open Marsh Water Management (OMWM) ponds. After the second year, stands of remaining *Phragmites* were sprayed with Rodeo. A month later, the stand was mowed and mulched with an amphibious low ground pressure personnel carrier bearing a Seppi mulching head. This head can cut up to 4 acres of Phragmites per day.

A 5-acre site at South Cove in Old Saybrook was sprayed with Rodeo and, after 6 months, the *Phragmites* remains were mulched. The Chapman Pond site in East Haddam was sprayed with Rodeo in 1995 and mulched in September 1996.

Recent Results: Saybrook Point site showed a tremendous change in *Phragmites* height after one year; no data after spraying the remaining Phragmites. South Cove site, after the first year, 50% of the site has become revegetated. At the Chapman Pond site, at least 90% of the Phragmites has been eliminated as of the fall of 1996.

Monitoring: Not specified, but will be monitoring vegetation changes over a several year period.

Preparer's Name: Ralph Tiner
Affiliation: U.S. Fish and Wildlife Service

Special Note: Prepared from an October 24, 1996, summary of Lower Connecticut River restoration efforts written by Paul Capotosto, Wetland Restoration Biologist, CT DEP Wildlife Division-Wetlands Restoration Program, Franklin Wildlife Management Area, North Franklin, CT. Since 1986, more than 1,500 acres of degraded salt marshes have been restored in Connecticut by this program.

SECTION 6. PHRAGMITES WORKING GROUP RECOMMENDATIONS

Based on discussions of the Phragmites Working Group, there are several recommendations to improve the science, our knowledge on the extent of the problem, and current policy and regulatory review procedures. EOEA and participating federal agencies (namely the Corps of Engineers and EPA) should seek funds to investigate these topics. Likewise, universities are encouraged to develop grant proposals (e.g., Sea Grant) for similar purposes.

6.1. Science and Inventory Recommendations

The Phragmites Working Group identified four major areas of inquiry (listed in priority order):

1. Conduct studies on the effectiveness of various control techniques at achieving the desired objective and evaluating the overall habitat benefits, especially in freshwater environments. Especially investigate the effect of different cutting practices on *Phragmites*. Although some work has been done in this area, more study would be beneficial. Perhaps some optimal cutting schedule can be established. Other studies should examine whether a combination of cutting and removal of leaf litter helps encourage revegetation by other species.

2. Develop a program to inventory significant stands of common reed and identify invasive *Phragmites* stands where control and/or marsh restoration is desirable. Be sure to include small sites where *Phragmites* is beginning to place endangered species or their habitats in jeopardy. The Wetlands Conservancy Mapping Program should be encouraged to identify *Phragmites* marshes as a separate wetland type in their mapping, since such marshes are photointerpretable.

3. Initiate studies to investigate the wildlife use of common reed marshes under a variety of environmental settings and compare with use of other vegetation.

4. Conduct ecological studies on numerous topics, including growth rates of stands, differences in salinity tolerances, identifying ecotypes, and differences in seed production and viability. Of particular interest are genetic studies in New England to determine if there are two or more distinct forms of *Phragmites*--native vs. exotic.

6.2. Regulatory and Management Recommendations

Some members of the Phragmites Working Group have reported problems initiating *Phragmites* control/wetland restoration projects due to the regulatory process, including varied interpretation of state wetland regulations that have precluded wetland restoration and required mitigation involving in-kind replacement of altered *Phragmites* marshes (creating new or expanding existing *Phragmites* marshes) that are a major cause for concern.

The Phragmites Working Group has identified four areas for improved regulation and management regarding *Phragmites* control and wetland restoration.

1. Identify situations where permitting processes (including MEPA review) can be streamlined to facilitate wetland restoration and control of invasive *Phragmites* and develop appropriate procedures.

2. Discourage planting of common reed for various uses (e.g., erosion control, bank stabilization, and wastewater treatment), except where there are clear benefits and appropriate safeguards to prevent or minimize the spread of *Phragmites* to neighboring sites.

3. Initiate control of *Phragmites* in degraded salt marshes by restoring tidal flow to the degree possible given various constraints, mainly low-lying development. For the latter sites, promote the use of self-regulating tidegates or similar devices that can improve tidal flushing while protecting development from damaging floods.

4. In towns with heavy concentrations of common reed, initiate a public awareness program on the problems associated with common reed and the need to manage it.

PHRAGMITES BIBLIOGRAPHY

Allen, S.E. and W.H. Pearsall. 1963. Leaf analysis and shoot production in *Phragmites*. Oikos 14: 176-189.

Andersen, F.O. and J.I. Hansen. 1982. Nitrogen cycling and microbial decomposition in sediments with *Phragmites australis* (Poaceae). Hydrological Bulletin 16: 11-19.

Armstrong, J., W. Armstrong, and P.M. Beckett. 1992. *Phragmites australis*: venturi- and humidity-induced pressure flows enhance rhizome aeration and rhizosphere oxidation. New Phytol. 120: 197-207.

Axell, H.E. 1982. Control of reeds (*Phragmites communis*) at Minsmere, England. Chapter 4. In: D.A. Scott (editor). Managing Wetlands and Their Birds. A Manual of Wetland and Waterfowl Management. Proc. 3rd Tech. Mtg. on Western Palearctic Migratory Bird Mgmt. pp. 44-50.

Bayly, I.L. and T.A. O'Neill. 1972. Seasonal ionic fluctuations in a *Phragmites communis* community. Can. J. Bot. 50: 2103-2109.

Beck, R.A. 1971. *Phragmites* control for urban, industrial, and wildlife needs. Proc. Northeastern Weed Science Meeting 25: 89-90.

Beck, R.A. and J.H. Stennis. 1964. *Phragmites* control in Delaware. Proc. Northeast Weed Control Conference, New York, NY: 504-506.

Beck, R. 1957. Herbicides increase game foods and edge in solid stands of *Phragmites*. Down to Earth 13 (1): 2-3.

Belova, M. 1993. Microbial decomposition of freshwater macrophytes in the littoral zone of lakes. Hydrobiologia 251(1-3): 59-64.

Benoit, L. 1997. Impacts of *Phragmites* on tidal marsh birds. *Phragmites* workshop. Institute of Ecosystem Studies, Millbrook, NY. (April 29, 1997). Abstract.

Bernard, J.M. 1993. Growth and development of stolons of *Phragmites communis* Trin. Wetlands: Proceedings of the 13th Annual Conference of the Society of Wetland Scientists, New Orleans, LA, USA.

Besitka, M.A.E. 1996. An Ecological and Historical Study of *Phragmites australis* Along the Atlantic Coast. Department of Bioscience and Biotechnology, Drexel University, Philadelphia, PA. M.S. thesis.

Best, E.P.H., M. Zippin, and J.H.A. Dassen. 1981. Growth and production of *Phragmites australis* in Lake Vechten (the Netherlands). Hydrobiological Bulletin, Netherlands Hydrobiological Society 15(3): 165-174.

Bibby, C.J. and J. Lunn. 1982. Conservation of reed beds and their avifauna in England and Wales. Biological Conservation 23: 167-186.

Bird, E.C.F. 1961. Reed growth in the Gippsland Lakes. Vict. Nat. 77: 262-268.

Bjork, S. 1967. Ecologic Investigations of *Phragmites communis*: Studies in Theoretic and Applied Limnology. Oslo University Press, Oslo, Norway. Folia Limnologica Scandinavica No. 14.

Blom, C.W.P.M., H.M. van de Steeg, and L.A.C.J. Voesenek. 1996. Adaptive mechanisms of plants occurring in wetland gradients. In: G. Mulamoottil, B.G. Warner, and E.A. McBean (editors). Wetlands: Environmental Gradients, Boundaries and Buffers. Lewis Publishers/CRC Press, Inc., Boca Raton, FL. pp. 91-112.

Bolen, E.G. 1964. Plant ecology of spring-fed salt marshes in western Utah. Ecol. Mongr. 34: 143-166.

Bongiorno, S.F., J.R. Trautman, T.J. Steinke, S. Kawa-Raymond, and D. Warner. 1984. A study of restoration in Pine Creek Salt Marsh, Fairfield, Connecticut. In: Proceedings of the llth Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Environmental Studies Center, Tampa, Florida. pp. 10-23.

Bontje, M.P. 1988. The application of science and engineering to restore a salt marsh, 1987. In: F.J. Webb (editor). Proceedings 15th Annual Conf. on Wetlands Restoration and Creation. Hillsborough Community College, Tampa, FL. pp. 16-24.

Boone, J., E. Furbish, and K. Turner. 1987. Control of *Phragmites communis*: results of burning, cutting, and covering with plastic in a North Carolina marsh. National Park Service, U.S. Department of the Interior. CPSU Technical Report 41.

Boone, J., E. Furbish, K. Turner, and S. Bratton. 1988. Clear plastic. A non-chemical herbicide. Restoration & Management Notes 6: 101.

Brix, H. 1988. Light-dependent variations in the composition of the internal atmosphere of *Phragmites australis* (Cav.) Trin. ex Steudel. Aquatic Botany 30 (4): 319-329.

Buck, E.L. 1995. Selected Environmental Factors and the Spread of *Phragmites australis* (Common Reed) in the Tidelands of the Lower Connecticut River. Department of Botany, Connecticut College, New London. Honor's thesis.

Bucsbaum, H., M. Horowitz, Y. Kleifeld, G. Herzlinger, and A. Bargutti. 1985. Experiments on the control of *Phragmites* in drainage canals. Phytoparasitica 13(3-4): 249-250.

Burdick, D.M. and M. Dionne. 1994. Comparison of Salt Marsh Restoration and Creation Techniques in Promoting Native Vegetation and Functional Values. Office of State Planning, Concord, NH, USA.

Burgoon, P.S., K.R. Reddy, and T.A. DeBusk. 1989. Domestic wastewater treatment using emergent plants cultured in gravel and plastic substrates. In: D.A. Hammer (editor). Constructed Wetlands in Wastewater Treatment. Lewis Publishers, Chelsea, MI. pp. 536-541.

Burian, K. 1971. Primary production, carbon dioxide exchange and transpiration in *Phragmites communis* Trin. on the Lake Nevsiedler See, Austria. Hydrobiologia 12: 203-218.

Buttery, B.R. and J.M. Lambert. 1965. Competition between *Glyceria maxima* and *Phragmites communis* in the region of Surlingham Broad. I. The competition mechanism. J. Ecol. 53: 163-181.

Buttery, B.R., W.T. Williams, and J.M. Lambert. 1965. Competition between *Glyceria maxima* and *Phragmites communis* in the region of Surlingham Broad. II. The fen gradient. J. Ecol. 53: 183-195.

Casagrande, R.A. 1997. Potential of European insects to control North American *Phragmites*. *Phragmites* workshop (April 29, 1997). Institute of Ecosystem Studies, Millbrook, NY. Abstract.

Catchpole, C.K. and C.F. Tydeman. 1975. Gravel pits as new wetland habitats for the conservation of breeding bird communities. Biol. Conserv. 8 (1): 47-59.

Chambers, R.M. 1997. Porewater chemistry associated with *Phragmites* and *Spartina* in a Connecticut tidal marsh. Wetlands 17(3): 360-367.

Cizkova-Koncalova, H., J. Kvet, and K. Thompson. 1992. Carbon starvation: a key to reed decline in eutrophic lakes. Aquatic Botany 43: 105-113.

Clayton, W.D. 1968. The correct name of the common reed. Taxon 17 (2): 168-169.

Conway, T.E. and J.M. Murtha. 1989. Iselin Marsh Pond Meadow. In: D.A. Hammer (ed.). Constructed Wetlands in Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, MI. pp. 139-144.

Cooper, P.F. and J.A. Hobson. 1989. Sewage treatment by reed bed systems: the present situation in the United Kingdom. In: D.A. Hammer (editor). Constructed Wetlands in Wastewater Treatment. Lewis Publishers, Chelsea, MI. pp. 153-171.

Cowie, N.R., W.J. Sutherland, M.K.M. Ditlhogo, and R. James. 1992. The effects of conservation management of reed beds. II. The flora and litter disappearance. J. Appl. Ecol. 29: 277-284.

Cross, D.H. and K.L. Fleming. 1989. Control of *Phragmites* or common reed. Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.12. U.S. Fish and Wildlife Service, Washington, DC. 5 pp.

Daniels, R.E. 1975. Observations on the performance of *Narthecium ossifragum* (L.) Huds. and *Phragmites communis* Trin. J. Ecol. 63 (3): 965-977.

Daniels, R.E. 1991. Variation in performance of *Phragmites australis* in experimental culture. Aquatic Botany 42: 41-48.

Daukas, P., D. Lowry, and W. W. Walker. 1989. Design of wet detention basins and constructed wetlands for treatment of stormwater runoff from a regional shopping mall in Massachusetts. In: D.A. Hammer (ed.). Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, MI. pp. 686-694.

Dawson, B. 1989. High hopes for cattail. Civil Engineering CEWRA9 Vol. 59: 48-50.

DeBusk, T.A., P.S. Burgoon, and K.R. Reddy. 1989. Secondary treatment of domestic wastewater using floating and emergent macrophytes. In: D.A. Hammer. Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, MI. pp. 525-529.

De Jong, J. 1976. The purification of wastewater with the aid of rush or reed ponds. In: J. Tourbier and R.W. Pierson, Jr. (editors). Biological Control of Water Pollution. University of Pennsylvania Press, Philadelphia, PA.

de la Cruz, A.A. 1978. The production of pulp from marsh grass. Economic Botany 32: 46-50.

de la Cruz, A.A. and G.R. Lightsey. 1981. Pulping characteristics and paper making potential of non-wood wetland plants. Mississippi-Alabama Sea Grant Consortium, Ocean Springs, MS. Publication No. MASGP-80-016.

Dill, H.H. 1958. Controlling cattail and *Phragmites* with amitrol. Proceedings North Central Weed Control Conference 15:40.

Dinka, M. 1986. The effect of mineral nutrient enrichment of Lake Blaton on the common reed (*Phragmites australis*). Folia Geobotanica et Phytotaxonomica 21 (1): 65-84.

Downing, D.M. 1977. Ecology of common reed (*Phragmites communis*): an annotated bibliography. Coop. Wildl. Res. Lab., Southern Illinois University, Carbondale, IL.

Evans, D.M. 1987. *Phragmites* control with glyphosate through selective equipment. Proc. 6th EWRS International Symposium on Aquatic Weeds. Brussels, Belgium. pp. 209-211.

Fell, P.E., S.P. Weissbach, D.A. Jones, M.A. Fallon, J.A. Zeppieri, E.K. Faison, K.A. Lennon, K.J. Newberry, and L.K. Reddington. 1998. Does invasion of oligohaline tidal marshes by reed grass, *Phragmites australis* (Cav.) Trin. Ex Steud., affect the availability of prey resources for the mummichog, *Fundulus heteroclitus* L.? J. Exp. Mar. Biol. Ecol. 222: 50-77.

Fernald, M.L. 1932. *Phragmites communis* Trin., var. *berlandieri* (Fournier), comb. var. Rhodora 34: 211-212.

Geisslhofer, M. and K. Burian. 1970. Biometric studies in the dense stands of reeds of the Lake of Neusiedl. Oikos 21: 248-254.

Geller, M.S. 1972. *Phragmites*: life preserver of the salt marsh. Underwater Natur. 7: 4-11.

Gersberg, R.M., S.R. Lyon, B.V. Elkins, and C.R. Goldman. 1984. The removal of heavy metals by artificial wetlands. In: Proceedings Water Reuse Symposium III: Future of Water Reuse. San Diego, CA. Vol. 2: 639-648.

Gorham, E. and W.H. Pearsall. 1956. Production ecology III. Shoot production in *Phragmites* in relation to habitat. Oikos 7: 206-214.

Graneli, W. 1984. Reed Phragmites australis (Cav.) Trin. ex. Steudel as an energy source. Biomass 4: 183-208.

Graneli, W. 1989. Influence of standing litter on shoot production in reed, *Phragmites australis* (Cav.) Trin. ex Steudel. Aquatic Botany 35: 99-109.

Gries, C. and D. Garbe. 1989. Biomass, and nitrogen, phosphorus and heavy metal content of *Phragmites australis* during the third growing season in a root zone waste water treatment. Archiv fur Hydrobiologie 117: 97-105.

Gries, C., L. Kappen, and R. Losch. 1990. Mechanism of flood tolerance in reed, *Phragmites australis* (Cav.) Trin. ex Steudel. The New Phytologist 114: 589-593.

Gryseels, M. 1989. Nature management experiments in a derelict reedmarsh I: Effects of winter cutting. Biological Conservation 47: 171-193.

Hara, T., J. van der Torn, and J.H. Mook. 1993. Growth dynamics and size structure of shoots of *Phragmites australis*, a clonal plant. J. Ecol. 81: 47-60.

Haslam, S.M. 1975. The performance of *Phragmites communis* Trin. in relation to temperature. Ann. Bot. 39: 881-889.

Haslam, S.M. 1973. Some aspects of the life history and autecology of *Phragmites communis* Trin. A review. Pol. Arch. Hydrobiol. 20: 79-100.

Haslam, S.M. 1972. *Phragmites communis* Trin. Biol. Flora Brit. Isles. J. Ecol. 60: 585-610.

Haslam, S.M. 1971. Shoot height and density in *Phragmites* stands. Hydrobiologia 12: 113-119.

Haslam, S.M. 1971. Community regulation in *Phragmites communis* Trin. II. Mixed stands. J. Ecol. 59: 75-88.

Haslam, S.M. 1971. Community regulation in *Phragmites communis* Trin. I. Monodominant stands. J. Ecol. 59: 65-73.

Haslam, S.M. 1971. The development and establishment of young plants of *Phragmites communis* Trin. Ann. Bot. 35: 1059-1072.

Haslam, S.M. 1970. The performance of *Phragmites communis* Trin. in relation to water-supply. Ann. Bot. 34: 867-877.

Haslam, S.M. 1970. The performance of *Phragmites communis* Trin. Ann. Bot. 34: 147-158.

Haslam, S.M. 1970. The development of annual population in *Phragmites communis* Trin. Ann. Bot. 34: 571-591.

Haslam, S.M. 1969. The development of shoots in *Phragmites communis* Trin. Ann. Bot. 33: 695-709.

Haslam, S.M. 1969. Stem types of *Phragmites communis* Trin. Ann. Bot. 33: 127-131.

Haslam, S.M. 1969. Development and emergence of buds in *Phragmites communis* Trin. Ann. Bot. 33: 289-301.

Haslam, S.M. 1968. The biology of reed (*Phragmites communis*) in relation to its control. Proc. British Weed Control Conf. 9: 392-397.

Hellings, S.E. and J.L. Gallagher. 1992. The effects of salinity and flooding on *Phragmites australis*. J. Applied Ecol. 29: 41-49.

Horstman, A.J. 1995. Use of Emergent Wetlands on Mined Lands by Threatened and Endangered Avifauna. M.S. thesis, Department of Zoology, Southern Illinois University, Carbondale, IL.

Howard, R., D.G. Rhodes, and J.W. Simmers. 1978. A Review of the Biology and Potential Control Techniques for *Phragmites australis*. Environmental Laboratory, Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, MS. Dredged Material Research Program, Internal Working Document D-78-26. 78 pp.

Imhof, G. 1973. Aspects of energy flow by different food chains in a reed bed. A review. Pol. Arch. Hydrobiol. 20: 165-168.

Kamio, A. 1985. Studies of the drying of marshy and heavy clay soil ground by means of vegetations - changes in soil water caused by evapotranspiration of *Phragmites communis*. J. Yamagata Agr. For. Soc. 42: 53-60.

Kim, C.S. 1975. A study on standing crops in *Phragmites communis* communities and their environmental factors. Korean J. Bot. 18: 129-134.

Kiviat, E. 1987. Common reed (*Phragmites australis*). In: D.J. Decker and J.W. Enck (editors). Exotic Plants With Identified Detrimental Impacts on Wildlife Habitats in New York State. Exotic Plant Committee of the New York Chapter--The Wildlife Society. Department of Natural Resources, Cornell University Agricultural Experiment Station, Ithaca, NY. pp. 22-30.

Klotzli, F. 1971. Biogenuous influence on aquatic macrophytes, especially *Phragmites communis*. Hydrobiologia 12: 107-111.

Kohl, J.-G., P. Woitke, H. Kühl, M. Dewender, and G. König. 1998. Seasonal changes in dissolved amino acids and sugars in basal culm internodes as physiological indicators of the C/N-balance of *Phragmites australis* at littoral sites of different trophic status. Aquatic Bot. 60: 221-240.

Koppitz, H. 1998. Analysis of genetic diversity within and between world-wide reed populations (*Phragmites australis* (Cav.) Trin. ex Steudel). Aquatic Botany (submitted).

Koppitz, H., H. Kühl, K. Hesse, and J.-G. Kohl. 1997. Some aspects of the importance of genetic diversity in *Phragmites australis* (Cav.) Trin. ex Steudel for the development of reed stands. Bot. Acta 110: 217-223.

Krolikowska, J. 1971. Transpiration of reed (*Phragmites communis* Trin.). Pol. Arch. Hydrobiol. 18: 347-358.

Kühl, H. and J.-G. Kohl. 1993. Seasonal nitrogen dynamics in reed beds (*Phragmites australis* (Cav.) Trin. ex Steudel) in relation to productivity. Hydrobiologia 251: 1-12.

Kühl, H. and D. Neuhaus. 1993. The genetic variability of *Phragmites australis* investigates by random amplified polymorphic DNA. In: Ostendorp. W. and Krumscheid-Plankert (editors). Seeuferzerstörung and Seeuferrenaturierung in Mitteleuropa. Limnologie aktuell 5: 9-18.

Kühl, H., H. Koppitz, H. Rolletschek, and J.-G. Kohl. 1998. Clone specific differences in a reed population (*Phragmites australis* (Cav.) Trin. Ex Steudel). Aquatic Botany (submitted).

Kühl, H., P. Woitke, and J.-G. Kohl. 1997. Strategies of nitrogen cycling of *Phragmites australis* at two sites differing in nutrient availability. Int. Revue ges. Hydrobiol. 82: 57-66.

Kvet, J. 1973. Mineral nutrients in shoots of reed (*Phragmites communis* Trin.). Pol. Arch. Hydrobiol. 20: 137-146.

Jones, G.S., R.R. Kunkel, J.P. Kelly, and M.A. Ciaranca. 1991. Checklist Wildlife of the Back Bay Fens and Vicinity, Boston, Massachusetts. Center for Vertebrate Studies, Department of Biology, Northeastern University, Boston, MA.

Jones, W.L. and W.C. Lehman. 1987. *Phragmites* control and revegetation following aerial applications of glyphosate in Delaware. In: W.R. Whitman and W.H. Meredith (editors). Waterfowl and Wetlands Symposium. Delaware Dept. of Natural Resources & Environmental Control, Dover, DE.

Jontos, R., Jr. and C.P. Allan. 1984. Test salt to control *Phragmites* in salt marsh restoration (Connecticut). Restoration & Management Notes 2: 32.

Kiviat, E. 1994. Reed, sometimes a weed. News from Hudsonia 10(3): 4-6.

Kiviat, E. 1995. Nearshore environments of the Hudson: the state of our knowledge of the shallows, wetlands, and shorelines. News from Hudsonia 11(2): 1-6.

Lee, S.Y. 1990. Net aerial primary productivity, litter production and decomposition of the reed (*Phragmites communis* in a nature reserve in Hong Kong: management implications. Marine Ecology Progress Series 66: 161-173.

Lelito Environmental Consultants (LEC). No date given. Restoration of Post Island Marsh: Strategy for Control of the Common Reed, *Phragmites australis*. LEC, Sagamore Beach and Peabody offices.

Marks, M., B. Lapin, and J. Randall. 1993. Element Stewardship Abstract for *Phragmites australis*--Common Reed. The Nature Conservancy, Arlington, VA.

Marks, M., B. Lapin, and J. Randall. 1994. *Phragmites australis* (*P. communis*). Threats, management, and monitoring. Natural Areas Journal 14: 285-294.

McNabb, C.D. and T.R. Batterson. 1991. Occurrence of the common reed, *Phragmites australis*, along roadsides in Lower Michigan. Academician 23: 211-220.

Miller, G. 1989. Use of artificial cattail marshes to treat sewage in northern Ontario, Canada. In: D.A. Hammer (editor). Constructed Wetlands in Wastewater Treatment. Lewis Publishers, Chelsea, MI. pp. 636-642.

Monsanto, Inc. 1992. Rodeo Herbicide. Marketing booklet. Monsanto, St. Louis, MO.

Mook, J.H. and J. Van der Toorn. 1982. The influence of environmental factors and management on stands of *Phragmites australis*. II. Effects on yield and its relationships with shoot density. J. Applied Ecol. 19: 501-517.

Nawrot, J.R., W.B. Klimstra, and J.E. Sandusky. 1990. Biochemical treatment of mine drainage through a reedgrass wetland. In: J. Skousen, J. Sencindiver, and D. Samuel (editors). Proceedings of the 1990 Mining and Reclamation Conference and Exhibition. West Virginia University, Morgantown, WV. Vol. II. pp. 353-363.

Nawrot, J.R. 1981. Stabilization of slurry impoundments without soil cover: factors affecting vegetation establishment. In: Symposium on Surface Mining Hydrology, Sedimentology and Reclamation. University of Kentucky, Lexington, KY. December 7-11, 1981. pp.469-476.

Neuhaus, D., H. Kühl, J.-G. Kohl, P. Dörfel, and T. Börner. 1993. Investigation on the genetic diversity of *Phragmites* stands using genomic fingerprinting. Aquatic Botany 45: 357-364.

Newsted, J.L. 1994. An Assessment of Potential Effects on Aquatic and Terrestrial Organisms Resulting from the Use of Rodeo and a Surfactant of *Phragmites* in the Back Bay Fens and the Riverways, City of Boston. University of Massachusetts, Department of Forestry and Wildlife Management, Amherst, MA. 16 pp.

Niering, W.A. and R.S. Warren. 1980. Vegetation patterns and processes in New England salt marshes. BioScience 30: 301-307.

Niering, W.A. and R.S. Warren. 1977. Our dynamic tidal marshes: vegetation changes as revealed by peat analysis. Connecticut Arboretum Bulletin 12. 22 pp.

Ondok, J. 1970. The horizontal structure of reed stands *Phragmites communis* and its relation to productivity. Predlia (Prague) 42: 256-261.

Ondok, J.P. 1973. Photosynthetically active radiation in a stand of *Phragmites communis* Trin.: II. Model of light extension in the stand. Photosynthetica (Prague) 7: 50-57.

Ondok, J.P. 1973. Photosynthetically active radiation in a stand of *Phragmites communis* Trin.: III. Distribution of irradiance on sunlit foliage area. Photosynthetica (Prague) 7: 311-319.

Orians, G.H. 1980. Some Adaptations of Marsh-nesting Blackbirds. Princeton University Press, Princeton, NJ. 295 pp.

Orson, R.A., R.S. Warren, and W.A. Niering. 1987. Development of a tidal marsh in a New England river valley. Estuaries 10 (1): 20-27.

Pelikan, J. 1978. Mammals in the reedswamp ecosystem. In: D. Dykyjova and J. Kvet (editors). Pond Littoral Ecosystems, Springer-Verlag, Berlin. pp. 357-365.

Phillips, R.C., H.E. Westerdahl, A.L. Mize, and S.A. Robinson. 1993. Summary of Literature Describing the Functional Ability of Wetlands to Enhance Wastewater Quality. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Wetlands Research Program Tech. Rept. WRP-CP-2. 97 pp. plus appendices.

Phillips, S.F. 1976. The relationship between evapotranspiration by *Phragmites communis* Trin. and water table fluctuations in the Delta Marsh, Manitoba. Diss. Abstr. Int'l. B. The Sciences and Engr. Vol. 37 #6.

Polunin, N.V.C. 1982. Processes contributing to the decay of reed (*Phragmites australis*) litter in fresh water. Arch. Hydrobiol. 94: 182-209.

Ricciuti, E.R. 1983. The all too common, common reed. Audubon Magazine, September issue: 65-66.

Riemer, D.N. 1973. Effects of rate, spray volume, and surfactant on the control of *Phragmites* with glyphosate. Proc. Ann. Meeting Northeast Weed Sci. Soc. 27: 101-104.

Riemer, D.N. 1976. Long-term effects of glyphosate applications to *Phragmites*. J. Aqu. Plant Manag. 14: 39-43.

Rigg, G.B. 1931. The occurrence of *Phragmites communis* in western Washington and Oregon. Rhodora 33: 170-171.

Rolletschek, H., H. Kühl, A. Bumiller, and J.-G. Kohl. 1998. Genotypic variation in morphology, productivity and N/C-cycling in stands of *Phragmites australis* (Ca.) Trin. Ex Steudel. Oecologia (submitted).

Roman, C.T., W.A. Niering, and R.S. Warren. 1984. Salt marsh vegetation change in response to tidal restriction. Environ. Manage. 8: 141-150.

Rosza, R. 1995. Tidal marshes of Long Island Sound: ecology, history, and restoration. In: G.D. Dreyer and W.A. Niering (editors). Connecticut College Arboretum, New London, CT Bulletin No. 34.

Sinicrope, T.L., P.G. Hine, R.S. Warren, and W.A. Niering. 1990. Restoration of an impounded salt marsh in New England. Estuaries 13: 25-30.

Skuhravy, V. 1978. Invertebrates: destroyers of common reed. In: D. Dykyjova and J. Kvet (editors). Pond Littoral Ecosystems, Structure and Functioning. Springer-Verlag, Berlin. pp. 376-388.

Smid, P. 1975. Evaporation from a reedswamp. J. Ecol. 60: 299-309.

Stalter, R. 1975. *Phragmites communis* in South Carolina. Rhodora 77: 159.

Stennis, J.H., E.B. Chamberlain, and R.A. Beck. 1959. Recent developments in *Phragmites* control. Proc. 13th Annual Meeting Northeast Weed Control Conf., New York, NY. pp. 293-298.

Szajnowski, F. 1973. Relationship between leaf area index and shoot production of *Phragmites communis* Trin. Pol. Arch. Hydrobiol. 20: 257-268.

Thompson, D.J. and J.M. Shay. 1989. First-year response of a *Phragmites* marsh community to seasonal burning. Can. J. Bot. 67: 1448-1455.

Thompson, D.J. and J.M. Shay. 1985. The effects of fire on *Phragmites australis* in the Delta Marsh, Manitoba. Can. J. Bot. 63: 1964-1969.

Tiner, R.W., Jr. 1987. A Field Guide to Coastal Wetland Plants of the Northeastern United States. The University of Massachusetts Press, Amherst, MA. 285 pp.

Tscharntke, T. 1989. Attack by a stem-boring moth increases susceptibility of *Phragmites australis* to gall-making by a midge: mechanisms and effects of midge population dynamics. Oikos 55: 93-100.

Tull, D. 1987. A Practical Guide to Edible & Useful Plants. Texas Monthly Press.

van der Linden, M.H.H.A. 1980. Nitrogen economy of reed vegetation in the Zuidelijk Flevoland Polder, The Netherlands 1. Distribution of nitrogen among shoots and rhizomes during the growing season and loss of nitrogen due to fire management. Acta Oecologica Oecologia Plantarum 1: 219-230.

van der Valk, A.G. 1981. Succession in wetlands: a Gleasonian approach. Ecology 62(3): 688-696.

van der Merff, M., J.W. Simmers, and S.H. Kay. 1987. Biology, Management and Utilization of Common Reed *Phragmites australis*. U.S. Army Corps of Engineers report. Contract No. DAJA45-86-M-0482. 101 pp.

van der Toorn, J. and J.H. Mook. 1982. The influence of environmental factors and management of stands of *Phragmites australis*. I. Effects of burning, frost and insect damage on shoot density and shoot size. J. Applied Ecol. 19: 477-499.

van Deursen, E.J.M. and H.J. Drost. 1990. Defoliation and treading by cattle of reed *Phragmites australis*. J. Applied Ecol. 27: 284-297.

Veber, K. 1978. Propagation, cultivation and exploitation of common reed in Czechoslovakia. In: D. Dykyjova and J. Kvet (editors). Pond Littoral Ecosystems, Springer-Verlag, Berlin. pp. 416-423.

Waisel, Y. and Y. Rechaw. 1971. Ecotypic differentiation in *Phragmites communis* Trin. Hydrobiologia 12: 259-266.

Walker, J.M. and E.R. Waygood. 1968. Ecology of *Phragmites communis*. I. Photosynthesis of a single shoot in situ. Can. J. Bot. 46: 549.

Wang, T. and J.H. Peverly. 1996. Oxidation states and fractionation of plaque iron on roots of common reeds. Soil Sci. Soc. Am. J. 60: 323-329.

Warren, R.S., E.L. Buck, and P.E. Fell. 1995. *Phragmites australis* in the lower Connecticut River tidelands: rates of invasion, stand structure, productivity and decomposition in relation to salinity and hydroperiod. Abstract, Society of Wetland Scientists 16th Annual Meeting, 28 May-2 June, Boston, MA, USA.

Weisner, S.E.B. and W. Graneli. 1989. Influence of substrate conditions on the growth of *Phragmites australis* after a reduction in oxygen transport to below-ground parts. Aquatic Botany 35: 71-80.

Woitke, P., A. Kiehl, H. Kühl, and J.-G. Kohl. 1997. Nitrogen and carbohydrate pools of two rhizome types of *Phragmites australis* (Cav.) Trin. ex Steudel. Int. Revue ges. Hydrobiol., 82(2): 161-168.

Wolverton, B.C. 1981. New Hybrid Wastewater Treatment System Using Anaerobic Microorganisms and Reed (*Phragmites communis*). NASA, National Space Technology Laboratories, NSTL Station, MS. NASA Technical Memorandum TM-X-72739.

Wolverton, B.C., R.C. McDonald, and W.R. Duffer. 1983. Microorganisms and higher plants for waste water treatment. Journal of Environmental Quality 12: 236-242.

Yamasaki, S., M. Kimura, and T. Yoneyama. 1992. Early withering of lower leaves of *Phragmites australis* (Cav.) Trin. ex Steud. in a eutrophic stand: role of oxygen concentration, fate of nitrogen and nitrogen uptake by the plants. Aquatic Botany 42: 143-157.

Yamasaki, S. 1984. Role of plant aeration in zonation of *Zizania latifolia* and *Phragmites australis*. Aquatic Botany 18: 287-297.

Zeidler, A., S. Schneider, C. Jung, A.E. Melchinger, and P. Dittrich. 1994. The use of DNA fingerprinting in ecological studies of *Phragmites australis* (Cav.) Trin. ex Steudel. Bot. Acta 107, 237-242.

APPENDIX A

PHRAGMITES CONTROL BASELINE CONDITIONS REPORT FORM

PHRAGMITES CONTROL BASELINE CONDITIONS REPORT FORM

Project Name:____
Location*:____

*Please attach detailed map (portion of a USGS topographic map) showing specific location of site.

I. SITE CHARACTERISTICS

A. Habitat

Habitat type: Salt Marsh____ Brackish Marsh____ Tidal Fresh Marsh____ Wet Meadow____ Mixed Wet Meadow-Shrub Swamp____ Mixed Marsh-Shrub Swamp____ Freshwater Shrub Swamp____ Shrub Bog____ Freshwater Forested Wetland____ Roadside Ditch____ Open Upland Field____ Agricultural Field____ Mixed Upland Shrub-Field____ Deciduous Upland Forest____ Other (specify and indicate whether wetland or upland)____________________

Size of *Phragmites* stand: _______acres

Does *Phragmites* dominate the entire habitat or just a portion of the habitat type (briefly explain)?
____
____

% Areal Cover of *Phragmites* in Study Plots (size of plot________): Plot #1____ #2____ #3____ #4____ #5____ #6____ #7____ #8____ #9____ #10____

Average Height of *Phragmites* in Study Plots (in feet or meters, specify): #1____ #2____ #3____ #4____ #5____ #6____ #7____ #8____ #9____ #10____

Maximum Height of *Phragmites* in Study Plots (in feet or meters, specify): #1____ #2____ #3____ #4____ #5____ #6____ #7____ #8____ #9____ #10____

Stem Density of *Phragmites* in Study Plots: #1____ #2____ #3____ #4____ #5____ #6____ #7____ #8____ #9____ #10____

B. Soils

Mapped Soil Type (on USDA Soil Survey Report):______________________________
Is soil organic or mineral?____
Soil texture within one foot of the surface: Sandy____ Nonsandy____ (if possible, indicate specific texture, e.g. coarse sand or silty clay loam, etc.): ____________________________
Hydric Soil Field Indicators Present? Yes____ No____ If yes, please check off applicable indicators: Organic soil____, Histic epipedon____, Low chroma matrix and bright mottles within 12"____, Organic streaked sandy soil within 6 "____, Other (specify):
____

C. Existing Vegetation

Dominant Species for Each Stratum (representing 20% or more of the total cover)
Trees:____
Shrubs:_______________________________________
Herbs:____

Nondominant Species
Trees:____
Shrubs:_______________________________________
Herbs:____

Mosses present? Yes____ No____ (If yes, are they common or uncommon?________________)

D. Baseline (Pre-existing) Hydrology (complete only for wetland sites)

Is site tidal or nontidal?____

If tidal, is the hydrology altered to the point of being significant tidally restricted (i.e., significant enough to see a significant vegetation change on either side of the restricting feature? Yes___ No___

If tidally restricted, describe the type of restriction:

____
____
____

Additional Comments:____
____

E. Wildlife

Presence of rare and endangered species (list)
____

Current wildlife use of area (briefly describe)
____

II. STATEMENT OF THE PHRAGMITES PROBLEM

Briefly describe the problem and the conditions believed responsible for it:
____
____

III. PROJECT GOALS

Indicate the project goals:
____
____
____

IV. PHRAGMITES CONTROL TECHNIQUE TO BE APPLIED

Check as appropriate: Increase tidal flooding/salinity____ Cutting/mowing____ (specify if mulching: Yes____ No____) Mowing and Disking____ Plastic Covers____ Hydro-raking____ Dredging and Ditching____ Prescribed Burning____ Burning and Tilling____ Burning and Flooding____ Mowing and Flooding____ Flooding____ Herbicide Application____ (specify chemical: ____________) Herbicide Application with Burning____ Herbicide Application with Flooding____ Other (describe)____

____

Briefly describe the actual technique used, including date or dates of application______________

____

____

V. MONITORING PLAN

Briefly describe your plans to monitor results:

____

____

____

____

Investigator:____

Signature:____

Affiliation:____

Telephone:____

Mailing Address:____

Date of Report:____

APPENDIX B.

PHRAGMITES CONTROL MONITORING FORM

PHRAGMITES CONTROL MONITORING FORM

Project Name:____
Location:____

Date of Baseline Conditions Report:____

I. PHRAGMITES CONTROL TECHNIQUE APPLIED

Check as appropriate: Increase tidal flooding/salinity____ Cutting/mowing____ (specify if mulching: Yes____ No____) Mowing and Disking____ Plastic Covers____ Hydro-raking____ Dredging and Ditching____ Prescribed Burning____ Burning and Tilling____ Burning and Flooding____ Mowing and Flooding____ Flooding____ Herbicide Application____ (specify chemical:______________) Herbicide Application with Burning____ Herbicide Application with Flooding____ Other (describe)____

Date(s) Applied:____

Briefly describe the actual technique used:____
____
____
____
____
____
____

II. MONITORING RESULTS

Time elapsed since treatment? ____ years ____ months
Number of Sample Plots____

Variables Measured:

1. Stem density

Average Change in Density of Phragmites from last report: ____ stems/____ to ____ stems/____ (plot by plot assessments are recorded on back of page)

2. Height of Phragmites

Average Change in Phragmites height from last report: ____ feet to ____ feet (for tallest plant in study plots) (plot by plot assessments are recorded on back of page)

Average Change in Phragmites height from last report: ____ feet to ____ feet (for average height plants in study plot) (plot by plot assessments are recorded on back of page)

3. Areal Cover of Phragmites

Average Change in the areal cover of Phragmites from the last report: ____% to ____%
(plot by plot assessments are recorded on back of page)

4. Associated Species

Change in associated species from last report:

Species with an increase in cover: ____
____

Species with a decrease in cover: ____
____

(Please indicate estimated cover changes for each species in each study plot on separate sheet)

5. If salinity changes were a desired result of the project, indicate any changes in salinity readings from the last report: ____ ppt to ____ ppt

Additional Comments on Results of Monitoring: ______________________________________
____
____
____
____
____

Is project going as expected (briefly explain)? _____________________________________
____
____
____

Will monitoring be continued in the future? Yes____ No____ (If not, would it be possible for someone else, e.g., a WetRAT, to continue monitoring? Yes____ No____)

Investigator:____
Signature: ____
Affiliation:____
Telephone:____
Mailing Address:____
____
Date of Report:____

Monitoring Data for Individual Study Plots

Project Name:______________________________ Location:________________________________

Time Period:__________ to __________ Investigator:_________________________________

% Areal Cover of *Phragmites* in Study Plots (size of plot__________):

Plot #	% Cover Time 1	% Cover Time 2	Plot #	% Cover Time 1	% Cover Time 2

Average Height of *Phragmites* in Study Plots (in feet or meters, specify):

Plot #	Average Height Time 1	Average Height Time 2	Plot #	Average Height Time 1	Average Height Time 2

Maximum Height of *Phragmites* in Study Plots (in feet or meters, specify):

Plot #	Maximum Height Time 1	Maximum Height Time 2	Plot #	Maximum Height Time 1	Maximum Height Time 2

Stem Density of *Phragmites* in Study Plots:

Plot #	Stem Density Time 1	Stem Density Time 2	Plot #	Stem Density Time 1	Stem Density Time 2