The Green Shovels Collaborative presents:

PHRAGMITES SUMMARY REPORT

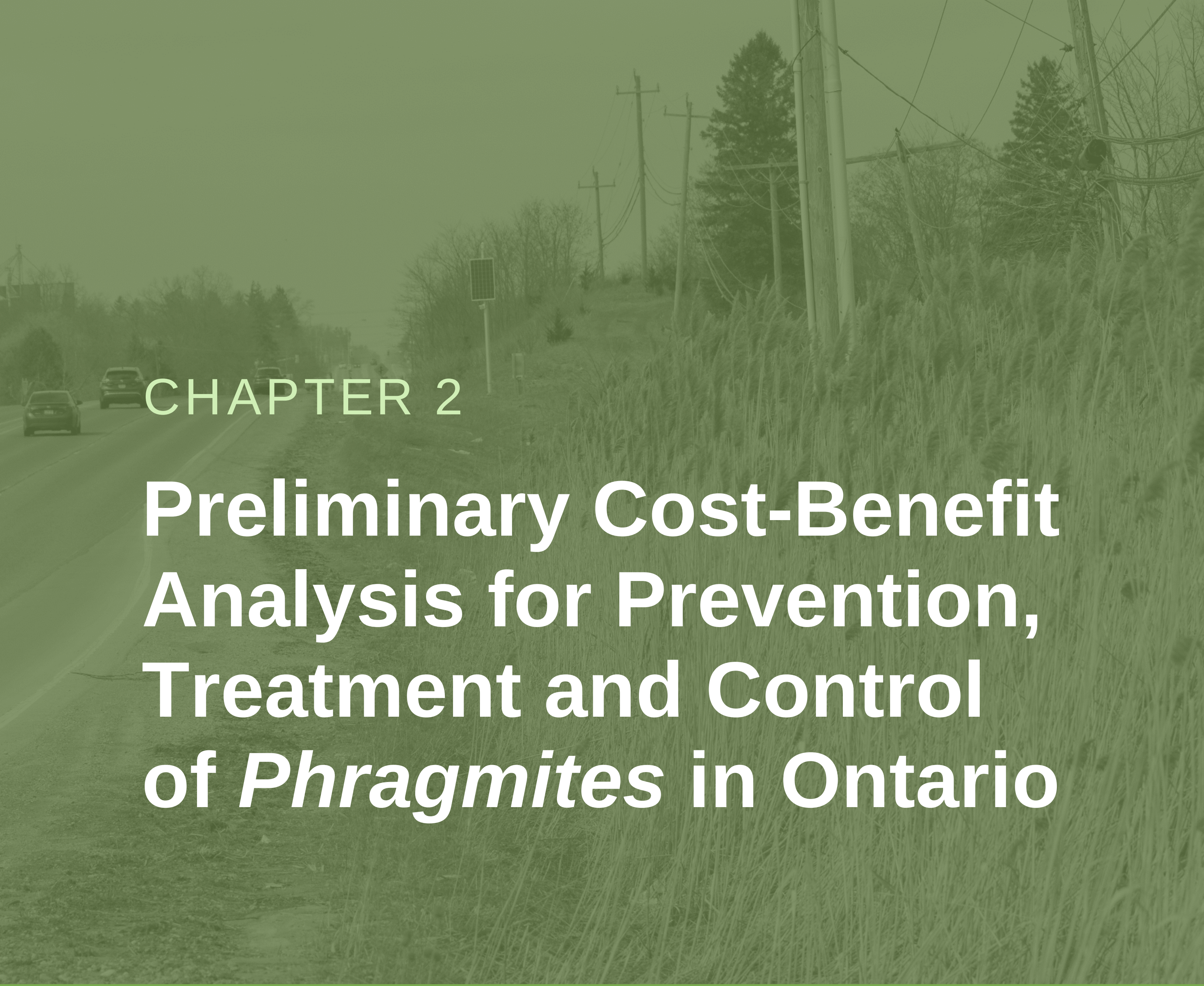
ABOUT THE GREEN SHOVELS COLLABORATIVE

We are a coalition of conservation organizations, including Ducks Unlimited Canada (DUC), Federation of Ontario Cottagers' Associations (FOCA), Invasive Species Centre (ISC), the Nature Conservancy of Canada (NCC), Ontario Federation of Anglers and Hunters (OFAH), and Ontario Turtle Conservation Centre (OTCC).

Together we represent millions of people, with members and supporters who are nature lovers, cottagers, outdoor recreationists, anglers and hunters. We are also land managers, with many hectares of land under ownership or management. We came together to offer a list of shovel ready projects which would achieve the government's objectives of job creation and economic recovery, along with important benefits to local communities and the environment.

This Phragmites Framework project of the Green Shovels Collaborative (GSC) was led by Eric Cleland and Mhairi McFarlane (NCC), coordinated by Colin Cassin and Sarah Rang (ISC), and reviewed by Erling Armson (DUC), Terry Rees (FOCA), and Sophie Monfette (OFAH).

Front cover photo: Joseph McCauley, US Fish and Wildlife Service, Bugwood.org



CHAPTER 2

Preliminary Cost-Benefit Analysis for Prevention, Treatment and Control of *Phragmites* in Ontario

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Special thanks to Colleen Cirillo, whose extensive efforts led to the collection of invaluable information that was used to estimate the costs of *Phragmites* control in Ontario. Colleen also wrote the two *Phragmites* control scenarios in the appendix of this chapter.

Front page photo: Mhairi McFarlane

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EXECUTIVE SUMMARY

Phragmites australis ssp. australis is a non-native plant that grows densely and can reach over six metres in height, has been spreading rapidly across Ontario since the 1990s. *Phragmites*, which is often found in wetland areas and along roads and other corridors, has negatively impacted native plant biodiversity and contributed to a variety of economic impacts. This invasive species has become a high priority threat to address in a number of areas of the province, and despite considerable local efforts to control *Phragmites*, it continues to spread. To slow this spread and effectively manage *Phragmites*, a province-wide control program is needed. The purpose of this report is to conduct a preliminary cost-benefit analysis for such a program.

The costs of *Phragmites* control in Ontario are estimated based on costs per hectare of specific control methods and on the estimated total area of *Phragmites* in the province. Control costs in Ontario are determined based on a survey of land managers involved in *Phragmites* control. The total area of *Phragmites* along roads and in wetlands is estimated based on the results of a number of studies. The estimated total cost for the first year of a province-wide *Phragmites* control program, based on the simplifying assumption that all areas of *Phragmites* could be treated in the first year, is $90.0 million to $109.2 million. Control costs tend to be highest in the first year of treatment and decline to some degree in subsequent years.

Benefits of *Phragmites* control accrue through the reduction in economic impacts that would occur if *Phragmites* were eradicated. The economic impacts of *Phragmites* are estimated for agriculture, tourism and recreation, property values and property taxes, wetlands, stormwater management ponds, road safety, and power outages. The values of these impacts are estimated based on results of previous related studies and on a number of assumptions regarding the nature of these impacts. The total estimated benefits of *Phragmites* control is $113.4 million annually, plus a one-time benefit of $357 million due to a reduction in impacts on waterfront property values.

The results of this cost-benefit analysis present evidence that suggests that the benefits may outweigh the costs of a *Phragmites* control program in Ontario. However, it is important to note that these are preliminary estimates of the costs and benefits of *Phragmites* control. There are a number of identified gaps in information that may detract from the accuracy of these estimates. These gaps include:

- Current data on the total area of *Phragmites* in the province, by location type (i.e., roads, wetlands, private property, utility corridors, etc.)
- The area of *Phragmites* that could be treated in a year, for each control method
- Cost of mowing following herbicide application along roads
- Impacts on other sectors such as infrastructure
- Additional ecological impacts, including impacts on species at risk

This cost-benefit analysis can be revised as more data and information become available in the future.

1.0 INTRODUCTION

Phragmites australis is a non-native perennial reed grass that grows primarily in wetland areas and along roadways. In contrast, the native subspecies of *Phragmites – Phragmites australis* subsp. *americanus* – has a lower stem density and typically coexists with a number of other wetland plants. The remainder of this report will focus on the invasive *Phragmites*, which grows very densely and can reach over six metres in height. *Phragmites* is very aggressive, allowing it to outcompete native vegetation for nutrients and water. Its roots release toxins that suppress the growth of other plants. As a result, *Phragmites* reduces native plant biodiversity. The density of *Phragmites* stands also negatively impacts wildlife habitat, including habitat for several species at risk. In addition to environmental impacts, *Phragmites* contributes to economic impacts on property values, tourism and recreation, and agriculture. *Phragmites* can also affect road safety, as the height and density of stands in roadside ditches can reduce visibility at rural intersections, and can increase fire hazards due to the large amount of dry biomass from dead stalks. In 2005, it was named Canada’s worst invasive plant by Agriculture and Agri-Food Canada.

Phragmites has been rapidly expanding in Ontario since the 1990s. It is well-established in coastal wetlands along the Great Lakes and has been spreading inland along highways, rural roads, and agricultural and municipal drains. Due to the extensive spread of this invasive species and its negative impacts on wetlands and biodiversity, it has become a high priority species for a number of municipalities and conservation authorities across the province. Considerable efforts and expenditures have been incurred in some local areas to control *Phragmites* and reduce its impacts on local ecosystems, however they do not appear to be sufficient to adequately control *Phragmites* across the province. In some cases, not enough funding has been allocated to fully address this invasive species, resulting in a patchwork of control efforts that are insufficient to slow the spread.

To effectively slow the spread and reduce the amount of *Phragmites* in Ontario, a coordinated, province-wide approach should be considered. Given the current extent to which this invasive species has spread across the province, such an approach would require a considerable amount of expenditure. This amount would likely far exceed the annual amount that is currently being spent on control activities by municipalities across the province. For example, based on a 2019 survey of municipalities and conservation authorities across Ontario, the total estimated expenditure on control activities for *Phragmites* was $3.2 million (Vyn, 2019). However, a number of the survey respondents indicated that current budgets or expenditure amounts were insufficient for adequate control. As a result, *Phragmites* will continue to expand across the province despite these localized control efforts. This suggests that prevention and control efforts and expenditures need to be scaled up dramatically to achieve adequate control or to eradicate *Phragmites*. However, to help justify this province-wide coordinated approach, both the benefits and costs to the province and other partners of preventing and controlling *Phragmites* need to be better understood.

The purpose of this report is to conduct a cost-benefit analysis for control of *Phragmites* in Ontario. There are different methods of control for *Phragmites*; the method(s) used for control depends on a number of factors, such as objective, location, stand density, accessibility, timing, training and budget.

Costs of these control methods, as reported by organizations in Ontario that have been involved in *Phragmites* control activities, are used to estimate total costs across the province to adequately control *Phragmites*. The benefits of control are estimated based on the value of reductions in environmental and economic impacts that would occur if *Phragmites* could be controlled or eradicated in Ontario. The sum of the estimated potential benefits is then compared to projected costs to determine whether there is a net benefit to the province and other partners to prevent and control *Phragmites*.

In the next section, prevention and control methods are described, and costs of each control method are used to project total costs of control in the province. In the third section, the benefits of *Phragmites* control are estimated based on the reduction in the economic impacts of *Phragmites* that would result from controlling this invasive species. The fourth section discusses the results of the cost-benefit analysis, while the fifth section describes the limitations of this study and identifies gaps in knowledge and next steps.

This draft report has been developed by Dr. Richard Vyn, University of Guelph, with the assistance of Colleen Cirillo, under contract to the Invasive Species Centre. The document is part of a larger *Phragmites* project under the Green Shovels Collaborative. The document draws upon a land managers survey and workshop coordinated by the Nature Conservancy of Canada, Invasive *Phragmites* Control Centre and Ontario Invasive Plant Council, as well as a series of subsequent land manager interviews and literature review. We thank all land managers and organizations who provided valuable information on costs and benefits. We recognize that this is among the first efforts to estimate the costs and benefits of *Phragmites* control in Ontario, and so welcome comments and additional information on costs and benefits. It is anticipated that this cost-benefit analysis will continue to evolve with additional information and input.

2.0 COSTS OF *PHRAGMITES* CONTROL

This section describes the process for estimating total costs of control for eradication of *Phragmites* in Ontario. A brief overview of various methods of control is provided, and the relative effectiveness of these methods is discussed. The process for estimating total costs involves determining the costs per hectare for various control methods that are used in Ontario and estimating the total area of *Phragmites* along roadways and in wetlands.

To assist in estimating total costs of control, a number of organizations in Ontario that have been involved in *Phragmites* control were contacted in early 2021 to participate in a survey. In some cases, follow-up phone and email correspondence were conducted regarding the control activities that they were conducting for *Phragmites*. The intent of this survey and subsequent correspondence was to gain better insight and information on *Phragmites* control activities in Ontario, particularly on the control methods being used and their associated costs. This information is used to estimate the total costs required for effective control of *Phragmites* across the province.

2.1 Methods of Prevention and Control

There are a variety of methods that can be used to prevent *Phragmites*, including communication, outreach, control on critical pathways of spread, community science, early detection and rapid response. There are many areas in Ontario where *Phragmites* is either not established or exists in small patches. In these areas, the best strategy is to prevent *Phragmites* from becoming established. Prevention is the most cost-effective stage of invasive species management.

Once *Phragmites* becomes established, there are a variety of control methods, including chemical, physical, and biological methods.[1] In general, it is recommended that land managers take an integrated pest management approach which combines multiple methods, uses data to inform methods, and commits to a long-term solution. Chemical methods include herbicide application. Physical methods include mowing, cutting, burning, and flooding. Biological methods include the introduction of a natural predator to help reduce its abundance. Biological methods of controlling *Phragmites* are under active investigation in the United States and Canada, with the small-scale release of new biocontrol agents which are permitted under federal regulation. The method(s) used for control depends on a number of factors, such as objective, location, stand density, accessibility, timing, training and budget.

Herbicide application is one of the most common methods of control and is recognized as the most effective. Based on reports from organizations involved in *Phragmites* control in Ontario, herbicide application often results in over 90% control. However, while herbicide application is permitted over water in the US, until very recently there have been no herbicides approved for over water use to control *Phragmites* in Ontario. This means that other methods have been required for controlling *Phragmites* in areas of standing water. This situation may be changing with the recent federal approval of a herbicide for over water use. Though there may be limitations on appropriate scenarios for use of this herbicide, this could change some of the potential costs of control in the future. Relative to other control methods, herbicide application may have greater efficacy and may result in lower costs of control. As

[1] These methods are only briefly described in this section. Greater detail on these control methods for *Phragmites* is available in a report published in 2011 by the Ontario Ministry of Natural Resources: http://www.ontarioinvasiveplants.ca/wp-content/uploads/2016/07/*Phragmites*_BMP_FINAL.pdf. Studies on the effectiveness and challenges of different control methods for *Phragmites* are summarized by Hazelton et al. (2014).

such, the inability to apply herbicide over water has been a significant challenge for control efforts in Ontario.

There are different ways in which herbicides can be applied for *Phragmites* control. Application to control roadside stands of *Phragmites* is typically conducted using a truck equipped with a boom or hydraulic handheld wand sprayer. For larger areas of *Phragmites*, application can be done with a sprayer attached to an Argo or other specialized tracked machinery, or in cases where stands are too large or difficult to access, spraying has been completed by helicopter under special permit. However, aerial control is not typically used since no herbicide has been available that includes this application method on the label (outside of a special research program at Long Point and Rondeau). For smaller areas of *Phragmites* or for spot control, backpack spraying can be done.

Due to the extensive root system of *Phragmites*, effective control usually requires more than a single herbicide application. Additional control efforts may be required in subsequent years to achieve better control or to fully eradicate *Phragmites*. This may involve additional application of herbicide or the use of other control methods. Costs of control tend to be highest in the first year and then decline in subsequent years.

Mowing is a physical method that can be used to reduce growth of *Phragmites* or to cut down dead stalks. On its own, this method is not very effective for controlling *Phragmites* due to the extensive root system, and would have to be repeated multiple times during the growing season. Mowing may be done in combination with herbicide application, where the dead stalks are mowed following the herbicide treatment.

Burning is another physical method that is often used in combination with herbicide application. This is an effective method for removing dead biomass that remains following herbicide treatment. This allows for easier spot treatments of any remaining plants the following season, and also makes it easier for native vegetation to regrow. As with mowing, this method may not be very effective when used on its own.

Phragmites can also be cut with tools or pulled by hand. This method is typically used in relatively small stands of *Phragmites*, and can be very labour-intensive. When this method has been used in Ontario it tends to rely heavily on volunteer efforts, which can reduce the financial cost.

For *Phragmites* stands in water, a flooding, or cut-to-drown, method can be used. This involves cutting the plants at least 30cm below the surface of the water, near the end of the season, in order to drown the root systems. This can be done manually, typically by volunteers, or can be done by Truxor machines, which are quite costly. For dense stands of *Phragmites*, Truxor machines can be more effective, particularly due to the time-intensive and labour-intensive nature of manual cutting.

Biological control agents are currently being tested for *Phragmites*, primarily for maintenance following treatment with other control methods, but are not yet available for control. If biological control agents did become effective in the future, this could reduce some of the costs of maintaining control of *Phragmites*. Effective Integrated Pest Management with an approved biological control agent will likely involve the use of herbicides, physical control, and other methods outlined above.

2.2 Effectiveness of Prevention and Control Methods

Investments in outreach, education, community science, early detection and rapid response can be very effective in preventing invasive species from becoming established or spreading. Prevention is the most cost-effective action for many invasive species, including *Phragmites*.

A number of studies have been conducted on the effectiveness of different control methods for *Phragmites*. In a survey of wetland managers in the Great Salt Lake Watershed in the western US by Rohal et al. (2018), 97% of respondents reported the use of herbicide, and over half used a combination of spraying and burning. The burning of dead *Phragmites* plants can increase the effectiveness of herbicide treatments in subsequent years. Herbicide application costs reported by survey respondents included herbicide costs ranging from US$2/ac to US$855/ac (Cdn$6/ha to Cdn$2,420/ha) and labour costs ranging from US$12/ac to US$2,000/ac (Cdn$34/ha to Cdn$5,661/ha).[2]

Brooks et al. (2015) compared the effectiveness of two different approaches to controlling *Phragmites* in two locations, where a regional-scale aerial spraying approach was used in one location and a property-scale patchwork approach was used in a second location. The results of this research indicated that the regional-scale approach was much more effective at controlling *Phragmites* than the property-scale approach. Part of the reason for this difference in effectiveness may have been the lack of follow-up treatment in the location with the property-scale approach. Brooks et al. (2015) note that these results point to the importance of follow-up spot treatments for successful longer-term control of *Phragmites*, as the one-time control efforts had relatively poor success.

Ailstock et al. (2001) examined two control methods for *Phragmites* in wetland areas, which included glyphosate application at one site and a combination of glyphosate application and burning following application at a second site. Both methods significantly reduced the *Phragmites* stands and increased plant biodiversity, although the plant re-growth occurred faster at the site where burning followed herbicide application. Despite the short-term success of these control methods, the authors noted that unless *Phragmites* is fully eradicated, it is likely to eventually re-establish dominance within the habitat. Similarly, the

[2] Canadian currency figures were calculated using data on exchange rates and inflation from the Bank of Canada.

results of Turner and Warren (2003) indicated that if herbicide is only applied intermittently (i.e., once every few years), *Phragmites* will re-establish quickly and become dominant in the habitat. Conversely, if follow-up spraying is conducted each year, the percentage of *Phragmites* plant cover in the habitat will remain minimal and native vegetation will recover more effectively and maintain a high proportion of plant cover in the habitat.

Table 1: Estimated efficacy for various control methods for *Phragmites* in Ontario, as reported in the Ontario *Phragmites* Land Manager Survey, 2021

Method	Location	Efficacy (Year 1)
Herbicide application	Natural areas; roadside	75-100%
Herbicide application	Natural areas	85%-95%
Herbicide application	Natural areas	98%
Herbicide application	Roadside (county roads)	95%
Herbicide application	Roadside (highways)	80%-85%
Herbicide application	Roadside	Close to 100%
Herbicide application	Roadside	95%
Cut-to-drown (Truxor)	Inland wetlands	80%-90%
Cut-to-drown (Truxor)	Coastal wetlands	80%
Cut-to-drown (manual)	Wetlands	40%
Spading	Natural areas	40%
Tarping	Natural areas	98%

Information was collected from organizations involved in *Phragmites* control in Ontario on the efficacy of different control methods (see Table 1). For herbicide application, reported efficacy ranged from 75% to 100% control after the first application. The efficacy can vary depending on factors such as size of stand and stand density. The reported efficacy for cut-to-drown varied depending on the approach taken and water depth, as it was much higher for cutting by Truxor machines than for manual cutting.

2.3 Costs of Prevention and Control

In a 2019 survey of municipalities and conservation authorities (CAs) across Ontario coordinated by the Invasive Species Centre, combined expenditures of over $1.3 million were reported on *Phragmites* control and management activities. Expenditure amounts by responding municipalities and CAs for *Phragmites* ranked fifth among all invasive species, following emerald ash borer, zebra mussels, gypsy moth, and quagga mussels. Extrapolation of these survey results across all municipalities and CAs in Ontario generated an estimated provincial expenditure on *Phragmites* control of $3.2 million (Vyn, 2019). This amount represented 6.3% of the total estimated provincial expenditure on invasive species control and management activities. While not asked specifically, two municipalities indicated that they were about to begin efforts to control *Phragmites*. Given the ongoing expansion of *Phragmites* in the province and the increased attention on the need for additional prevention and control efforts, it is likely that this expenditure will continue to increase. In general, the survey also indicated that almost 80% of the local expenditure was for control activities and only 20% was for prevention activities.

Information on costs of *Phragmites* control in other jurisdictions has been provided in previous studies. For example, Martin and Blossey (2013) conducted a survey of 285 land managers from US public and private conservation organizations across 40 states to assess related management programs. This survey collected information on control methods and expenditures, as well as management outcomes. While expenditures and area treated varied considerably across organizations, the information collected through this survey allowed for determining control costs per hectare. The average annual cost of these management programs was US$51.60/ha (2009 prices), which is the equivalent of Cdn$72.07/ha, after adjusting for the exchange rate and inflation.[3] Herbicide application was the primary control method used for 92% of the treated areas under these programs, which implies that this average annual cost closely approximates the cost per hectare of herbicide application. However, the survey results also indicated that few organizations achieved their management objectives, which implies that this average expenditure did not result in adequate control of *Phragmites*. It should also be noted that there were a few respondents that indicated annual expenditures of over US$5,000/ha (Cdn$6,969/ha).

While costs of *Phragmites* control incurred in other jurisdictions can be used to estimate total costs of control for Ontario, more accurate estimates could be generated by using cost information specific to Ontario. As mentioned earlier, as part of the Green Shovels Collaborative, in January 2021, information on control methods used and costs of control was gathered from land managers in Ontario that are involved in *Phragmites* control activities.[4] The reported costs per hectare for various control methods, which are used to estimate total costs for *Phragmites* control in Ontario, are summarized in Table 2.

As evident in Table 2, costs per hectare vary substantially across different methods. There can also be a considerable range in the cost per hectare for individual methods. For example, the reported costs of herbicide application with a boom truck along roads ranged from $800/ha to $4,750/ha. The wide ranges in costs for some methods are due in part to situation-

[3] These adjustments were made using data on exchange rates and inflation from the Bank of Canada.
[4] The Great Lakes Commission's Great Lakes *Phragmites* Collaborative is working to gather information and help standardize methods of control and report on their effectiveness and costs.

dependent factors, such as density and size of *Phragmites* patches. This makes it challenging to estimate a total cost to eradicate all patches of *Phragmites*, as treatment costs per hectare will depend largely on specific site conditions. To address this challenge, an average or a most likely rate per hectare, based on the reported costs in Table 2, is applied to the total area of *Phragmites* to estimate the total cost. Costs are estimated separately for roadside areas of *Phragmites* and for *Phragmites* in wetlands, since different methods are used for these locations. Herbicide application tends to be used for *Phragmites* along roads, while cut-to-drown and other manual control methods tend to be used in wetlands, since herbicide application over standing water is not currently permitted in Ontario (although this may be changing in the near future).

For herbicide application along roads, the cost per hectare is reported to be lower for highways than for county roads. Based on the reported costs in Table 2, it is assumed for the purposes of estimation of total costs that herbicide application would cost $1,200/ha along highways (which is about the midpoint of the reported range) and $4,000/ha along county roads (which is the most frequently reported cost). In addition to herbicide application, control methods along roads may also include mowing. The reported cost of mowing is $10,000/ha, but this is based on only one observation, and may be rather high. In addition, mowing may already occur along rural roads, in which case this would not be an additional cost associated specifically with *Phragmites* control.

For the cut-to-drown method used in wetland areas, the cost is based on the assumption that Truxor machines are primarily used for this method, rather than manual cutting, since these machines are more efficient for cutting large areas and dense stands of *Phragmites*. The costs associated with Truxor machines are typically per-day amounts, which are converted to per-hectare amounts based on the area of *Phragmites* that can be cut in a day with these machines. This area can range widely depending on the density of the stand and amount of biomass. Personal communication with someone directly involved in work with these machines indicated that for high density stands of *Phragmites* with typical site conditions, two Truxor machines could cut and remove about one hectare per day. Based on this rate and on reported Truxor costs for individual projects in Ontario, this method is estimated to cost $6,240/ha. But it should be noted that this rate could vary considerably depending on site conditions. In addition, there are relatively few Truxor machines available in Ontario for *Phragmites* control, which could be a limiting factor for the use of this method in controlling *Phragmites* in wetland areas.

Table 2: Estimated costs of various methods of *Phragmites* control reported by organizations in the Ontario *Phragmites* Land Manager Survey, 2021

Location	Control Method	Area Controlled	Total Cost	Estimated Cost per Hectare
Coastal wetland area[5]	Herbicide application (with helicopter)	1,500 ha	$4.5 million[6]	$3,000/ha
Wetlands	Herbicide application (hose and handgun or backpack sprayer)			$4,000/ha to $6,000/ha
Wetlands	Cut-to-drown with Truxor machines		$15,600	
Stormwater ponds	Spading			$8,500/ha to $11,000/ha
Stormwater ponds	Cut then herbicide application (dry areas around ponds)			$3,200/ha
Natural area	Mainly herbicide application; also some cut-to-drown, spading, and tarping			$1,483/ha
Roadside	Herbicide application followed by mowing	3.735 ha	$52,290 (year 1) $9,110 (year 2)	$4,000/ha for herbicide; $10,000/ha for mowing
Roadside	Herbicide application			$4,000/ha
Roadside	Herbicide application (boom truck)	13.02 ha	$16,500	$1,267/ha
Roadside	Herbicide application			$2,134/ha (glyphosate) $2,917/ha (glyphosate and imazapyr)
Roadside	Herbicide application (highways)	150 ha (year 1) 388 ha (year 2)	$208,598 (year 1) $423,458 (year 2)	$1,391/ha (year 1) $1,091/ha (year 2)
Roadside	Herbicide application (highways)			$800/ha to $1,200/ha
Roadside	Herbicide application (county roads)			$800/ha to $4,000/ha
Roadside	Herbicide application (boom truck)			$3,950/ha to $4,750/ha
Roadside	Herbicide application (spot spray with hose and handgun)			$7,700/ha to $9,200/ha

[5] In this case, an exception was made for over-water herbicide application.
[6] This total cost is for herbicide application over a six-year period (2015-2020), and does not include monitoring costs, which are at least $250,000 per year.

2.4 Estimated Area of *Phragmites* in Ontario

The cost of *Phragmites* control in Ontario is directly affected by the extent of the area with this invasive species in Ontario. Unfortunately, there is a lack of current data on the area of *Phragmites* across the province. This represents one of the biggest challenges to conducting a cost-benefit analysis for *Phragmites* control in Ontario, as without this current data it is difficult to accurately estimate the total costs of control. Environment and Climate Change Canada is currently working on mapping locations of *Phragmites* across the province for the purpose of modeling the spread of *Phragmites*, but this initiative is still in the early stages. *Phragmites* area has been mapped and estimated for small geographical areas (i.e., individual townships), and for specific projects, but not in great detail for the province as a whole. In addition, estimates of this area that were made in prior years may no longer be accurate due to the rapid spread of *Phragmites*. As a result, assumptions regarding the rate of expansion over time are imposed to estimate the total current area. Separate estimates are conducted for the area of *Phragmites* along roads and the area in wetlands, due to the use of different control methods in these locations and the resulting differences in costs.

In addition to *Phragmites* along roads and in wetlands, there are also other areas on dry land that are not accounted for, such as in natural areas, in parks, and on private property. However, there is a lack of data on the amount of *Phragmites* in these areas. *Phragmites* in these dry land areas would be treated primarily by herbicide application, as with roadside areas. If more data becomes available on the amount of *Phragmites* in other dry land areas, the estimated costs of control can be updated to account for these areas.

2.4.1 Estimated Area along Roads

Using mapping techniques based on satellite image data, Marcaccio (2019) estimated that the total cover of *Phragmites* along Ministry of Transportation of Ontario (MTO) highways and along arterial rural roads in southwestern Ontario was 1,544 hectares in 2015. This estimate was derived by extrapolating the total *Phragmites* area along these roads observed in the 2010 images based on the growth rate that was observed between 2006 and 2010. However, this estimate only accounts for the area of *Phragmites* in one region of Ontario; there are other regions for which estimates are needed. Marcaccio (2019) also estimated the amounts of *Phragmites* along MTO highways only (which does not include roads maintained by municipalities) for the south central and central regions of Ontario (as well as for the southwestern region). The proportions of *Phragmites* area reported along MTO highways within each of these two regions, relative to the reported area along MTO highways in the southwestern region, are used to estimate the combined *Phragmites* area along both MTO highways and rural roads for each of these two regions, based on the amount estimated by Marcaccio (2019) for the southwestern region. This process results in estimated areas along roads in 2015 of 708 hectares in the south-central region and 36 hectares in the central region. [7]

The studies by Marcaccio (2019) and Marcaccio and Chow-Fraser (2018) did not map the area of *Phragmites* in the eastern region of Ontario. According to the Early Detection and Distribution Mapping System, a publicly available invasive species reporting system used across Ontario, there is a considerable amount of *Phragmites* in this region of the province as well. As such, roadside *Phragmites* in this region should also be included in the estimated total provincial amount. Being similar in size to the south-central region, and with both regions having a considerable number of positive sightings of *Phragmites*, for the purposes of this study it is assumed that the area of *Phragmites* along roads in the eastern region is approximately similar to that of the south-central region.[8] Aggregating the estimated areas of *Phragmites* across the four regions results in a total estimated area along roads in Ontario of approximately 3,000 hectares in 2015.[9]

Without current data on roadside *Phragmites* area in the province, the estimated area for 2015 can be extrapolated based on an assumed growth rate. Since an increasing number of municipalities have implemented roadside *Phragmites* control initiatives in recent years, the rate of expansion along roads may have diminished since 2015. For a conservative estimate of this expansion, it is assumed that the growth rate is similar to the rate observed along MTO highways between 2010 and 2015 (Marcaccio, 2019), which reflected increased control efforts along those highways.[10] Applying this increase of 28% over the five-year period to the estimated total area in 2015 generates an estimated total area in 2020 of 3,840 hectares.

Based on the results of Marcaccio (2019) and Marcaccio and Chow-Fraser (2018), approximately 40% of the *Phragmites* area along roads in southwestern Ontario was found along highways, with the remaining 60% found along rural roads. Applying these proportions to the estimated total area generates estimated areas in 2020 of 1,536 hectares along highways and 2,304 hectares along arterial rural roads. The reason for breaking down the estimated *Phragmites* area by type of road is that herbicide application costs per hectare are reported to be different for highways than for rural roads (see Table 2).

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[7] This approach may slightly overestimate the amount of *Phragmites* along roads in 2015, as Marcaccio and Chow-Fraser (2018) found that the rate of expansion of *Phragmites* area on MTO highways slowed between 2010 and 2015, due to an extensive control strategy through herbicide application that MTO began around 2012. However, this would not have affected the rate of expansion along rural roads that are not under MTO jurisdiction.

[8] This assumption is imposed for the purpose of generating an estimate of total area in the province. The accuracy of this assumption is uncertain.

[9] This total does not account for the area of *Phragmites* in Northern Ontario, as there is a lack of data on *Phragmites* in this region. If data on the area of *Phragmites* along roads in Northern Ontario becomes available, it could be added to this total.

[10] It is worth noting that despite these increased control efforts, the area of *Phragmites* along these highways still increased by 28%.

2.4.2 Estimated Area in Wetlands

The amount of *Phragmites* area in wetlands is estimated based on studies that have mapped wetlands area and *Phragmites* area in the Great Lakes region. Bourgeau-Chavez et al. (2015) mapped the coastal Great Lakes wetlands and determined the area of *Phragmites* within these wetlands. However, this study reported the combined area on both sides of the border and did not break down the amount of wetlands area or *Phragmites* area between the two sides of the border. An earlier study by Bourgeau-Chavez et al. (2013) mapped *Phragmites* in coastal Great Lakes wetlands on only the US side of the border. Since both studies used the same mapping methods, the difference between the figures reported in these two studies would be approximately equal to the area of *Phragmites* in coastal wetlands in Ontario. Bourgeau-Chavez et al. (2015) reported total wetlands area of 2,200,361 hectares within 10 km of the Great Lakes on both sides of the border, of which 37,282 hectares were *Phragmites*, while Bourgeau-Chavez et al. (2013) reported 852,640 hectares of wetlands area within 10 km of the Great Lakes in the US, of which 24,643 hectares were *Phragmites*. This implies that there are 12,639 hectares of *Phragmites* in coastal Great Lakes wetlands in Ontario.

2.5 Estimated Costs of Control

Total costs of *Phragmites* control in Ontario can be estimated based on the estimated area (in hectares) and the average cost per hectare of control. Total costs are estimated separately for *Phragmites* along roads and for *Phragmites* in wetlands, due to different methods of control used in these two settings. These costs are estimated for year 1, based on the simplifying assumption that the entire area of *Phragmites* along roads and in wetlands could be treated in the first year. The limitation associated with this assumption is discussed below.

Along roads, *Phragmites* could be controlled by herbicide application, which may be followed up by mowing the dead stalks. The cost per hectare of herbicide application varies by type of road, with these costs specified above as $1,200/ha along highways and $4,000/ha along rural roads. Based on the estimated areas of *Phragmites* along each type of road (1,536 ha along highways; 2,304 ha along rural roads), the total year 1 cost for herbicide application would be $11.1 million.

While not necessarily required for control of *Phragmites*, mowing the dead *Phragmites* stalks following herbicide application can make it easier to conduct spot treatment in subsequent years and can enable native vegetation to regrow. The reported cost of mowing is $10,000/ha (see Table 2). However, this cost, which is considerably higher than the cost of herbicide application, is based on only one observation, so it is unclear whether this cost is representative of typical mowing costs. In addition, in some areas roadside mowing may be occurring regardless of whether *Phragmites* exists along the roads, in which case this would not represent an additional cost associated with *Phragmites* control. If additional mowing is assumed to be required for half of the area of *Phragmites* along roads, this would result in an additional cost in the first year of $19.2 million. However, given the uncertainty regarding the cost of mowing and the extent to which additional mowing would be required, more information is required to determine the accuracy of this estimate.

In wetland areas, since an approval for over water herbicide was just received and the cost of this herbicide application is not yet known, the cost of *Phragmites* control is estimated based on the cost of the cut-to-drown method using Truxor amphibious machines. Based on the cost per hectare for Truxors estimated above ($6,240/ha) and the estimated area of *Phragmites* in wetlands (12,639 ha), the total year 1 cost would be $78.9 million. If the cost of the over water herbicide is similar to the cost of roadside herbicide application ($4,000/ha), then the estimated control costs for *Phragmites* in wetlands would be somewhat lower. When the cost of this herbicide has been determined, the estimated costs of control can be updated.

There are important factors to consider with respect to this estimated cost for *Phragmites* in wetlands. First, this estimated cost is based on the amount of *Phragmites* in wetlands in the coastal Great Lakes area (i.e., within 10 km of the Great Lakes). Although a large proportion of *Phragmites* in wetland areas would be in this area, this would not account for all *Phragmites* stands in wetlands across the province. This implies that the cost of control in wetlands may be underestimated. Second, the cost of *Phragmites* control in wetlands is based on the use of Truxors, which can be an effective method in large, dense stands of *Phragmites*. However, in many cases with smaller and less dense stands, cutting is done manually, which would cost considerably less than the Truxor approach, particularly when cutting is done by volunteers. In addition, the cost per hectare for Truxors is based on the rate of progress in very dense stands. For stands that are less dense, Truxors can cut a larger area per day, which would reduce the cost per hectare. This implies that the cost of control in wetlands may be overestimated. Further, it is possible that the recently approved over water herbicide may be a less costly method of control in wetlands, relative to Truxors. As such, the influence of these factors on the estimated cost of control in wetlands would be offsetting to some extent. Additional information is needed to appropriately account for these factors and revise the estimated cost accordingly. In particular, information on over water herbicide application costs is needed, since this method may become the primary control method in Ontario for *Phragmites* in wetlands.

Combining the estimated costs of control along roads and in wetlands results in an estimated total cost of control for *Phragmites* in Ontario in year 1 of $90.0 million without mowing costs and $109.2 million with mowing costs. A summary of these estimated costs (without mowing costs) is provided in Table 3.

For simplicity, this estimated cost for year 1 is based on the assumption that the entire area of *Phragmites* along roads and in wetlands could be treated in the first year.[11] The advantage associated with imposing this simplifying assumption is that it implies that this estimated total cost represents the highest possible annual cost that could be incurred for control of *Phragmites*, and permits the comparison of the highest cost with the value of the benefits of control. If all existing areas of *Phragmites* could receive the initial treatment in the first year, the costs of control would be highest in the first year and would decline to some degree in subsequent years. However, due to capacity constraints, treating all areas of *Phragmites* in one year would most likely not be feasible. For example, quite a few Truxor machines would be needed to cut all the existing area of *Phragmites* in wetlands in one year, and due to the high capital costs and narrow seasonal window to complete the work, this would be challenging.

The estimate above is intended to represent a starting point for the total cost determination for a province-wide *Phragmites* eradication program. It should be noted that this cost estimate is based on the estimated total area of *Phragmites* along roads and in wetlands. There are other areas of *Phragmites* that are not included in this total, such as areas on private property, in parks, and along waterfronts, which would be difficult to estimate. As such, the total cost may be underestimated to some degree.

Table 3: Summary of estimated costs of *Phragmites* control in Ontario

Type	Area	Estimated Cost/ha	Total Estimated Cost in Year 1[12]
Highways	1,536 ha	$1,200/ha	$1.8 million
Rural Roads	2,304 ha	$4,000/ha	$9.2 million
Wetlands	12,639 ha	$6,240/ha	$78.9 million

The annual cost for eradication of *Phragmites* depends on how much area can be treated each year. For example, if only 25% of the total area could be treated in the first year of the eradication program, then initial treatments, which are costliest, would take at least four years, but the cost in each of these years would be considerably lower than the estimate based on treating the entire area of *Phragmites* in the first year.

At this point, additional information is needed to determine the current operating and personnel capacity to control *Phragmites* and to make suggestions on a proposed phasing of

[11] In reality, the *Phragmites* control program would be phased in over a number of years.
[12] Based on the simplifying assumption that the entire area of *Phragmites* could be treated in the first year. Figures may not add up to the total provided in the text due to rounding.

a *Phragmites* program. Another project under the Green Shovels Collaborative is developing a comprehensive province-wide management framework, and this will help to guide estimates of the annual costs of control. The next step, pending support, would use the *Phragmites* framework to further develop this work, and to develop annual costs and benefits of *Phragmites* prevention and control.

3.0 BENEFITS OF *PHRAGMITES* PREVENTION AND CONTROL

The spread of invasive species such as *Phragmites* cause negative environmental, social and economic impacts, some of which were briefly discussed in Section 1. The benefits of preventing and controlling *Phragmites* accrue through the reduction in these impacts. This section describes estimation approaches for quantifying the value of these impacts, and then estimates the magnitudes of economic impacts for specific categories.

3.1 Estimation of Economic Impacts

The economic benefits of invasive species management are specified as the sum of avoided costs of damages caused by invasive species if control measures are not implemented (Hanley & Roberts, 2019). Estimating these costs of damages, or economic impacts, can be quite challenging, particularly for non-market goods or benefits. For example, Epanchin-Niell (2017) identified the valuation of biodiversity and ecosystem services as a key data gap in the literature on the economics of invasive species management.

Hanley and Roberts (2019) identify two categories of economic impacts. The first is an impact on the well-being or utility of people, referred to as utility impacts, and the second is an impact on the profits of firms, referred to as production effects. The economic impacts of *Phragmites* that are identified and estimated in this section include both categories of impacts. While estimates for both categories of impacts are included in the measure of the benefits of controlling *Phragmites*, an important distinction between the two categories is that the valuation of production effects tends to be private values (i.e., benefits to firms or industries), and the valuation of utility impacts tends to be social values (i.e., benefits to society as a whole).

For production effects, the economic impacts of invasive species can often be estimated using market prices. For example, if invasive species cause reduced crop yields, this impact can be estimated using market prices for crops. However, the ecological impacts of invasive species are difficult to quantify economically. To estimate the value of non-market environmental goods and services, a contingent valuation approach can be used. This often involves conducting surveys in which respondents are asked to indicate how much they would be willing to pay for a specific change in the provision of an environmental good. This would be an example of utility impacts, as identified in Hanley and Roberts (2019). The drawback of this approach is that the resulting estimates are not based on actual payment for a good but rather on how much respondents state that they would be willing to pay. Despite the potential limitations of stated preference approaches in generating accurate estimates of economic value, relative to revealed preference approaches for market goods, contingent valuation is widely used to estimate the value of environmental and other non-market goods and services.

Some of the economic impacts estimated in this section are based on the results of previous related studies. Figures from previous studies are converted to Canadian currency, where necessary, based on average annual exchange rates recorded by the Bank of Canada.[13] Figures from these studies are also adjusted for inflation, using the Bank of Canada's inflation calculator[14], to provide current values of these estimates.

There are both advantages and drawbacks to using the results of previous studies to estimate these impacts. One potential drawback of this approach is the required assumption that impacts that occur in another jurisdiction would apply similarly to Ontario. This may not necessarily be the case. In addition, in some cases the impacts estimated in previous studies are not specific to *Phragmites*, but rather for other aquatic invasive species. It is assumed that the similarity of *Phragmites* to other aquatic invasive species would result in similar economic impacts. However, despite these potential drawbacks and their effect on the accuracy of the estimated impacts for Ontario, this approach is a cost-effective alternative to conducting primary research. Conducting similar studies to estimate these impacts specifically for Ontario would be a very costly and lengthy process. Ultimately, this would still result in estimates of impacts based on potentially limiting assumptions that must be imposed in the estimation process.

3.2 Agriculture Industry

Phragmites has not yet been identified as a weed of concern by the agriculture industry in Ontario. According to weed specialists in the province, *Phragmites* has not contributed to the need for additional weed control or to reduced crop yields due to its presence within fields. Rather, impacts on agriculture have occurred primarily through the presence of *Phragmites* in ditches and municipal drains, which can clog up outlets from field tiles and prevent drainage from fields. This can particularly be an issue in the spring, when wet fields need to drain and dry out in order for crops to be planted. The blockage of tile outlets in ditches can cause flooding in fields and prevent fields from drying out, which would delay the planting of crops.

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[13] https://www.bankofcanada.ca/rates/exchange/legacy-noon-and-closing-rates/
[14] https://www.bankofcanada.ca/rates/related/inflation-calculator/

Clogged drains could also cause flooding in the fields after planting, which would require replanting of crops. In both cases, the delayed planting or replanting of crops would negatively impact yield potential.

The potential economic impact of *Phragmites* on agriculture is estimated based on the approach used by Vyn (2016), which involves estimating the value of crop yield loss due to delayed planting in the spring. Based on the results of field trials conducted in Ontario, yield expectations for various planting dates are reported by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) in their publication entitled Agronomy Guide for Field Crops. The results of these field trials indicate that delaying planting by two weeks past the optimum planting date would reduce expected yield by approximately 7% for both corn and soybeans (Ontario Ministry of Agriculture, Food and Rural Affairs, 2017). These two crops account for about three-quarters of total field crop acreage in Ontario, according to statistics provided on OMAFRA's website.[15] Farm cash receipts in Ontario for these two crops averaged $2.9 billion annually between 2015 and 2019, according to Statistics Canada.[16] If an assumption is imposed that 5% of the corn and soybean area in the province was to be affected by clogged drains and ditches due to *Phragmites*[17], such that the planting of corn and soybeans in these affected areas was delayed by two weeks, the resulting 7% yield loss and corresponding reduction in farm cash receipts for these two crops would generate a total impact on the agriculture industry of $10.2 million annually.

3.3 Tourism and Recreation Industry

Dense stands of *Phragmites* in water bodies can negatively impact the ability to use affected water bodies for recreational activities, such as swimming, fishing, and boating, and can reduce their aesthetic value. Since *Phragmites* can also reduce native wildlife populations, this could negatively impact recreational activities such as birdwatching and hunting. These impacts can cause economic harm for the tourism and recreation industry.

The economic impact of invasive species on these industries can be measured by the amount that people would be willing to pay to avoid the negative impact on recreational activities by controlling or eradicating the invasive species. This approach was used in a study by Bell (2006), which found that visitors to Florida lakes for recreational purposes were willing to pay an additional US$12.64 per year to visit these lakes if a program were implemented to control aquatic invasive species such as hydrilla. Based on the number of lake visits per user per year, this worked out to a willingness to pay of US$5.06 per visit.

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[15] Source: http://www.omafra.gov.on.ca/english/stats/crops/index.html

[16] Source: Statistics Canada. Table 32-10-0045-01 Farm cash receipts, annual (x 1,000).

[17] Since there is no existing information on the area of corn and soybeans that is currently affected by *Phragmites*, this assumption is imposed to generate an estimate of the impact for a specific scenario.

With the lakes from this study being used for similar recreational activities as lakes in Ontario (e.g., boating, fishing, and swimming), it is assumed that visitors to Ontario lakes for these recreational activities would be willing to pay a similar amount to visit lakes where *Phragmites* has been controlled. Adjusting this amount for the exchange rate and for inflation results in a willingness to pay of Cdn$8.05 per visit to Ontario lakes. According to the Ontario Parks website, there are almost nine million visitors to the provincial parks per year. Based on the estimated willingness to pay per visit, the total economic value to these users of keeping *Phragmites* out of the lakes and parks and eliminating the negative impacts of *Phragmites* on recreational activities within the parks is estimated to be approximately $72 million per year. However, not all visitors to provincial parks would be visiting for the purpose of participating in these aquatic recreational activities, as parks also provide opportunities for non-aquatic recreational activities. This implies that this impact may be overestimated to some degree.[18] For a more conservative estimate, under the assumption that only half of the visitors to provincial parks participate in aquatic recreational activities and would be willing to pay for the benefits that accrue from controlling *Phragmites*, the economic value to this industry of a program to eradicate *Phragmites* would be $36 million per year.

The economic impacts of invasive species on recreation can also be estimated based on the loss in value resulting from the reduced capacity for recreational activities. Lauber et al. (2020) estimated the impacts of specific aquatic invasive species on recreational fishing on the Great Lakes. One of the invasive species examined in this study was hydrilla, an aquatic plant that can establish itself in aquatic environments in a similar fashion to *Phragmites*, by growing aggressively and outcompeting native plants, and has similar negative impacts on recreational activities. Based on a worst-case scenario, where hydrilla forms dense monocultures in shallow areas of lakes and reduces habitat quality for native fish, the results of this study indicate an average annual loss of consumer surplus of US$6.64 per angler (2011 prices) in the states surrounding the Great Lakes.[19] Adjusting this figure for the exchange rate and for inflation produces a corresponding value of Cdn$7.70 per angler.

Assuming that anglers in Ontario would experience a similar loss of consumer surplus due to *Phragmites* infestations in lakes, the economic impact on recreational fishing can be estimated for Ontario. According to the 2012 Canadian Nature Survey, 21% of Ontario residents age 18 and over participate in recreational fishing (Federal, Provincial, and Territorial Governments of Canada, 2014). Based on the total adult population in Ontario reported in this study (10,157,995), and assuming that the survey is representative of the

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[18] Conversely, there may be plenty of opportunities for aquatic recreational activities outside of provincial parks, which suggests that basing the estimate on the number of provincial park visitors who participate in these activities may underestimate the total impact.

[19] Under the best-case scenario, hydrilla would grow only in deeper areas of the lakes, which may actually improve habitat and fishing opportunities for certain species of fish. However, this scenario is unlikely to be the case for *Phragmites*, since it only grows in shallow water. As such, the worst-case scenario described in Lauber et al. (2020) is more likely to occur with *Phragmites*.

entire population, there would be 2,133,179 adults in Ontario that participate in recreational fishing. Based on the loss of consumer surplus per angler estimated by Lauber et al. (2020), the corresponding economic impact for anglers in Ontario from *Phragmites* would be $16.4 million annually.

This approach can be applied to other affected recreational activities, including other aquatic recreational activities such as swimming and boating as well as hunting and birdwatching, under the assumption that the loss of consumer surplus would be similar for these activities as for recreational fishing. According to the 2012 Canadian Nature Survey, 42% of Ontario residents participate in non-motorized water and beach activities (e.g., swimming), 22% participate in motorized water vehicle use, 19% participate in birdwatching, and 5% participate in hunting. Based on the estimated loss in consumer surplus for each of these activities, the resulting economic impacts of *Phragmites* are estimated to be $32.9 million annually for non-motorized water and beach activities, $17.2 million annually for motorized water vehicle activities, $14.9 million annually for birdwatching, and $3.9 million annually for hunting. The total estimated annual economic impact across all of these recreational activities would be $85.3 million.

Since the loss of consumer surplus estimated by Lauber et al. (2020) is based on a worst-case scenario, this may represent the high end of the potential range of economic impacts. For a more conservative estimate, the loss of consumer surplus is assumed to be half of the original estimate, or $3.85 per person. Following the approach described above, this would result in an estimated annual economic impact on recreational activities of $42.7 million.

3.4 Property Values

The presence of *Phragmites* can negatively impact property values due to the visual disamenity associated with *Phragmites* stands. This is particularly the case for waterfront properties, which derive a considerable amount of value from amenities associated with the view and from recreational opportunities afforded by bodies of water, both of which can be negatively impacted by *Phragmites*. Based on the nature of these impacts, the properties that would be impacted the most by *Phragmites* would be waterfront cottages in Ontario. Other types of properties that could be impacted include waterfront lodges and hotels.

There are a few revealed preference studies that have been published on the impacts of *Phragmites* and other aquatic invasive species on property values. These studies have typically used actual property sales data to estimate these impacts. A scan of the peer-reviewed literature on this topic found only one study related to *Phragmites* and property values. Iseley et al. (2017) examined the impact of proximity to *Phragmites* on property values in Michigan. The results of this study indicated that a one-metre increase in distance to *Phragmites* was associated with an increase in the property sale price of US$3.90. While this study did not directly estimate the impact that a *Phragmites* infestation would have on surrounding property values relative to values in an area with no *Phragmites*, the results of this study can be used to approximate this impact. Specifically, these results implied that the value of a property that has *Phragmites* or is immediately adjacent to *Phragmites* would be worth approximately US$3,900 less than a similar property for which the nearest patch of *Phragmites* is one kilometre away.[20] Based on this study's median property price of US$185,000, this price difference represents 2.1% of the value.

Studies on the impacts of other aquatic invasive species, such as Eurasian watermilfoil, on property values have also been conducted in a number of jurisdictions. Zhang and Boyle (2010) found that Eurasian watermilfoil, a species which like *Phragmites* also impedes easy access for watercraft, swimming and angling, reduced lakefront property values in the state of Vermont by 0.3% to 16.4%, depending on the level of infestation. Horsch and Lewis (2009) found that property values in Wisconsin were reduced by 8% around lakes affected by Eurasian watermilfoil, while Olden and Tamayo (2014) found a 19% reduction around affected lakes in Washington. The results of a study by Liao et al. (2016) on the impacts of watermilfoil on waterfront property values in Idaho indicated a 13% reduction in value.

Based on the results of previous studies, and assuming that property values in Ontario would be impacted similarly to values in the jurisdictions examined in these studies, a conservative estimate of the potential impact of *Phragmites* on waterfront property values in Ontario would be 5%. This represents the midpoint of the range of estimated impacts based on the results of Iseley et al. (2017) and the average of the results of Zhang and Boyle (2010) and of Horsch and Lewis (2009). While the values of waterfront properties vary widely across Ontario, an average value for these properties can be used for estimation purposes. According to Royal LePage's Recreational Property Report for 2020, the average price for a waterfront property in Ontario was $571,266.[21] Thus, a conservative estimate of the impact of *Phragmites* on the value of the average waterfront property would be $28,563.

The total impact of *Phragmites* on property values in Ontario would depend on the extent of the infestation of *Phragmites* in lakes across the province. For example, for a single lake with 100 average-priced waterfront properties, the impact of a *Phragmites* infestation on property values would be over $2.8 million.

If *Phragmites* infestations were to affect 5% of waterfront properties in Ontario, the magnitude of the property value impact would escalate dramatically. As indicated on the

[20] At a distance of 400 metres, a stand of *Phragmites* would likely be visible from the property and could still have an impact on the property's value. However, at a distance of one kilometre, the aesthetic and recreational impacts would likely be negligible. As such, the magnitude of the price difference at one kilometre could approximate the price difference between a property adjacent to *Phragmites* and a property that is not affected by *Phragmites*. Hence, it is assumed that this difference represents the impact of *Phragmites* on property values, based on the results of the study by Iseley et al. (2019).

[21] https://www.royallepage.ca/en/realestate/news/canadian-recreational-house-prices-soar-11-5-as-remote-work-drives-demand-in-cottage-country/

website of the Federation of Ontario Cottagers' Associations, there are about 250,000 waterfront properties in Ontario.[22] Based on the average value for waterfront properties of $571,266 and the estimated 5% reduction in value due to *Phragmites*, the total impact on property values in this scenario would be approximately $357 million. However, this estimate would not account for impacts on the values of tourism-related waterfront properties.

3.5 Property Taxes

A reduction in the values of waterfront properties will also affect the amount of property tax revenue for the municipalities in which these properties are located. According to the Federation of Ontario Cottagers' Associations, the annual property taxes for waterfront cottages in Ontario is over $700 million. Based on the scenario above in which 5% of waterfront properties are impacted by *Phragmites*, resulting in a 5% loss of value, the subsequent impact on property tax revenue can be estimated. Under the assumption that changes in property values are reflected by proportional changes in assessed property taxes, this scenario would result in a reduction in property tax revenue of at least $1.8 million annually.

An alternative approach to estimating the impact on property tax revenue would be to apply the average property tax rate in Ontario to the estimated total impact on property values from the scenario above. The average property tax rate across 64 cities and municipalities in 2019 was 1.21%.[23] Based on this rate, the loss of property tax revenue from the estimated $357 million reduction in waterfront property values would be $4.3 million annually.

3.6 Value of Ecological Impacts

Phragmites can take over waterfront and wetland areas and negatively impact native biodiversity. *Phragmites* can also cause the drying of wetlands and the loss of hydrological functions and the associated value of these functions. Wetlands can be valued in different ways. For example, wetlands can be valued based on the value that people place on the biodiversity and environmental benefits associated with wetlands. Whitehead et al. (2009) used travel cost and contingent valuation to estimate the value that people place on wetlands, which can be a proxy for the ecological value of wetlands. This study found that people in Michigan valued wetlands at US$756/ha (2005 prices). After accounting for the exchange rate and inflation, the corresponding value in Canadian currency for 2021 would be $1,202.15/ha.

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[22] https://foca.on.ca/about/our-community/
[23] Source: https://wowa.ca/taxes/ontario-property-tax

Wetlands can also be valued based on the ecosystem services that they provide, which include flood control, water supply, and nutrient cycling. Brander et al. (2013) conducted a meta-analysis of 38 studies on the value of ecosystem services provided by wetlands. While estimated wetland values were found to range widely across studies, the results of this study found median values of US$427/ha/year for flood control, US$57/ha/year for water supply, and US$243/ha/year for nutrient cycling, for a total of US$727/ha/year (2007 prices). After adjusting for the exchange rate and inflation, the resulting annual value of wetlands is estimated to be $987/ha. This estimate is relatively close to the value estimated above based on the results of Whitehead et al. (2009).

Brander et al. (2013) then used a value transfer approach to estimate the values of wetlands for specific regions. This approach involves estimating the value of an ecosystem by using the values estimated in previous studies for similar ecosystems. The results of this approach indicated a value for wetlands in Canada of US$223/ha/year, which is the current equivalent in Canadian currency of $303/ha/year. However, this may be a conservative estimate of the value of wetlands in southern Ontario. In comparison to the median value indicated above, the estimate for the value of wetlands in Canada is considerably lower. Brander et al. (2013) noted that estimated values were considerably lower in countries that are sparsely populated and have abundant wetland stocks, such as Canada. However, in comparison to the rest of Canada, southern Ontario is much more densely populated. As such, the estimated value for wetlands in southern Ontario is assumed to be closer to the median value of $987/ha/year based on the meta-analysis results.

In comparison, a study by Kennedy and Wilson (2009) estimated that the value of wetlands in the Credit River Watershed, a highly populated area in the Greater Toronto Area (GTA), was $186.8 million, or $31,682/ha/year (2007 prices). However, this value is unlikely to be representative of the value of wetlands in other areas of the province where the population density is much lower.

As described in Section 2, based on the results of Bourgeau-Chavez et al. (2015) and Bourgeau-Chavez et al. (2013), the estimated area of *Phragmites* in Great Lakes coastal wetlands in Ontario is 12,639 hectares. The resulting loss in value can be estimated using the results of the study by Brander et al. (2013). Based on the conservative estimated value of $303/ha/year, the impact of *Phragmites* on the value of coastal wetlands in Ontario would be $3.8 million annually. If it is assumed that the value per hectare of wetlands in this region is closer to the median value of the meta-analysis by Brander et al. (2013) of $987/ha, which is more likely for southern Ontario, the resulting impact on the value of wetlands would be $12.5 million annually.

3.7 Stormwater Management Ponds

Phragmites can easily infest stormwater management ponds, as the shallow water in these areas provides an ideal habitat. *Phragmites* can fill in these ponds, trapping sediment and inhibiting the draining of water, which can reduce the flood storage capacity of these ponds. *Phragmites* can also negatively impact the aesthetic views of these ponds and surrounding areas. Since stormwater management ponds provide similar ecological functions to wetlands, the economic impacts of *Phragmites* on these ponds may be estimated through a similar approach as the impacts on wetlands.

While there is a lack of information on total area of stormwater management ponds in Ontario, a rough estimate can be generated from available information on the number and size of these ponds. For example, there are over 1,000 stormwater management ponds in the GTA[24], and these ponds are typically at least 5 hectares in size[25], for a total area of at least 5,000 hectares. Assuming a similar proportion of area affected by *Phragmites* as coastal wetland area in Ontario (approximately 1%), there would be 50 hectares of *Phragmites* in stormwater management ponds in the GTA. Based on the value of wetlands in the GTA estimated by Kennedy and Wilson (2009), and adjusting for inflation, the estimated economic impact of *Phragmites* in these stormwater management ponds would be $2.0 million annually.

This may be a conservative estimate, since it only accounts for stormwater management ponds in the GTA. With the GTA accounting for just under half of Ontario's population, there may be twice as many stormwater management ponds in total in Ontario, although in lower populated areas the value of these ponds would be considerably less than the value of wetlands in the GTA that was estimated by Kennedy and Wilson (2009). Additional information on the total area of stormwater management ponds in the province and on the area of *Phragmites* in these ponds is needed in order to generate a more accurate estimate of these impacts.

3.8 Road Safety

Phragmites often grows in ditches and drains along roadways. Because it grows so tall and densely, it can reduce visibility at intersections, which can increase the possibility for serious vehicle collisions. Economic costs of traffic collisions were estimated by Council et al. (2005) in a study conducted for the Federal Highway Administration of the US Department of Transportation. This study estimated costs associated with collisions of varying levels of severity, and differentiated between collisions in rural areas and urban areas, based on speed

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[24] Source: https://www.watercanada.net/feature/the-ongoing-challenge-of-stormwater-maintenance/.
[25] Source: https://www.ontario.ca/page/understanding-stormwater-management-introduction-stormwater-management-planning-and-design.

limits. These estimated economic costs took into account medical costs, emergency services, property damage, lost productivity, and monetized quality-adjusted life years. The estimates by Council et al. (2005) for collisions in rural areas (i.e., with speed limits of at least 50 mph (80km/h)) are provided in Table 4. These estimates vary considerably with the severity of the accident, ranging from US$7,800 for collisions with no injuries to US$4.1 million for collisions with fatalities. These estimates have also been adjusted for the exchange rate and for inflation to provide current estimates in Canadian currency.

The estimated costs of traffic collisions in Table 4 are used to generate an estimate of economic costs that could occur due to the increased potential for collisions associated with the reduced visibility at intersections caused by *Phragmites* in roadside ditches. The numbers of collisions on roadways in Ontario are reported for each year by the Ministry of Transportation of Ontario. The most recent year for which this report is available is 2017. This report breaks down collisions in a wide variety of ways, including by road jurisdiction. Since *Phragmites* is likely to affect intersections only in rural areas, the estimated economic impact should be based on the number of collisions on rural roads. In 2017, on township and county roads in Ontario there were 107 fatal collisions, 2,968 collisions involving personal injury, and 13,029 collisions involving only property damage (Ministry of Transportation of Ontario, 2017). This report also indicates that 40.8% of all collisions occurred at intersections or were intersection related. This implies that 44 fatal collisions, 1,211 collisions involving personal injury, and 5,316 collisions involving only property damage occurred around intersections. If the reduced visibility at rural intersections due to *Phragmites* were to cause a 5% increase in the numbers of each of these categories of collisions, there would be an additional 2 fatal collisions, 61 collisions involving personal injury, and 266 collisions involving only property damage each year. Based on the cost of each category of collision provided in Table 4[26], this would result in an economic impact of $39.3 million annually.

[26] The cost per collision involving personal injury is calculated based on the average cost of the three injury categories in Table 4, which is $269,235.

Table 4: Estimated comprehensive economic costs of traffic collisions, derived from Council et al. (2005).

Severity of Collision	Economic Cost per Collision (US$, 2001 Prices)	Economic Cost per Collision (Cdn$, 2021 Prices)
Fatal	$4,106,620	$9,125,453
Incapacitating injury	$222,311	$494,004
Non-incapacitating injury	$91,622	$203,596
Possible injury	$49,549	$110,104
Property damage only	$7,800	$17,333

3.9 Fire Hazards and Power Outages

The significant amount of dry biomass from dead stalks in *Phragmites* stands contributes to increased fire hazards. According to Gilbert et al. (2014), dead stems account for about 70% of *Phragmites* stalks. In the past decade there have been a number of incidents in the US involving major fires in which large areas of *Phragmites* were burned.[27] Such fires could easily cause considerable damage to nearby houses or other buildings. For *Phragmites* stands in hydro transmission corridors, the risk of fire can cause significant economic impacts on the energy industry and on consumers due to power outages. A number of studies have been conducted to estimate the economic costs of power outages. For example, in a review of prior related studies, Lawton et al. (2003) found that, on average, residential customers in the US were willing to pay US$6.90 (Cdn$15.34) each to avoid a one-hour power outage and US$26.27 (Cdn$58.41) to avoid a power outage of 12 hours. This study also found that the average economic loss for small to medium commercial and industrial customers was US$1,859 (Cdn$4,134) for a one-hour outage and US$5,590 (Cdn$12,430) for an outage of 12 hours. By comparison, a contingent valuation study of residential customers in Germany found that, on average, households were willing to pay €14.90 (Cdn$24.13) to avoid a one-hour power outage and €88.40 (Cdn$143.13) to avoid a one-day outage (Praktiknjo, 2014). It is evident from such studies that the total economic impact of a power outage is largely dependent on the length of the outage and on the numbers and types of affected customers.

The economic impact of a power outage caused by a fire in a transmission corridor could be estimated using the results of the study by Lawton et al. (2003), based on the assumptions that the willingness to pay to avoid power outages and the economic losses from outages would be similar in Ontario for residential customers and for commercial and industrial customers, respectively. For example, if a power outage lasted 12 hours and affected 20,000

[27] Source: https://www.greatlakesphragmites.net/uncategorized/httpgreatlakesphragmites-netp2863/.

residential customers and 100 commercial and industrial customers, the estimated economic impact of this outage would be $2.4 million. If one such relatively local power outage is assumed to occur each year due to a fire from dead *Phragmites* stalks, the estimated impact would be $2.4 million. This may be a conservative estimate, as the number of fires due to *Phragmites* stands is difficult to predict, and the economic impacts would vary widely depending on the number of affected customers and the length of the power outage.

3.10 Summary of Economic Impacts

Based on the economic impacts estimated above, an aggregate estimated benefit of *Phragmites* control can be generated. This benefit is estimated to be $113.4 million annually, plus a one-time benefit of $357 million from avoiding the reduction in waterfront property values. These benefits are summarized in Table 5.

Table 5: Preliminary estimated economic impacts of *Phragmites* in Ontario, by category

Category	Description of Impact	Estimated Value of Impact
Agriculture	Reduced yields from delayed planting due to clogging of drains	$10.2 million/year
Tourism and Recreation	Reduced capacity for use of water bodies for recreational activities such as swimming, boating, and fishing; reduced habitat affects birdwatching and hunting	$42.7 million/year
Property Values	Reduced aesthetic appeal for waterfront properties	$357 million
Property Taxes	Lower property values will result in reduced property tax revenue	$4.3 million/year
Wetlands	Reduced ecosystem services such as flood control, water supply, and nutrient cycling	$12.5 million/year
Stormwater Management Ponds	Reduced flood storage capacity	$2.0 million/year
Road Safety	Increased risk of traffic collisions due to reduced visibility at rural intersections	$39.3 million/year
Fire Hazards and Power Outages	Increased risk of fire due to dry biomass in transmission corridors, which can cause power outages	$2.4 million/year

4.0 PRELIMINARY RESULTS OF THE COST-BENEFIT ANALYSIS

The net benefit of control of invasive species is equal to the value of avoided damages (i.e., economic impacts) that would have occurred due to the proliferation of invasive species less the costs of control (Hanley & Roberts, 2019). Based on the economic impacts estimated in Section 3, controlling *Phragmites* in Ontario would generate economic benefits of $113.4 million annually plus a one-time benefit of $357 million. The total estimated cost of control in Ontario is $90.0 million to $109.2 million in year 1, with total costs declining to some degree in subsequent years. Even with costs at the high end of this range, the level of estimated benefits of this control would be greater than the annual costs of control. As such, based on the assumptions imposed in estimation process and on the resulting preliminary estimates of costs and benefits of *Phragmites* control, there would be a net benefit of implementing a program to eradicate *Phragmites* in Ontario.

4.1 Potential Spread of *Phragmites* in Ontario

If not controlled, *Phragmites* could spread rapidly across Ontario. Permitting this spread could lead to additional economic impacts and would result in much higher costs of control in the future. A number of studies have examined the rate of spread of *Phragmites*. Howard and Turlock (2013) found that aerial cover of *Phragmites* at two sites in a Louisiana marsh increased by 543.6% and 675.8% over a five-year period. McCormick et al. (2010) found that the area of *Phragmites* in a wetland area in Maryland increased by 25 times over a 35-year period. In wetlands on the Great Salt Lake in Utah, Kettenring et al. (2016) noted increases in *Phragmites* patches of 11% to 46% per year. Here in Ontario, *Phragmites* cover was found to expand by 14% to 37% per year in the Long Point Peninsula (Jung et al., 2017). Since the area of *Phragmites* in Ontario is likely to expand rapidly if not adequately controlled, this would lead to substantial increases in the magnitude of the economic impacts. For example, some of the economic impacts are estimated based on assumptions regarding the proportion of area affected (e.g., agriculture; property values); as the area of *Phragmites* expands in Ontario, the proportion of area affected will increase, which will increase the estimated impacts. In addition, once *Phragmites* becomes well-established, the impacts and the costs of control increase substantially. As such, early detection and treatment is essential for minimizing both the economic impacts and the costs.

4.2 Implementation of a Province-Wide Program to Control *Phragmites*

Ideally, a province-wide approach to controlling *Phragmites* would strive for complete eradication. This approach has been conducted successfully on a smaller scale in St. Thomas, ON. This city in Elgin County implemented a *Phragmites* eradication strategy in 2014, targeting areas of *Phragmites* in wetland areas as well as roadside areas, and was able to become *Phragmites*-free by 2018. However, since *Phragmites* has not been eradicated from surrounding municipalities, annual monitoring and spot spraying continues in this area. As evident from the experience in St. Thomas, eradication on a larger scale would likely require several years to achieve, as full control cannot be achieved in one year. However, the costs of control are likely to decline in subsequent years.

Given the extent of *Phragmites* patches across the province and the existing capacity of contractors in terms of amount of area that can be treated, it is highly unlikely that all existing patches could be treated within the first year. As a result, it may take several years to conduct the initial treatment for all patches. This implies that the cost of a province-wide control program may remain relatively high for a few years before declining. Once the costs for each year have been estimated, it would be possible to determine the net present value of a province-wide program to eradicate *Phragmites*.

The recent federal approval for a herbicide that can be applied over open water in Ontario could greatly assist control efforts, particularly since there is a considerable amount of *Phragmites* in wetlands areas. Herbicide application typically has high efficacy, often resulting in over 90% control of *Phragmites*, with only spot spraying needed in subsequent years to control remaining plants. Other control methods for *Phragmites* patches in water, such as cut-to-drown, may not be as effective (see Table 1), and require considerably more time to conduct. As a result, the ability to apply herbicide over water could considerably enhance the likelihood of success of an eradication program in Ontario. This is also evident from one prior case in Ontario where emergency registration was provided for herbicide application over water. However, it should also be noted that even with herbicide application permitted over water, this does not necessarily mean that it would fully replace cut-to-drown control methods in wetlands. In some situations, it may be more appropriate to use cut-to-drown.

It would be important for the development of a province-wide control program for *Phragmites* to take into account situation-specific factors, as the considerations and activities required in the development of a local control plan may vary considerably from one situation to another. To provide examples of how *Phragmites* control decisions are made at the local level and the activities and considerations that are involved, two scenarios are provided in the appendix at the end of this chapter.

5.0 LIMITATIONS AND GAPS IN INFORMATION

It is important to emphasize and explain the limitations inherent in the approaches used in this study to estimate the costs and the economic impacts of *Phragmites* control. The estimates for the economic impacts are based on assumptions imposed regarding the nature of these impacts; the strength or appropriateness of these assumptions will directly affect the accuracy of the estimates. In a number of cases, economic impacts are estimated based on an assumption for the proportion of the industry or category affected by *Phragmites*. For example, the economic impact of *Phragmites* on the agriculture industry is based on a scenario in which 5% of fields are impacted by *Phragmites*, while the economic impact on property values is based on a scenario where 5% of waterfront properties are affected by *Phragmites*. These proportions are not necessarily reflective of the current level of impact, since this information is not available in most cases, but represents a specific scenario or a reasonable assumption of what could occur if *Phragmites* is permitted to continue to expand in Ontario. These proportions are imposed to provide examples of what the economic impacts of *Phragmites* could be under certain circumstances if it's not controlled. This estimation approach implies that the magnitudes of the estimated impacts are directly dependent on the assumed proportion of the industry or category that would be adversely affected by *Phragmites*. In light of the limitations associated with the approach used to estimate economic impacts, efforts were taken to use conservative estimates. However, given the limitations of this approach due to a lack of information on the current extent of the impacts on specific categories, it is important to view these estimates with caution. If more information or data related to these impacts becomes available, or if additional research is conducted related to these impacts, these estimates could be revised accordingly.

Similarly, data limitations may negatively impact the accuracy of the estimated costs of control. To be able to more accurately estimate the annual costs of control for *Phragmites* in Ontario, more information is needed on the extent and location of infestations across the province as well as on the potential rate of spread. There is a project currently being conducted by Environment and Climate Change Canada (ECCC) that is gathering data on locations of *Phragmites* stands across Ontario for the purpose of modeling the spread of *Phragmites* and predicting how it will evolve in the future.[28] Once the location data has been aggregated, it could be possible to estimate the annual costs of control with a greater degree of accuracy. In addition, the estimated cost of control for year 1 is based on the simplifying assumption that all areas of *Phragmites* can be treated in one year. More information is needed on the capacity to treat *Phragmites* across the province and the corresponding amount of time that would be required to treat all areas of *Phragmites*. This would permit a more accurate estimate of the costs for each year. This would also allow for calculating the

[28] This is part of an ECCC initiative called Assessing and Enhancing the Resilience of Great Lakes Coastal Wetlands.

present value of the costs and benefits for each year, from which the net present value of a *Phragmites* control program could be determined.

This study provides rough estimates of the costs and benefits of *Phragmites* control in Ontario, based on available information. While the accuracy of these estimates is affected by a number of identified limitations, these estimates represent a starting point for the determination of whether there would be a net benefit associated with a province-wide program to eradicate *Phragmites*. There are a number of gaps in information that potentially detract from the accuracy of these estimates. The main gaps include:

- Updated data on total area of *Phragmites* along roads and in wetland areas
- Data on other areas of *Phragmites* in Ontario, including areas on private property, in parks, along waterfronts, in utility corridors, in drainage ditches, and in stormwater management ponds
- Estimates of the rate of spread of *Phragmites*
- The area of *Phragmites* that could be treated in a year, for each control method
- Cost of control for the recently approved herbicide that can be applied over water
- Cost of mowing following herbicide application along roads, and the proportion of *Phragmites* area for which mowing is required
- The extent to which costs of control decline following initial treatment
- How many years it would take for all areas to receive an initial treatment, which would permit a more accurate estimate of costs in each year and the estimation of the net present value of a *Phragmites* control program
- Impacts on other sectors such as infrastructure
- Additional ecological impacts, including impacts on species at risk

As this information becomes available, cost and benefit estimates in this study could be updated.

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APPENDIX C: *PHRAGMITES* CONTROL SCENARIOS

Written by Colleen Cirillo

The following scenarios are fictional representations of two common scenarios facing land managers across Ontario. The planning, actions and budgets presented below are reflective of actual comparable situations. They have been provided to demonstrate the breadth of expenses and effort associated with common management scenarios.

Scenario 1: Municipal roadside *Phragmites* control

In 2018, a small city in southwestern Ontario hired college students to survey roadsides for *Phragmites* and map its occurrence. The students found 20 kilometers of roadside ditch, approximately one metre wide, to be infested with this invasive plant. That is a total of two hectares.

After a short deliberation, city council agreed to proceed with a *Phragmites* control program for the following reasons:

- *Phragmites* causes damage to road infrastructure;
- It impedes drainage;
- It hinders the ability of city roads staff and contractors to conduct regular maintenance and construction;
- It restricts sight lines for motorists, compromising the safety of all road users;
- It can present a fire hazard; and,
- It spreads to the city's nearby natural areas, where it degrades habitat.

The city consulted with nearby municipalities and reviewed provincially-recognized best practices to develop a multi-year plan for *Phragmites* control along roads, focused on public awareness and outreach, mapping, monitoring and chemical control. While the former tasks were accomplished by city staff (permanent and seasonal), a contractor was hired to apply the herbicide. It is important to note that the roadside ditches infested with *Phragmites* are free of standing water for much of the year, with the exception being early spring (snowmelt) and during and shortly after intense rain storms. Herbicides were applied during dry periods.

The decision to hire an experienced contractor as opposed to using staff for herbicide application was an easy one for the city, and was in line with the approach taken by nearby cities. Workers applying herbicides along roads must have an Industrial Vegetation Exterminator License and an Integrated Pest Management Certificate. The costs to obtain these certifications (both actual and staff time), paired with the lack of necessary equipment, contributed to the decision, as did the risk and liability associated with pesticide handling and application.

A contractor applied herbicide in early summer in year one (2019) and came back in the early summer in year two (2020) to spot-spray as required. In the fall of both years, city staff removed dead stalks to improve motorist visibility and to facilitate spot spraying. Contractor activities and costs were as follows:

Year one (2019): foliar spray of Roundup WeatherMAX on two hectares of roadside *Phragmites* using truck and boom; $2,500

Year two (2020): spot spray with Roundup WeatherMAX on two hectares of roadside *Phragmites* using hose and handgun; $5,000

In an effort to secure public support for this project and to reduce the ongoing spread of *Phragmites* from neighbouring lands and jurisdictions, the city developed and delivered a communications plan. Target audiences include private land owners, the local conservation authority, recreationists, neighbouring towns and cities, and contractors working on infrastructure projects.

Table A1: Annual budget

Communications and collaboration	$10,000
Follow-up cutting by permanent staff	$5,000
Mapping, monitoring and sign placement/removal by two students (450 hours at $20/hr)	$9,000
Contractor	$5,000
Disposal	$500
Total	**$29,500**

Scenario 2: Community *Phragmites* control along a shoreline

In 2016, a conservation organization in central Ontario secured funds to conduct a three-year *Phragmites* community outreach and eradication program. The success of this program was dependent on the substantial involvement of local residents, both full-time and seasonal, and the organization's dedicated volunteers. The local municipality and conservation authority were in full support of the program, and provided some of the funds and supplies.

College students surveyed two kilometres of shoreline, both public and privately owned, making note of *Phragmites* patches as well as items of ecological significance, such as bird nests and rare native plants. They found multiple patches, many extending well into the lake and varying in width from 5 to 10 metres. The estimated area of shoreline invaded with *Phragmites* was 1.5 hectares.

The organization made a strong case for *Phragmites* education and action based on the following points:

- Since its first sighting in 2010, *Phragmites* had spread quickly along the shoreline;
- This expansion reduced the presence of native shoreline plants and associated wildlife;
- It impaired the views and recreational enjoyment of the lake for residents and visitors;
- It reduced the property value of lakeside properties; and,
- In 2015, *Phragmites* spread from the shoreline to a nearby provincial park prized for its high ecological value.

The organization consulted with other groups controlling *Phragmites* along shorelines and reviewed provincially-recognized best practices to develop a plan that included community outreach, mapping (as described above), manual and chemical control, and monitoring. All of these tasks were completed by the organization's permanent and seasonal staff members and volunteers, except for herbicide application on dry land stands. A contractor with extensive experience controlling invasive plants near water applied herbicide in early summer every year. Volunteers removed dead stalks in the fall to facilitate follow-up removal efforts. Contractor activities and costs were as follows:

Hose and gun application of Roundup WeatherMAX on dry land stands only which equalled approximately 0.5 hectares in area; $2,000.

Because much of the *Phragmites* was in standing water, staff members and volunteers manually removed it using raspberry cane cutters and spades. Annually, volunteers dedicated 300 hours of removal work, valued at $7,500.

In an effort to secure public support for this program, the organization developed and delivered a communications plan. Tools included social and traditional media, signs, and flyers. Target audiences included permanent and seasonal waterfront residents, local naturalists and recreationists.

Table A2: Annual budget

Item	Amount	In-kind
Program management	$20,000	
Communications and collaboration	$5,000	
Mapping and monitoring by two students (450 hours at $18/hr)	$8,100	
Contractor	$2,000	
Truxor rental for one day	$3,140	
Manual removal by volunteers (300 hours at $25/hr)		$7,500
Manual removal tools (spades, raspberry cane cutters, etc.)	$750	
Disposal by municipality		$200
Totals	**$38,990**	**$7,700**

Table A3: Budget for three years (2016 – 2018)

Year one*	$40,490
Year two	$38,990
Year three	$38,990
Total	**$118,470**

* Year one's budget is higher due to the purchase of an aluminum boat for $1,500.