MN NWAC Risk Assessment Worksheet (04-2011)	Common Name	*Latin Name*
	introduced forms of common reed, non-native subspecies of Phragmites, non-native Phragmites	**introduced forms of *Phragmites australis***
Reviewer	**Affiliation/Organization**	**Date (mm/dd/yyyy)**
Anthony Cortilet	**Minnesota Department of Agriculture**	**09/12/2012**
Ken Graeve	**Minnesota Department of Transportation**	**August 2016**
Dave Hanson	**Minnesota Department of Transportation**	**07/09/2019**

Species Description:
Common reed, *Phragmites australis*, is represented in MN by a native subspecies (*Phragmites australis* subsp. *americanus*, hereafter native *Phragmites*) and a non-native form (P. *australis* haplotype M, hereafter introduced *Phragmites*). This risk assessment focuses on introduced *Phragmites.* Introduced *Phragmites* is highly invasive in many parts of North America, including adjacent and nearby states on the Great Lakes and has been shown to cause significant ecological disruption. It is present in Minnesota in widely scattered but small infestations (see box 6A). The abundance of introduced *Phragmites* in MN is far lower than in other affected states, but conditions are such that rapid spread is likely in the near future. There is some beneficial use of introduced *Phragmites* in the form of reed beds used for wastewater treatment, but this benefit is outweighed by the threats to wetland ecosystems in Minnesota. This risk assessment recommends that introduced *Phragmites* be regulated on the noxious weed list as a "Prohibited: Control" species in order to motivate control and containment within the state.

The following chart shows the steps in the risk assessment protocol that have led to this conclusion. However, because of the complexities of this species, more detail is provided in a narrative after the protocol (Appendix A).

Current Regulation: Minnesota Restricted Noxious Weed.

Box	Question	Answer	Outcome
1	Is the plant species or genotype non-native?	*Phragmites australis* is a wetland grass with a cosmopolitan distribution. Four distinct lineages have been identified in North America (Saltonstall 2007, Meyerson and Cronin 2013). One is a collection of several endemic haplotypes that has been formally described as *P. australis* subsp. *americanus* (Saltonstall 2004). Another lineage, often referred to as Haplotype M, is the most common lineage worldwide. Genetic comparisons and historical distribution data have	Yes Go to 3

Box	Question	Answer	Outcome
		shown that haplotype M was likely introduced to North America, possibly from sources in the United Kingdom, sometime before 1910 (Saltonstall 2002, Plut et al. 2011). Both native *Phragmites* and introduced *Phragmites* have been documented in Minnesota (Saltonstall 2002, Melchior and Weaver 2016).	
3	The plant, or a related species, is documented as being a problem elsewhere?	Introduced *Phragmites* is considered a highly invasive plant in North American marshes, is considered problematic in at least 18 states, and is especially invasive along the east coast, Great Lakes states, and Nebraska (Galatowitsch 2012, Falck and Olson 2015, Saltonstall 2002, Swearingen and Saltonstall 2010, Gucker 2008, Hodredge and Bertness 2010, Farnsworth et al 2003).	Yes Go to Step 6
6	The Plant has the capacity to establish and survive in MN?		
A.	Is the plant, or a close relative established in MN?	Yes. Both native *Phragmites* and introduced *Phragmites* have been documented morphologically and molecularly in MN (Saltonstall 2002, Melchior and Weaver 2016). University of Minnesota's Aquatic Invasive Species Research Center (MAISRC) researched the distribution of introduced *Phragmites* across the State of Minnesota beginning in 2017 and their work continues to the time of this update. The project is hereafter referred to as the 'MNPhrag' project. Reporters achieved a 95% success rate for morphological identification which has been verified with comparative genetic testing. Verification of identification by trained personnel is recommended prior to treatment (MNPhrag 2019). MNPhrag (2019) project to date verified 389 introduced *Phragmites* populations in Minnesota with a combined area of approximately 50 acres. The largest identified population as a result of this research is approximately 4 acres. Detailed descriptions of distribution are provided in Blanke et al. 2019.	Yes Go to Step 7

Box	Question	Answer	Outcome
		MNPhrag (2019) distribution maps for both native *Phragmites* and introduced *Phragmites* as well as additional related maps are found in Appendix B.	
7	The plant has the potential to reproduce and spread in MN?		
A.	Does the plant reproduce by asexual/vegetative means?	Yes. Introduced *Phragmites* reproduces vigorously by rhizomes, stolons, and roots. Fragments of these structures can be carried by human activities or by water and re-root (Bart and Hartman 2003, Kettenring and Mock 2012). Abundant viable seed is also produced making seed an important invasion vector (Albert et al, 2015, Gucker 2008, Meyerson et al. 2009) so information on sexual reproduction is included in Box 7C.	Go to 7B
B.	Are the asexual propagules – vegetative parts having the capacity to develop into new plants – effectively dispersed to new areas?	Yes. Water action along lakes, ponds, wetlands, or streams can break root fragments off of the plant and transport downstream to new areas. Rhizome or stolon fragments can also be transported by humans and equipment (Gucker 2008, Marks et al. 1994). Roadsides have been shown to be especially conducive to spreading this species due to their hydrologic characteristics and maintenance practices (Brisson et al. 2010). In addition, de-icing salts and resulting increased salinity are better tolerated by introduced *Phragmites* than by native *Phragmites* (Brisson et al. 2010, Vasquez et al. 2005). Increased salinity tolerance and connectedness of roadways facilitate dispersal of introduced *Phragmites* (Lelong et al. 2007, Jodoin et al. 2008).	Go to 7I
C.	Does the plant produce large amounts of viable, cold hardy seeds?	***Sexual reproduction does occur (Albert et al., 2015, Gucker 2008, Meyerson et al. 2009). In Minnesota it is thought to be restricted to growing seasons that extend late into the year, allowing time for seed maturation. While this is thought to be limited, such growing seasons will likely become increasingly common as the climate changes (Galatowitsch, pers comm. 2016, EPA 2016, Zandlo 2008). On the other hand, seed production may already be prevalent. Melchior and Weaver found evidence of sexual reproduction in Minnesota (2016) and a recent study in Quebec found that 84% of new plants grew from seed rather than fragments (Albert et al 2015).***	**Text is provided as additional information not directed through the decision tree process for this particular risk assessment.**

Box	Question	Answer	Outcome
		MNPhrag (2019) project divided the state into 9 regions and collected seed from across Minnesota. MNPhrag project reported that viable seed was collected from populations across the southern 2/3 of the state (regions 4-9). See Appendix C for Region Map and Table of Preliminary Viability Results.	
D.	For species that produce low numbers of viable seeds, do they have a high level of seed/seedling vigor or remain viable for an extended period (seed bank)?	***Seedlings are thought to be susceptible to winter freezing, and thus their survival limited to mild winters (Albert et al. 2015, Brisson et al. 2010). However, there is concern that seed will contribute more to spread as mild winters increase with climate change (Brisson et al. 2010). Evidence already exists for sexual reproduction in MN (Melchior and Weaver 2016).***	**Text is provided as additional information not directed through the decision tree process for this particular risk assessment.**
F.	Are sexual propagules – viable seeds – effectively dispersed to new areas?	***Phragmites seed is dispersed by wind (Gucker 2009).***	**Text is provided as additional information not directed through the decision tree process for this particular risk assessment.**
G.	Can the species hybridize with native species (or other introduced species) and produce viable seed and fertile offspring in the absence of human intervention?	***Yes, hybridization is thought to be rare (Fant et al. 2016) but both intra- and interspecific hybridization have been documented (Chu et al. 2011, Lambertini et al. 2012, Blossey et al. 2014, Paul et al. 2010).***	**Text is provided as additional information not directed through the decision tree process for this particular risk assessment.**
I.	Do natural controls exist, species native	No.	Go to Step 8

Box	Question	Answer	Outcome
	to Minnesota that are documented to effectively prevent the spread of the species in question?	Biological control research is being conducted. Two stem-mining noctuid moth species (*Archanara geminipuncta* and *A. neurica*) are under consideration. Blossey et al. (2018) submitted a petition to the USDA APHIS for the US field release of *Archanara geminipuncta* and *A. neurica* as biological control insects of introduced *Phragmites australis* on August 20, 2018. The USDA APHIS Technical Advisory Group (TAG) reviewed the proposal and recommended release on April 19, 2019 (https://www.aphis.usda.gov/plant_health/permits/tag/downloads/TAGPetitionAction.pdf). After a TAG recommendation the petition is reviewed further by the US Fish and Wildlife Service and USDA APHIS. If they recommend release an environmental impact statement is prepared and submitted for public comment. If it passes that step then APHIS can issue a permit for release. This stage of review often takes 1-2 years past the initial TAG recommendation. The first releases are likely to be at research sites in the eastern US. Minnesota could determine what, if any, program for biocontrol releases would be appropriate for the state. If the state is focused on targeted traditional management with the goal of eradication of introduced *Phragmites* then biocontrol would not be a tool toward that goal. Biocontrol is used when a species is widespread for the purpose of reducing the population. Blossey's proposal indicates that the proposed biocontrol insects *Archanara geminipuncta* and *A. neurica* have a host preference for introduced *Phragmites* but will also lay eggs and larvae can develop on the native *Phragmites*. Minnesota will need to determine if it will allow releases in the state if they are approved at the federal level. There is not consensus on the appropriateness of using biocontrol agents that are known to develop on the native *Phragmites*. If the insects are approved for the US and the first releases are done in the proposed research sites in eastern states, then Minnesota may have	

Box	Question	Answer	Outcome
		access to new research by the time Minnesota agencies need to determine if *Archanara geminipuncta* and *A. neurica* are appropriate to release in Minnesota.	
8	Does the plant species pose significant human or livestock concerns or have the potential to significantly harm agricultural production, native ecosystems, or managed landscapes?		
A.	Does the plant have toxic qualities, or other detrimental qualities, that pose a significant risk to livestock, wildlife, or people?	There have been no reported toxic qualities associated with *Phragmites*. There are reports that stems from the previous season, which are dry and broken can be stout enough and sharp enough to puncture soles or leather of footwear and ultimately puncture skin (J. Bohnen, pers comm. 2019).	No, Go to 8B
B.	Does, or could, the plant cause significant financial losses associated with decreased yields, reduced crop quality, or increased production costs?	No known impacts to production in the literature. There is a concern that introduced *Phragmites* could threaten wild rice production, not based on direct evidence but based on overlapping habitat requirements (Falck, pers comm. 2016).	Possibly, Go to 8C
C.	Can the plant aggressively displace native	Yes, introduced *Phragmites* has been shown to reduce native plant diversity through rapid growth, litter accumulation, hydrological alterations, and allelopathy (Ailstock et al. 2001, Chambers et al. 1999, Farnsworth and	Yes, Go to Step 9

Box	Question	Answer	Outcome
	species through competition (including allelopathic effects)?	Meyerson 1999, Galatowitsch 2012, Holdredge and Bertness 2010, Price et al. 2014, Rudrappa et al. 2007). Introduced *Phragmites* captures much of the available sunlight, draws many of the available nutrients and water from surrounding soils to create large amounts of biomass resulting in dense shade and very thick litter layers. End result is a reduction in native species (plant and animal) being able to reside or forage in the same location (Minchinton et al. 2006, Able et al. 2000).	
D.	Can the plant hybridize with native species resulting in a modified gene pool and potentially negative impacts on native populations?	***Hybridization has recently been confirmed to occur between wild populations of introduced and native Phragmites (Paul et al. 2010, Blossey et al. 2014).***	**Text is provided as additional information not directed through the decision tree process for this particular risk assessment.**
E.	Does the plant have the potential to change native ecosystems (adds a vegetative layer, affects ground or surface water levels, etc.)?	***Introduced Phragmites can grow in such dense stands that it alters ecosystem structure and function. Considered to be an ecosystem engineer, introduced Phragmites growth and rapid litter accumulation alter hydrology, and cause changes in nutrient cycling, soil properties, surface temperatures, and light levels within marsh communities (Gucker 2009, Meyerson et al. 2009). These changes have been associated with reduced plant and animal diversity and with significant alterations at the base of the food web (Able and Hagan 2000, Able and Hagan 2003, Benoit and Askins 1999, Gratton and Denno 2006, Meyer et al. 2010, Meyerson et al 2009, Gucker 2008). Introduced Phragmites also hampers wetland restoration by crowding out target plant communities (Meyerson et al. 2009).***	**Text is provided as additional information not directed through the decision tree process for this particular risk assessment.**
9	The plant has clearly defined benefits that outweigh associated negative impacts?		

Box	Question	Answer	Outcome
A.	Is the plant currently being used or produced and/or sold in MN or native to MN?	Yes Introduced *Phragmites* was indicated as being used in reed beds for wastewater treatment at 17 facilities in Minnesota during the 2016 risk assessment (Sherry Bock, pers comm. 2016). As of 2019, there are 16 facilities in MN (Blanke et al. 2019., Julia Bohnen, pers comm. 2019). *Phragmites* subsp. *americanus* is native and may be sold in certain wetland mixes/restoration mixes. However, no known sales in the nursery trade at this time have been established (Power pers comm, 2016., Shimek pers comm, 2016., Malone pers comm. 2016).	Go to 9B

Box	Question	Answer	Outcome
B.	Is the plant an introduced species and can its spread be effectively and easily prevented or controlled, or its negative impacts minimized through carefully designed and executed management practices?	Introduced *Phragmites* is a non-native form of *Phragmites australis* and is distinct from the native subspecies, *P.a.* subsp. *americanus* (Saltonstall 2002). The risk of spread from wastewater treatment facilities has been downplayed by that industry, with claims that rhizomes are effectively contained by the liner used in the reed bed structure and that disposal requirements for biosolids ensure that it gets applied to unsuitable (upland) sites (Bock, pers comm. 2016, Davis, pers comm. 2016). Even so, there are naturalized populations adjacent to at least two treatment facilities in MN and three in Wisconsin (Bock pers comm 2016, Falck 2015, Wright County) although genetic analysis to determine the source of these infestations has not been done. Even if rhizome containment is 100% effective, it does not address sexual reproduction. Given the strong evidence for spread by seed in MN (Galatowitsch pers comm. 2016, Melchior and Weaver 2016), it would be irresponsible to assume that containment of rhizomes is sufficient. Seed production in reed beds could be prevented by mowing during August. Currently the logistics of accomplishing such a mowing are difficult but solutions are being investigated (Davis pers comm. 2016, Hegeman pers comm. 2016). The resulting biosolids from the reed bed facilities can contain rhizomes and seeds which necessitate thoughtful and potentially costly disposal options. Blanke et al. (2019) discuss the three waste water treatment facilities in Northern Wisconsin mentioned above (pages 65-66). Introduced *Phragmites* was replaced with native subspecies after it was shown that nearby wild populations were in fact genetically related to the introduced *Phragmites* in use at the facilities. Information provided to the research team by Gabrielle VanBergen, Red Cliff Band of Lake Superior Chippewa.	Go to 9C
	C. Is the plant native to Minnesota?	No	Go to Question D
	D. Is a non-invasive, alternative	Yes	Go to Step 10

Box	Question	Answer	Outcome
	plant material commercially available that could serve the same purpose as the plant of concern?	While there are no rigorous studies comparing the performance of native with introduced *Phragmites* in reed beds, the designer of the majority of reed bed systems in North America, Scott Davis of the Constructed Wetlands Group, is increasingly using native *Phragmites* in new installations. Davis has observed the native *Phragmites* to be a little more difficult to propagate but its overall performance is similar to that of introduced *Phragmites*. Native *Phragmites* has already been installed in one reed bed in MN (Bock pers comm. 2016) and possibly three others (Evanocheck pers comm. 2016). Nebraska prohibits the use of *P. australis* subsp. *australis* in reed beds and Indiana has also banned the practice (Hegeman).	
	E. Does the plant benefit Minnesota to a greater extent than the negative impacts identified at Box #8?	***No.*** ***The various ecological and infrastructure impacts described above are extensive but difficult to quantify. The cost of controlling introduced Phragmites, although undoubtedly a vast underestimate of impacts, represents a more accessible quantitative measure of its impacts. Regional control projects for which expenditures are readily available include efforts in the central Platte river valley of Nebraska, which has spent $4.5million over six years (Walters, unpublished data); and work in the great lakes totaling over $16 million since 2010 (Braun, pers comm. 2016). An economic survey of management efforts by Martin and Blossey (2013) found that organizations across the U.S. spent over $4.6million per year from 2005-2009, but that few organizations had accomplished their management objectives.*** ***Michigan DOT (MDOT) has indicated success in eradicating Phragmites from some Upper Peninsula counties. But, have also expressed frustration in other areas with new populations being found. In areas where introduced Phragmites is not widespread, MDOT spent $250,000 in 2017 on introduced Phragmites control and expect the 2018 budget numbers to be similar once calculated (Jones, pers comm. 2019).***	**Text is provided as additional information not directed through the decision tree process for this particular risk assessment.**

Box	Question	Answer	Outcome
		The benefits of non-native P. australis in wastewater treatment reed beds are substantial in that they reduce the operating costs and environmental impact of wastewater treatment. However, it would be difficult to argue that these benefits outweigh the vast ecological impact of many thousands of acres of infestation. Also, native P. australis is increasingly being used as a replacement (Davis pers comm. 2016). Additionally, safe disposal of the reed bed biosolids which contain introduced Phragmites propagating parts is an additional cost.	
10	Enforce control as a noxious weed to prevent introduction and/or dispersal; designate as Prohibited or Restricted	The flow chart directs the analysis into Box 10 based on the analysis that this is a non-native plant with substantial negative impacts that are not outweighed by the benefits that it provides.	
A.	Is the plant currently established in MN?	Yes. Both native *Phragmites* and introduced *Phragmites* have been documented morphologically and molecularly in MN (Saltonstall 2002, Melchior and Weaver 2016). Yes. MNPhrag (2019) project research supports the presence of introduced *Phragmites* in Minnesota. See distribution maps in Appendix B.	Go to 10B
B.	Does the plant pose a serious human health threat	No threat to human health has been documented at this time.	Go to 10C
C.	Can the plant be reliably eradicated – entire plant – or controlled (top growth only to prevent pollen dispersal and seed	Control of introduced *Phragmites* infestations is possible. A common concern relating to control of introduced *Phragmites* is that an inability to distinguish it from native *Phragmites* can jeopardize the native subspecies. However, comparison of morphological characteristics with genetic markers by Swearingen and Saltonstall (2010) have revealed several useful field indicators. Although Swearingen and Saltonstall warn that field identification	Yes – List as a Prohibited Noxious Weed on the Control List and modify Statute 18.78 subdivision 2 to include introduced *Phragmites*. Include a

Box	Question	Answer	Outcome
	production as appropriate) on a statewide basis using existing practices and available resources?	using morphological characteristics without genetic testing may not be 100% reliable, the correlation is strong and Minnesota stands of *Phragmites* have shown 100% correlation between morphological characters and genetic markers (Melchior and Weaver 2016). Also, states like NE have listed it as a noxious weed and have been relatively successful through University of NE Extension in providing enforcement agents in local governments with education on discerning between the native and non-native. MN Phrag (2019) reporters achieved a 95% success rate for morphological identification which has been verified with comparative genetic testing. Verification of identification by trained personnel is recommended prior to treatment to prevent accidental treatment of native *Phragmites*. Treating *Phragmites* growing below the ordinary high water mark would require a permit from the Minnesota Department of Natural Resources which would be a chance for professionals to verify species identification. Control efforts in other states have shown success with various combinations of treatments such as herbicide, mowing, burning, and restoration (Gucker 2009). Coordinated efforts in Nebraska have reduced infestations and improved flow conveyance in the Platte River (Walters, unpublished data). However, as a word of caution, there are studies that question the landscape-scale and long-term effectiveness of control (Hazelton et al 2014, Martin and Blossey 2013). Wastewater treatment facility *Phragmites* have a lifespan and could be allowed to continue until they have reached the lifespan of the bed and then transition to a different species than introduced *Phragmites.* Reed bed facilities could also implement seed control measures such as mowing flowering heads before seeds develop although the feasibility of this may vary among reed beds. Reed beds could be given permits to continue work as they transition away from introduced *Phragmites*.	phase out clause for waste water treatment facilities.

Box	Question	Answer	Outcome
		The Blanke et al. (2019) report provides detailed information on locations of introduced Phragmites in Minnesota and it divides the state into 12 regions and gives a summary of response needs in each region. Introduced *Phragmites* is an emergent wetland and shore land plant and so differs from every other plant on the Noxious Weed List besides purple loosestrife (*Lythrum salicaria*). Destruction of plants that grow below the ordinary high water require permits from the Minnesota Department of Natural Resources. There are introduced Phragmites locations that could include both public waters (below the ordinary high water mark) and are generally managed by the Minnesota Department of Natural Resources and the areas above ordinary high water mark which could be on private property. In the Minnesota Department of Agriculture Noxious Weed Statutes 18.78, Subdivision 2 it lays out specific clarification language regarding responsibilities of the Minnesota Department of Agriculture and the Minnesota Department of Natural Resources. If introduced Phragmites is recommended to be regulated as a Prohibited Noxious Weed on the Control List, it is recommended that Statute 18.78, Subdivision 2 be modified to include purple loosestrife and introduced Phragmites. Underlined words indicate new words to be added to the statute. Current Statute 18.78 Subdivisions 1 and 2 (https://www.revisor.mn.gov/statutes/cite/18.78). **18.78 CONTROL OR ERADICATION OF NOXIOUS WEEDS.** **Subdivision 1. Generally.** A person owning land, a person occupying land, or a person responsible for the maintenance of public land shall control or eradicate all noxious weeds on the land at a time and in a manner ordered by an inspector or county-designated employee. **Subd. 2. Control of purple loosestrife and non-native Phragmites australis.** An owner of nonfederal lands underlying public waters or wetlands designated under section 103G.201 is not required to control or eradicate purple loosestrife	

Box	Question	Answer	Outcome
		and non-native Phragmites australis below the ordinary high water level of the public water or wetland. The commissioner of natural resources is responsible for control and eradication of purple loosestrife and non-native Phragmites australis on public waters and wetlands designated under section 103G.201, except those located upon lands owned in fee title or managed by the United States. The officers, employees, agents, and contractors of the commissioner of natural resources may enter upon public waters and wetlands designated under section 103G.201 and, after providing notification to the occupant or owner of the land, may cross adjacent lands as necessary for the purpose of investigating purple loosestrife or non-native Phragmites australis infestations, formulating methods of eradication, and implementing control and eradication of purple loosestrife or non-native Phragmites australis. The commissioner of natural resources shall, by June 1 of each year, compile a priority list of purple loosestrife and non-native Phragmites australis infestations to be controlled with herbicides in designated public waters. The commissioner of natural resources must distribute the list to county agricultural inspectors, local weed inspectors, and their appointed agents. The commissioner of natural resources shall control listed purple loosestrife infestations and non-native Phragmites australis in priority order within the limits of funding allocated for that purpose. This procedure shall supersede the other provisions for control of noxious weeds set forth elsewhere in this chapter. The responsibility of the commissioner of natural resources to control and eradicate purple loosestrife and non-native Phragmites australis on public waters and wetlands located on private lands and the authority to enter upon private lands ends ten days after receipt by the commissioner of a written statement from the landowner that the landowner assumes all responsibility for control and eradication of purple loosestrife and non-native Phragmites australis under sections 18.78 to 18.88. State officers, employees, agents, and contractors of the commissioner of natural resources are not liable in a civil action for trespass committed in the discharge of their duties under this section and are not liable to anyone for damages, except for damages arising from gross negligence.	

Box	Question	Answer	Outcome

2012 Final Results of Risk Assessment

Review Entity	Comments	Outcome
NWAC Listing Subcommittee	Control not thought to be possible or feasible - Eradication statewide not thought to be feasible so why expect landowners to attempt eradication? - Potential environmental impacts by forcing either control or eradication - forcing either control or eradication - Issues with regulation concerning aquatic (MN DNR) vs. terrestrial (MDA) Group spent a lot of time debating this issue; no real consensus to support regulation at this time	Undecided
NWAC Full Committee	Full membership discussed not listing *Phragmites* at this time. A motion was made and approved to vote for recommending that *Phragmites* be listed as a restricted noxious weed to at least bring attention to this species and restrict its sale and movement in the state.	Voted to Recommend listing as a Restricted Noxious Weed
MDA Commissioner		Commissioner Approved as a Restricted Noxious Weed – 1/14/2013

2016 Final Results of Risk Assessment

Review Entity	Comments	Outcome
NWAC Listing Subcommittee	Introduced *Phragmites* has been shown to cause major ecological disruption in other states. This species poses a major threat to Minnesota because of the large number of vulnerable ecosystems and current scattered distribution of infestations in the state. With the risk of rapid expansion increased by continuing climate change, the window of opportunity for containing introduced *Phragmites* and preventing widespread impacts in Minnesota may be closing. Infestations are too numerous for statewide eradication, but prudence dictates that a concerted effort be made to contain this species and eliminate	Prohibited Control Noxious Weed

2016 Final Results of Risk Assessment		
Review Entity	**Comments**	**Outcome**
	infestations wherever possible. Listing this species as a noxious weed in the "Prohibited: Control" category would be the regulatory approach most likely to facilitate motivate widespread control and containment. Exactly how such a regulation would be applied to the use of introduced *Phragmites* in reed beds needs further discussion, but phase-outs and methods to prevent flowering in existing stands should be considered. Such methods are being implemented or discussed in other states.	
NWAC Full Committee	Full membership voted 10 – 4 to accept the Listing Subcommittee's recommendation.	Prohibited Control Noxious Weed
MDA Commissioner	Commissioner reviewed NWAC's request to reclassify from a Restricted Noxious Weed to a Prohibited Noxious Weed on the Control List. Minnesota DNR Commissioner Tom Landwehr sent a letter of appeal within 45 days of the NWAC full membership vote (per NWAC bylaws) to express that the agency does not support reclassification of this species and that the Restricted Noxious Weed Category should remain. The appeal letter provides the DNR's reasoning for their opinion. Without support of the MN DNR – an agency with a significant amount of habitat that this risk assessment has concluded would be threatened by future spread of non-native *Phragmites* – and the 10 – 4 vote among NWAC constituent groups, the MDA rejected NWAC's recommendation and non-native Phragmites will remain a Restricted Noxious Weed (02/06/2017).	Restricted Noxious Weed

2019 Final Results of Risk Assessment		
Review Entity	**Comments**	**Outcome**
NWAC Listing Subcommittee	Discussed the new research available since the 2016 risk assessment. Discussed ways to address concerns by DNR and	Yes – List as a Prohibited Control Noxious Weed and modify Statute 18.78 subdivision

2019 Final Results of Risk Assessment		
Review Entity	**Comments**	**Outcome**
	wastewater treatment facilities if added to the Prohibited-Control list.	2 to include introduced *Phragmites*. Include a phase out clause for wastewater treatment facilities.
NWAC Full Committee	Vote was 15 to 0 in favor of listing as Prohibited Control with changes to Statute 18.78 including a phase out clause for wastewater treatment facilities. No one abstained. The phase out language for wastewater treatment facilities was not defined. The motion passed with the recommendation that MDA would work with the Minnesota Pollution Control Agency on phase out language.	Prohibited Control and modify Statute 18.78 subdivision 2 to include non-native Phragmites. Include a phase out clause for wastewater treatment facilities.
MDA Commissioner	Exact language and phase out needed to be worked out prior to review by the commissioner.	

2020 Final Results of Risk Assessment		
Review Entity	**Comments**	**Outcome**
NWAC Full Committee	Vote was 14 to 1 in favor of language changes and none abstaining. Language voted on was: List as a Prohibited Control Noxious Weed and modify Statute 18.78 subdivision 2 to include introduced Phragmites. Allow an exemption for wastewater treatment facilities adhering to state approved best management practices with the ultimate goal of enacting a phase out of introduced Phragmites if alternative wastewater treatment options can be found.	Modify Statute 18.78 subdivision 2 to include non-native Phragmites. Continue to work on wastewater treatment facility phase out language.
MDA Commissioner	Phase out needed to be worked out prior to review by the commissioner.	

2021 Final Results of Risk Assessment		
Review Entity	**Comments**	**Outcome**
MDA Commissioner	Conditions for changing the designation from Restricted to Prohibited Control include the following. 1. The Minnesota Department of Agriculture will work with the Minnesota Pollution Control Agency, University of Minnesota, and Minnesota Department of Natural Resources to explore options for phasing out non-native Phragmites australis ssp. australis as part of their operations. 2. Add the species name non-native Phragmites australis ssp. australis to M.S. 18.78 Subd. 2. Text changes are underlined below. 3. Allow an exemption for wastewater treatment facilities adhering to state approved best management practices with the ultimate goal of enacting a phase out of non-native *Phragmites* if alternative wastewater treatment options can be found.	Effective 02/18/2021, non-native Phragmites was regulated as a Prohibited Control Noxious Weed with conditions and language changes to Statute 18.78 subdivision 2. As of 06/07/2022 the statute change has not been submitted to the legislature.

Risk Assessment Current Summary (*Current Year – 2021*):

- Risk assessment was updated in 2019. The University of Minnesota MNPhrag project provided considerable updates to our understanding of how widespread introduced Phragmites is in the state, how well experts and trainees can identify introduced Phragmites, and an estimate of control costs for the state.
- A challenge to managing introduced Phragmites includes the complexity of managing in wet areas and below the ordinary high water mark and the issue of waste water treatment facilities that use introduced Phragmites. To address this challenge, it was suggested to modify statute language to mirror the language for purple loosestrife.
- An additional challenge is that there are waste water treatment facilities in Minnesota that use introduced Phragmites. To address this challenge, it was suggested allow a phase-out period determined by the MDA working in consultation with individual wastewater treatment facilities.
- It was necessary to develop conditions for changing the designation from Restricted to Prohibited Control. Conditions are:

1. The Minnesota Department of Agriculture will work with the Minnesota Pollution Control Agency, University of Minnesota, and Minnesota Department of Natural Resources to explore options for phasing out non-native *Phragmites australis* ssp. *australis* as part of their operations.
2. Add the species name non-native *Phragmites australis* ssp. *australis* to M.S. 18.78 Subd. 2. Text changes are underlined below.
3. Allow an exemption for wastewater treatment facilities adhering to state approved best management practices with the ultimate goal of enacting a phase out of non-native Phragmites if alternative wastewater treatment options can be found.

18.78 CONTROL OR ERADICATION OF NOXIOUS WEEDS.

Subdivision 1. Generally.

A person owning land, a person occupying land, or a person responsible for the maintenance of public land shall control or eradicate all noxious weeds on the land at a time and in a manner ordered by an inspector or county-designated employee.

Subd. 2. Control of purple loosestrife and non-native Phragmites australis ssp. australis.

An owner of nonfederal lands underlying public waters or wetlands designated under section 103G.201 is not required to control or eradicate purple loosestrife and non-native Phragmites australis ssp. australis below the ordinary high water level of the public water or wetland. The commissioner of natural resources is responsible for control and eradication of purple loosestrife and non-native Phragmites on public waters and wetlands designated under section 103G.201, except those located upon lands owned in fee title or managed by the United States. The officers, employees, agents, and contractors of the commissioner of natural resources may enter upon public waters and wetlands designated under section 103G.201 and, after providing notification to the occupant or owner of the land, may cross adjacent lands as necessary for the purpose of investigating purple loosestrife or non-native Phragmites infestations, formulating methods of eradication, and implementing control and eradication of purple loosestrife or non-native Phragmites. The commissioner of natural resources shall, by June 1 of each year, compile a priority list of purple loosestrife and non-native Phragmites infestations to be controlled with herbicides in designated public waters. The commissioner of natural resources must distribute the list to county agricultural inspectors, local weed inspectors, and their appointed agents. The commissioner of natural resources shall control listed purple loosestrife infestations and non-native Phragmites in priority order within the limits of funding allocated for that purpose. This procedure shall supersede the other provisions for control of noxious weeds set forth elsewhere in this chapter. The responsibility of the commissioner of natural resources to control and eradicate purple loosestrife and non-native Phragmites on public waters and wetlands located on private lands and the authority to enter upon private lands ends ten days after receipt by the commissioner of a written statement from the landowner that the landowner assumes all responsibility for control and eradication of purple loosestrife and non-native Phragmites australis ssp. australis under sections 18.78 to 18.88. State officers, employees, agents, and contractors of the commissioner of natural resources are not liable in a civil action for trespass committed in the discharge of their duties under this section and are not liable to anyone for damages, except for damages arising from gross negligence.

Appendix A:
Introduced *Phragmites* Risk Assessment Narrative (2016)

Both native and non-native lineages are present in North America

Phragmites australis is a wetland grass with a cosmopolitan distribution. Four distinct lineages have been identified in North America (Saltonstall 2007, Meyerson and Cronin 2013). One is a collection of several endemic haplotypes that has been formally described as P. *australis* subsp *americanus* (Saltonstall 2004). Another is a haplotype that is found along the Gulf Coast in North America, as well as in South America and on some islands in the southern Pacific. This lineage has been referred to variously as Haplotype I, the Gulf Coast Lineage, and *P. australis* subsp. *berlandieri* (Saltonstall 2002, Saltonstall 2007). The third lineage, often referred to as Haplotype M, is the most common lineage worldwide. Genetic comparisons and historical distribution data have shown that haplotype M was introduced to North America, possibly from sources in the United Kingdom, sometime before 1910 (Saltonstall 2002, Plut et al. 2011). Finally, another non-native lineage, referred to as haplotype L, was recently documented in Quebec (Meyerson and Cronin 2013). Both *P. australis* subsp. *americanus* (hereafter native *Phragmites*) and *P. australis* haplotype M (hereafter introduced *Phragmites*) have been documented in Minnesota (Saltonstall 2002, Melchior and Weaver 2016).

Introduced *Phragmites* is invasive and ecological harmful

Introduced *Phragmites* is considered a highly invasive plant in North American marshes, is considered problematic in at least 18 states, and is especially invasive along the east coast, great lakes states, and Nebraska (Gucker 2008, Hodredge and Bertness 2010, Farnsworth et al 2003).

Ecological differences

There are ecological differences in addition to genetic and morphological differences between native and introduced *Phragmites*. The latter demonstrates earlier emergence, faster growth rates, higher biomass accumulation, higher culm density, greater height, greater tolerance to flooding and greater salt tolerance than native *Phragmites* (Meyerson et al 2009). Introduced *Phragmites* has a faster growth response to elevated CO_2 and nitrogen than the native form (Holdredge et al. 2010, Mozdzer and Megonigal 2012). Introduced *Phragmites* also produces more toxic root exudates than native *Phragmites,* as shown in laboratory studies by Rudrappa et al. (2007). As with typical introduced species that are released from their native pests upon arrival on a new continent, introduced *Phragmites* suffers less aphid herbivory in North America than native *Phragmites* (Gucker 2009). Introduced *Phragmites* has been shown to be more invasive, with more detrimental impacts on native plant diversity, than native *Phragmites* (Price et al. 2014).

Changes in ecosystem structure

Introduced *Phragmites* can grow in such dense stands that it alters ecosystem structure and function. Considered to be an ecosystem engineer, introduced *Phragmites* growth and rapid litter accumulation alter hydrology, and cause changes in nutrient cycling, soil properties, surface temperatures, and light levels within marsh communities (Gucker 2009, Meyerson et al. 2009). These changes have been associated with reduced plant and animal diversity and with significant alterations at the base of the food web (Able and Hagan 2000, Able and Hagan 2003, Benoit and Askins 1999, Gratton and Denno 2006, Meyer et al. 2010, Meyerson et al. 2009, Gucker 2008). Introduced *Phragmites* also hampers wetland restoration by crowding out target plant communities (Meyerson et al. 2009).

Threats to native plant species

Introduced *Phragmites* has been shown to reduce native plant diversity through rapid growth, litter accumulation, hydrological alterations, and allelopathy (Ailstock et al. 2001, Chambers et al. 1999, Farnsworth and Meyerson 1999, Galatowitsch 2012, Price et al. 2013, Rudrappa et al. 2007, Holdredge et al. 2010). Native plant biodiversity increases following control of introduced *Phragmites* (Ailstock et al. 2001, Farnsworth and Meyerson 1999). One native plant species of both ecological and economic importance in Minnesota is wild rice (*Zizania* sp.). Because the habitat requirements of introduced *Phragmites* overlaps those of *Zizania* sp., there is concern that introduced *Phragmites* could cause significant harm to *Zizania* sp. populations and the wild rice industry (Falck, pers comm. 2016).

Threats to native *Phragmites*

Introduced *Phragmites* crowds out native *Phragmites* (Meyerson et al 2009) and the spread of introduced *Phragmites* has been associated with simultaneous declines of native *Phragmites* on the east coast, in the Great Lakes, and in Nebraska (Saltonstall 2002, Larson et al. 2011, Meyerson et al. 2009). Hybridization is another potential threat to populations of native *Phragmites*, and hybridization has recently been confirmed to occur between wild populations of Introduced and native *Phragmites* (Paul et al. 2010, Blossey et al. 2014). There is some concern that control of introduced *Phragmites* will lead to inadvertent harm to native *Phragmites*, but the risks to native *Phragmites* of allowing the continued spread of introduced *Phragmites* shed doubt on this concern.

Impacts to wildlife

Impacts on animals are less clear than impacts on native plants, with effects varying by species and sometimes more strongly influenced by landscape scale conditions than by dominant plant species (Gucker 2009). Several studies demonstrate impacts on marsh fauna and food webs (Able and Hagan 2000, Able and Hagan 2003, Benoit and Askins 1999, Gratton and Denno 2006, Meyer et al. 2010). Other studies show little difference in animal species diversity between monotype stands of introduced *Phragmites* and native plant communities, but in some of these same studies the species composition in introduced *Phragmites* stands has been shown to consist of fewer rare and specialist species and more generalist species (Gucker 2009, Robichauld and Rooney, 2016). One possible mechanism for this shift is that introduced *Phragmites* reduces overall structural diversity by replacing both wet meadow and cattail habitats with a single and novel habitat type (Robichauld and Rooney, 2016, Ailstock et al. 2001, Weis and Weis, 2003, Hanson et al. 2002). Among the rare and specialist species whose habitats are impacted by introduced *Phragmites* are the sandhill crane, least tern, piping plover, and least bittern, some of which are listed as threatened or endangered at the state or federal level (Larson et al. 2011, Robichauld and Rooney 2016,). Hydrological alterations caused by monotypic stands of introduced *Phragmites* are associated with detrimental effects on fish and in general alter the ability of the marsh to support biodiversity (Meyerson et al. 2009, Weinstein and Balletto 1999). Some studies that found little difference in introduced *Phragmites* stands were comparing with marshes dominated by another highly invasive species, *Typha angustifolia* (Gucker 2009).

Threats to infrastructure

Introduced *Phragmites* is a threat to highway infrastructure. Its relatively high tolerance for salinity and variable hydrology suit it to roadside ditch conditions. In this setting it can restrict visibility, which is a safety concern, and interfere with proper drainage, which both reduces safety and accelerates degradation of pavement and structures.

Control costs

The various ecological and infrastructure impacts described above are extensive but difficult to quantify. The cost of controlling introduced *Phragmites*, although undoubtedly a vast underestimate of impacts, represents a more accessible quantitative measure of its impacts. Regional control projects for which expenditures are readily available include efforts in the central Platte river valley of Nebraska, which has spent $4.5 million over six years (Walters, unpublished data); and work in the great lakes totaling over $16 million since 2010 (Braun, pers comm. 2016). An economic survey of management efforts by Martin and Blossey (2013) found that organizations across the U.S. spent over $4.6 million per year from 2005-2009, but that few organizations had accomplished their management objectives.

Benefits

Despite all of the negative impacts described above, there are possible benefits from introduced *Phragmites*. As an ecosystem engineer and a dominant climax community plant species, introduced *Phragmites* stands are likely to serve as carbon sinks and possibly as nitrogen sinks (Meyerson 2009). Also, its ability to increase elevation of marshes may be able to keep pace with climate-change-induced sea-level rise, thus providing significant ecosystem service of coastal protection (Meyerson et al. 2009). This latter effect is not likely to offer much benefit in Minnesota.

Introduced *Phragmites* is also used in reed beds for wastewater treatment in many places, including at 17 municipal facilities in Minnesota (Bock pers comm. 2016, Davis pers comm. 2016), where it provides environmental benefits in the form of effective, low-input dewatering of biosolids (Davis pers comm. 2016). These facilities have what seem to be ample protocols for containing the rhizomes, thus making vegetative spread a minor issue. However, containment methods seem to have overlooked the possibility of spread by seed or genetic outcrossing via pollen. There are no methods currently in place to prevent this, and several facilities exist in Minnesota and Wisconsin with nearby naturalized stands of introduced *Phragmites* (Wright County, Bock, pers comm, Falck 2015). It is possible that a mid-summer mowing of the reed beds could prevent the production of viable seed (Galatowitsch, pers comm. 2016) and this option is being explored in Wisconsin, but no easily accessible methods to accomplish it are known. The non-native strain has been the default for these systems because of its faster growth rates and greater resistance to aphids. Some have said that native *Phragmites* will not work in these systems (Bock, pers comm. 2016) but it is currently being used at one site in MN and Scott Davis, the foremost designer of these systems in North America, has conceded that native *Phragmites* will probably work nearly as well. Despite these benefits of introduced *Phragmites*, it would be nearly impossible to argue that they outweigh the impacts to native wetland plant communities and biodiversity.

Imminent threat to MN

Minnesota is a state that could be particularly vulnerable to ecological impacts of introduced *Phragmites* because of its high number of lakes and wetlands, substantial population of native *Phragmites*, and reliance on fishing and other lake-related recreation industries. While introduced *Phragmites* has become very abundant and impactful in many regions, it is still relatively uncommon in Minnesota. This suggests that there is still an opportunity to prevent widespread ecological impacts in this state.

Distribution

Despite being relatively uncommon in Minnesota, there are numerous small but widely scattered infestations of introduced *Phragmites* (see attached maps from MNPhrag 2019, Falck and Olson 2015, Melchior and Weaver 2016). Many of these infestations have been confirmed to be introduced *Phragmites* by genetic testing (Melchior and Weaver 2016). Numerous other infestations have been confirmed based on expert assessment of morphological characteristics that have been suggested as reliable indicators by Saltonstall and confirmed in Minnesota to correlate with genetic markers (Melchior and Weaver 2016). Introduced *Phragmites* is known to spread along road ditches (Brisson et al. 2010) and subsequently invade adjacent wetlands and streams. The survey by Melchior and Weaver (2016) found that most introduced *Phragmites* infestations are currently located in roadsides and have not yet reached the Mississippi or Minnesota Rivers but are very close in some cases. Invasion of a major river has already occurred in the St. Louis Estuary (Falck 2015). There are also up to 17 introduced *Phragmites* stands at wastewater treatment facilities scattered around the state (Bock, pers comm. 2016). This current distribution in Minnesota pre-positions it for rapid expansion in the state.

Spread

The rapid expansion of introduced *Phragmites* in Minnesota could be imminent. Vegetative reproduction is clearly an important means of spread but vegetative spread alone is relatively slow without human intervention and reduces possibilities for genetic variability (Albert et al. 2015, Gucker 2009). Sexual reproduction would allow more rapid spread and increased genetic variability, both of which can accelerate invasion. While sexual reproduction has been assumed to be limited in cold climates, with growing seasons being too short for seed maturation and many winters being too cold for seedling survival (Galatowitsch, pers comm. 2016), increasing evidence shows that sexual reproduction is possible and happening in cold climates such as Quebec (Albert et al. 2012, Albert et al. 2015) and Minnesota (Galatowitsch, pers comm. 2016, Melchior and Weaver 2016). Sexual reproduction is likely still limited in the state by short growing seasons and cold winters but climate data show that winters are becoming progressively milder and growing seasons longer (EPA 2016, Zandlo 2014). Data suggests that it is only a matter of time before Minnesota experiences a series of longer growing seasons and milder winters that, when coupled with the scattered distribution of introduced *Phragmites*, can lead to explosive spread. Once that happens it is likely that any possibility of containing the invasion of introduced *Phragmites* will have been lost.

Control is possible

MNPhrag research and literature review suggests that not only is control possible but for small infestations - eradication can be the goal (Blanke et al. 2019). The MNPhrag web pages have links to "Management Information" which lays out several strategies for dealing with introduced Phragmites infestations (MNPhrag 2019).

Control of introduced *Phragmites* infestations is possible. A common concern relating to control of introduced *Phragmites* is that an inability to distinguish it from native *Phragmites* can jeopardize the native subspecies. However, comparison of morphological characteristics with genetic markers by Swearingen and Saltonstall (2010) have revealed several useful field indicators. Although Swearingen and Saltonstall warn that field identification using morphological characteristics without genetic testing may not be 100% reliable, the correlation is strong and Minnesota stands of *Phragmites* have shown 100% correlation between morphological characters and genetic markers (Melchior and Weaver 2016). Also, states like NE have listed it as a noxious weed and have been relatively successful through

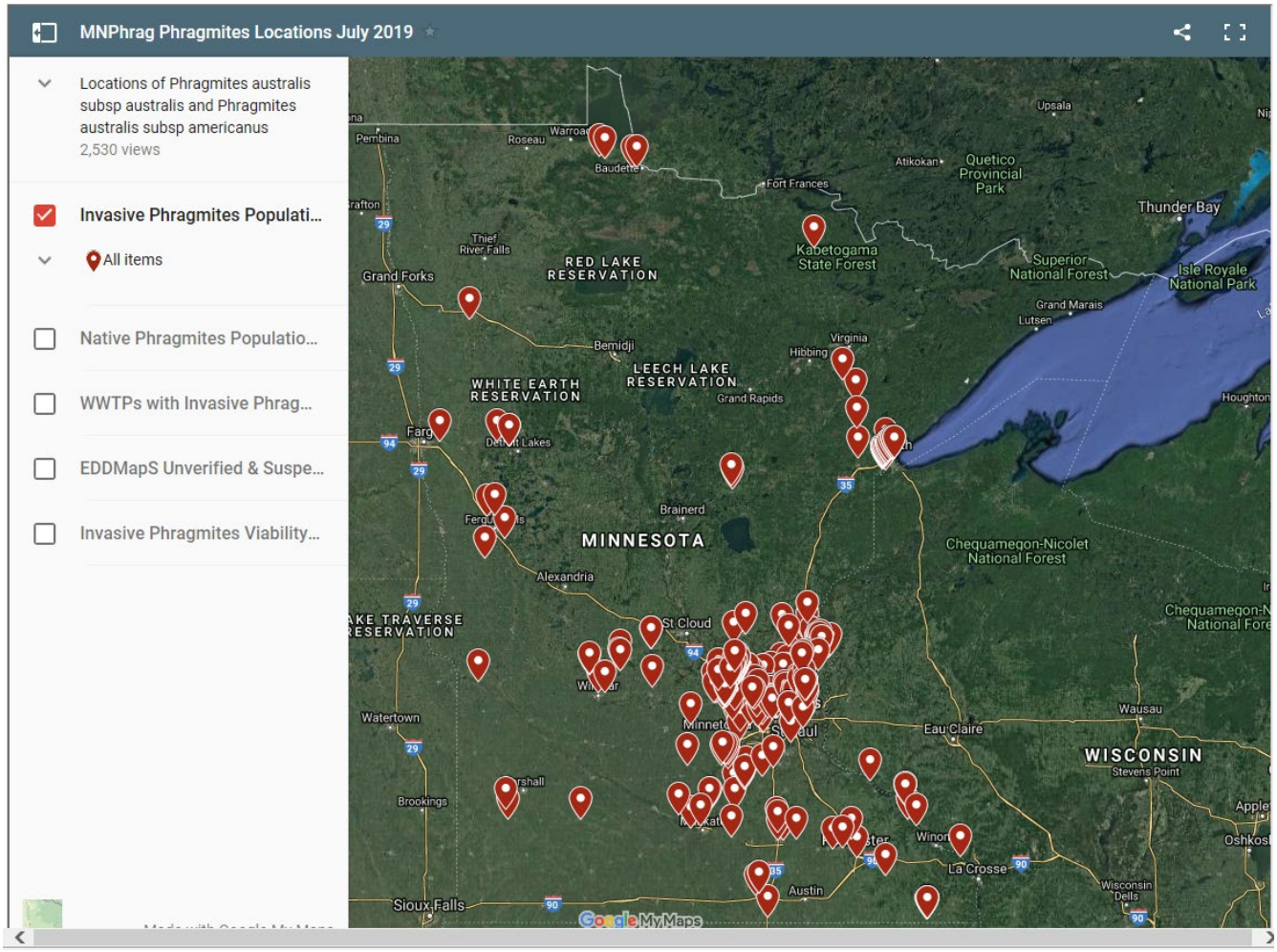
University of NE Extension in providing enforcement agents in local governments with education on discerning between the native and non-native.

Control efforts in other states have shown success with various combinations of treatments such as herbicide, mowing, burning, and restoration (Gucker 2009). Coordinated efforts in Nebraska have reduced infestations and improved flow conveyance in the Platte River (Walters, unpublished data). Restoration of ecosystem function and biodiversity are also possible upon control (Gratton and Denno 2006, Walters, unpublished data, Ailstock et al 2001). However, other studies have questioned the long-term and landscape scale effectiveness of control, and more research is likely needed into the long-term impacts of control and the integration of restoration activities with control treatments (Hazelton et al 2014, Martin and Blossey 2013). Biological control has been investigated (Tewskbury et al 2002) but may not be an option as due to concerns about threats to native *Phragmites* (Cronin et al. 2016). There is also some question as to population-level effectiveness/impact of potential biocontrol agents (Larkin, personal communication 2016).

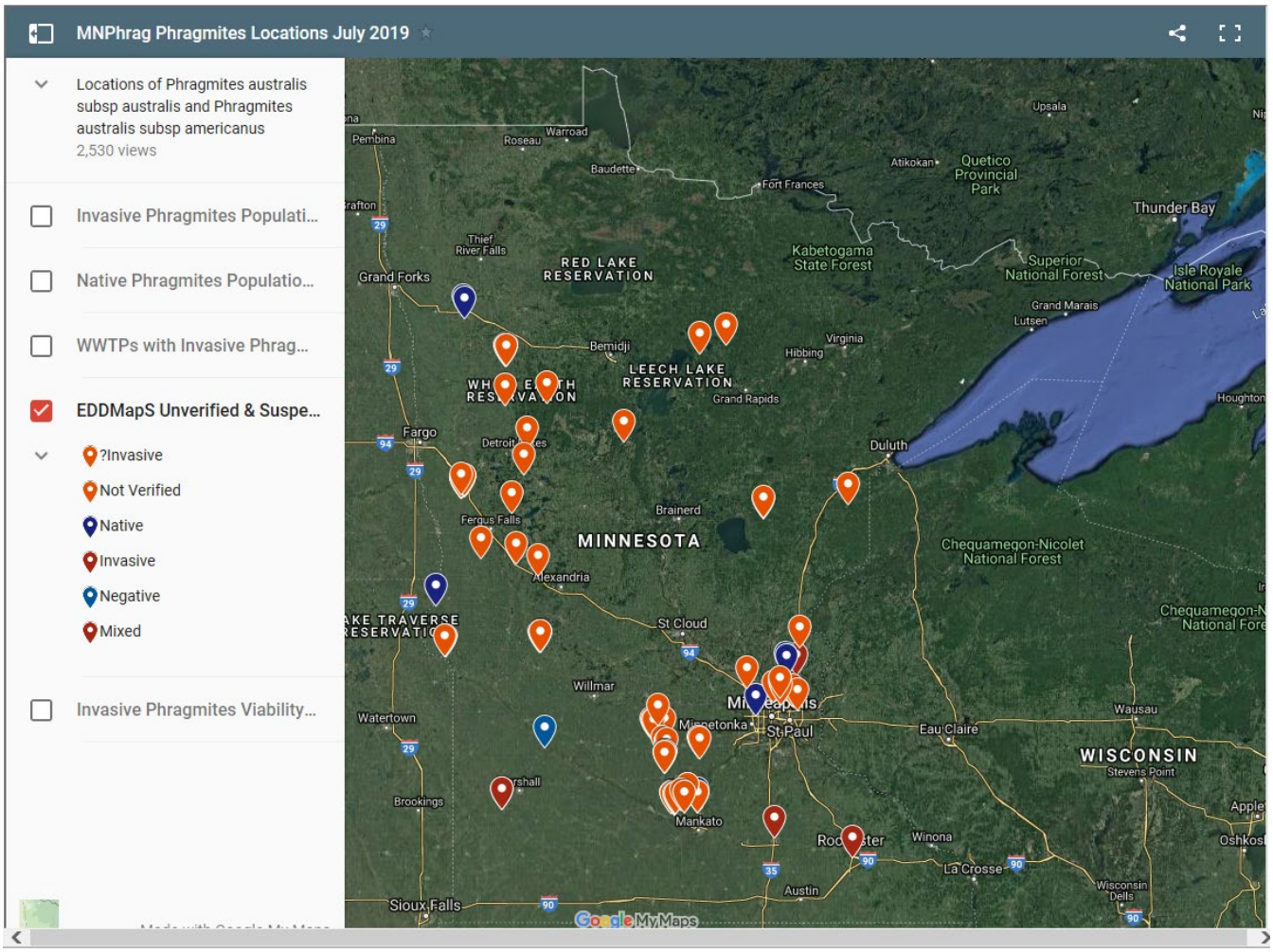
Recommendation

Introduced *Phragmites* has been shown to cause major ecological disruption in other states. This species poses a major threat to Minnesota because of the large number of vulnerable ecosystems and current scattered distribution of infestations in the state. Efforts to keep Phragmites in check should begin now while infestations are small and lack genetic variability necessary for seed production (Kettenring et al. 2011). Furthermore it has been shown that there is a higher probability of eradication when dealing with small infestations rather than large established infestations (Quirion et al. 2018). With the risk of rapid expansion increased by continuing climate change, the window of opportunity for containing introduced *Phragmites* and preventing widespread impacts in Minnesota may be closing. Infestations are too numerous for statewide eradication, but prudence dictates that a concerted effort be made to contain this species and eliminate infestations wherever possible. Listing this species as a noxious weed in the "Prohibited: Control" category would be the regulatory approach most likely to facilitate and motivate widespread control and containment. Exactly how such a regulation would be applied to the use of introduced *Phragmites* in reed beds needs further discussion, but phase-outs and methods to prevent flowering in existing stands should be considered. Such methods are being implemented or discussed in other states.

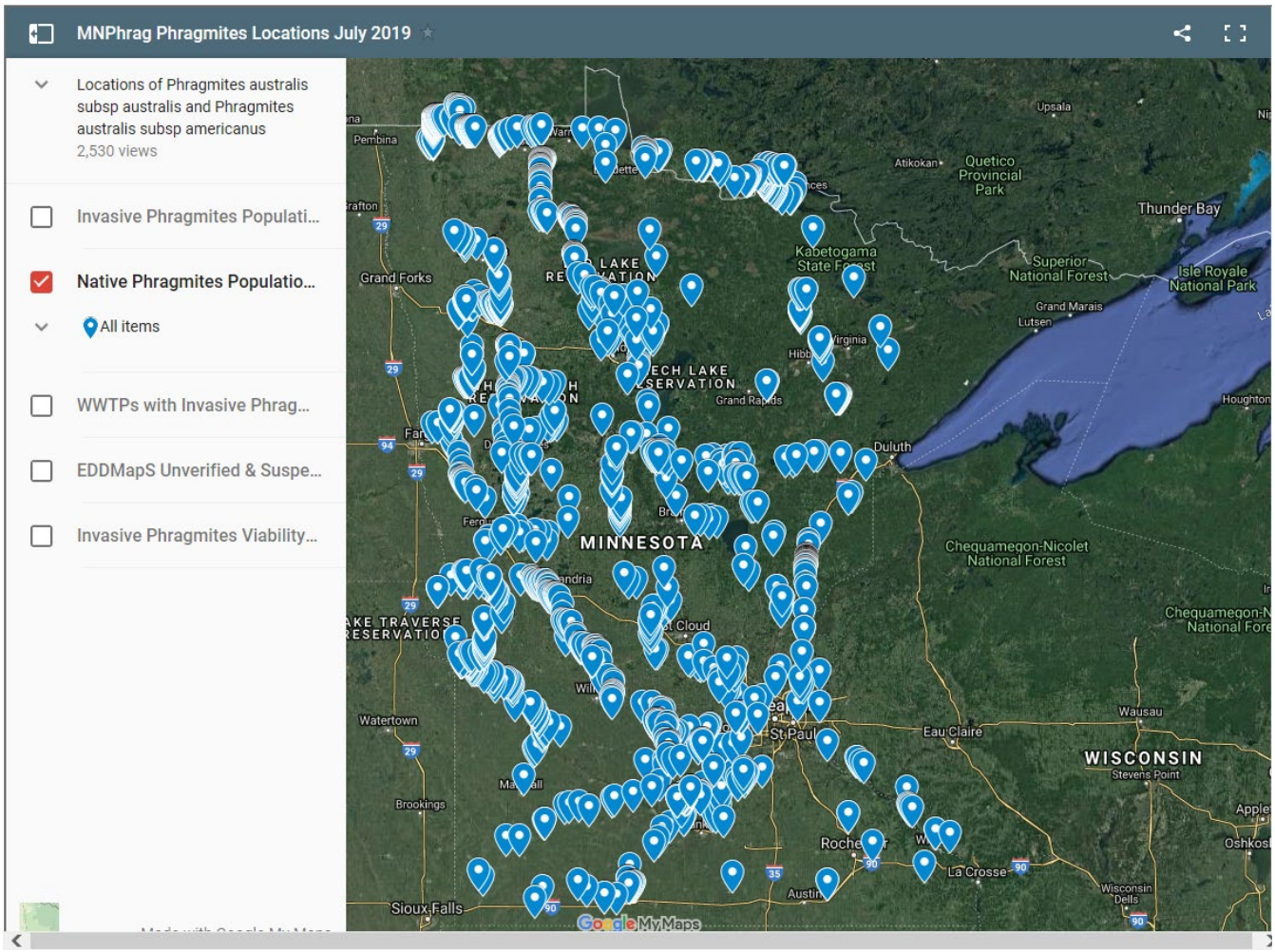
Appendix B: Distribution and Other Maps of Interest.



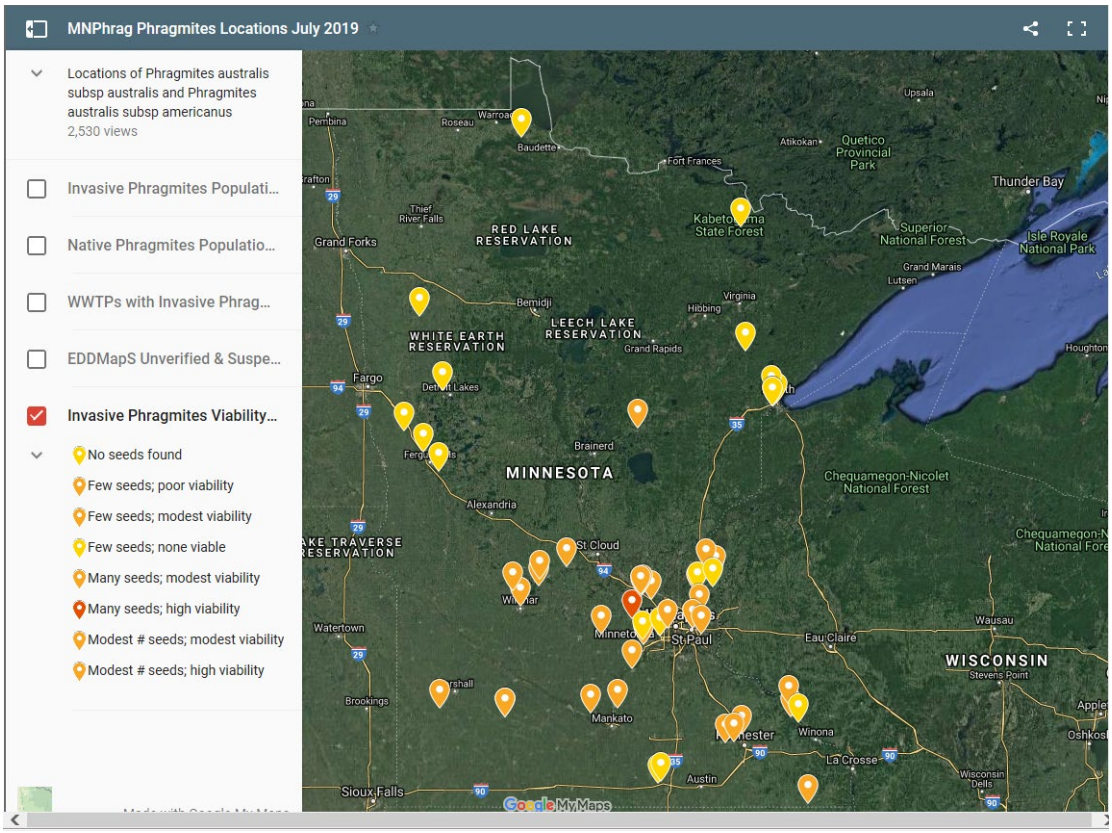
Introduced *Phragmites* Populations (MNPhrag).
Map accessed 8-19-2019. Web site: https://www.maisrc.umn.edu/phragmites-map



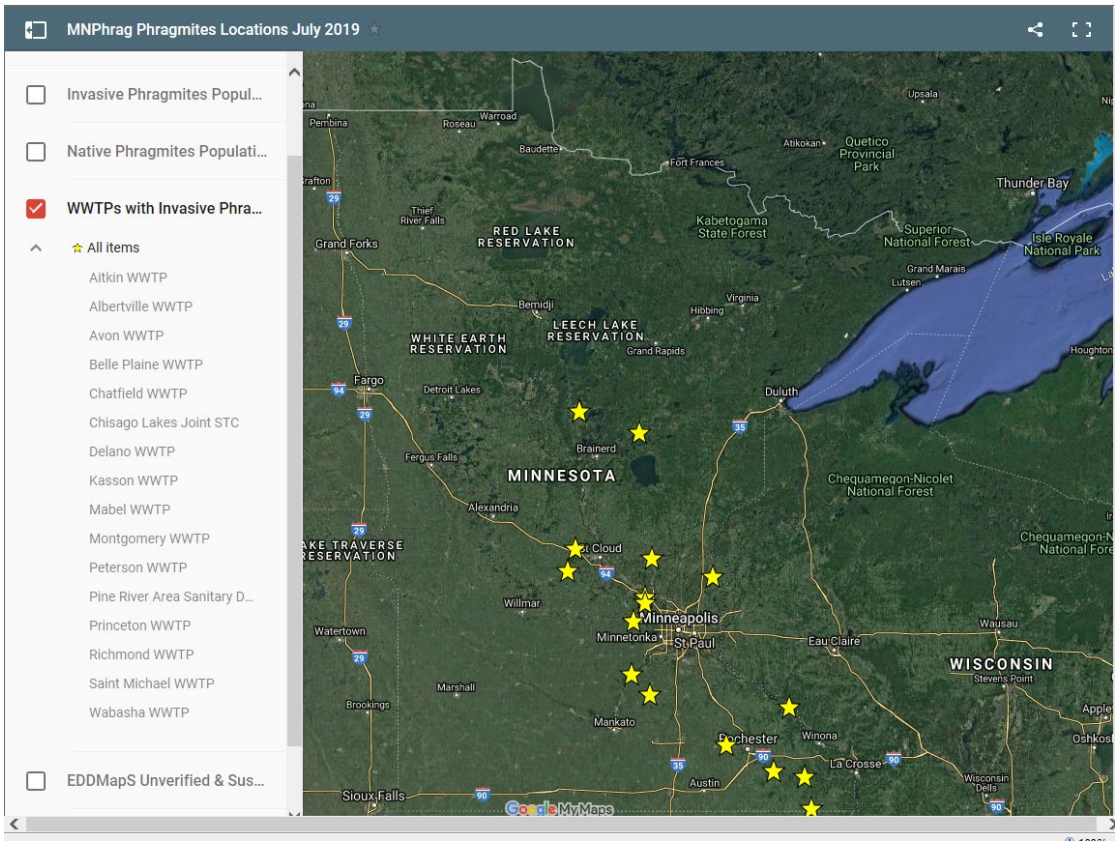
EDDMaps unverified and suspect populations (MNPhrag).
Map accessed 8-19-2019. Web site: https://www.maisrc.umn.edu/phragmites-map



Native *Phragmites* populations (MNPhrag).
Map accessed 8-19-2019. Web site: https://www.maisrc.umn.edu/phragmites-map

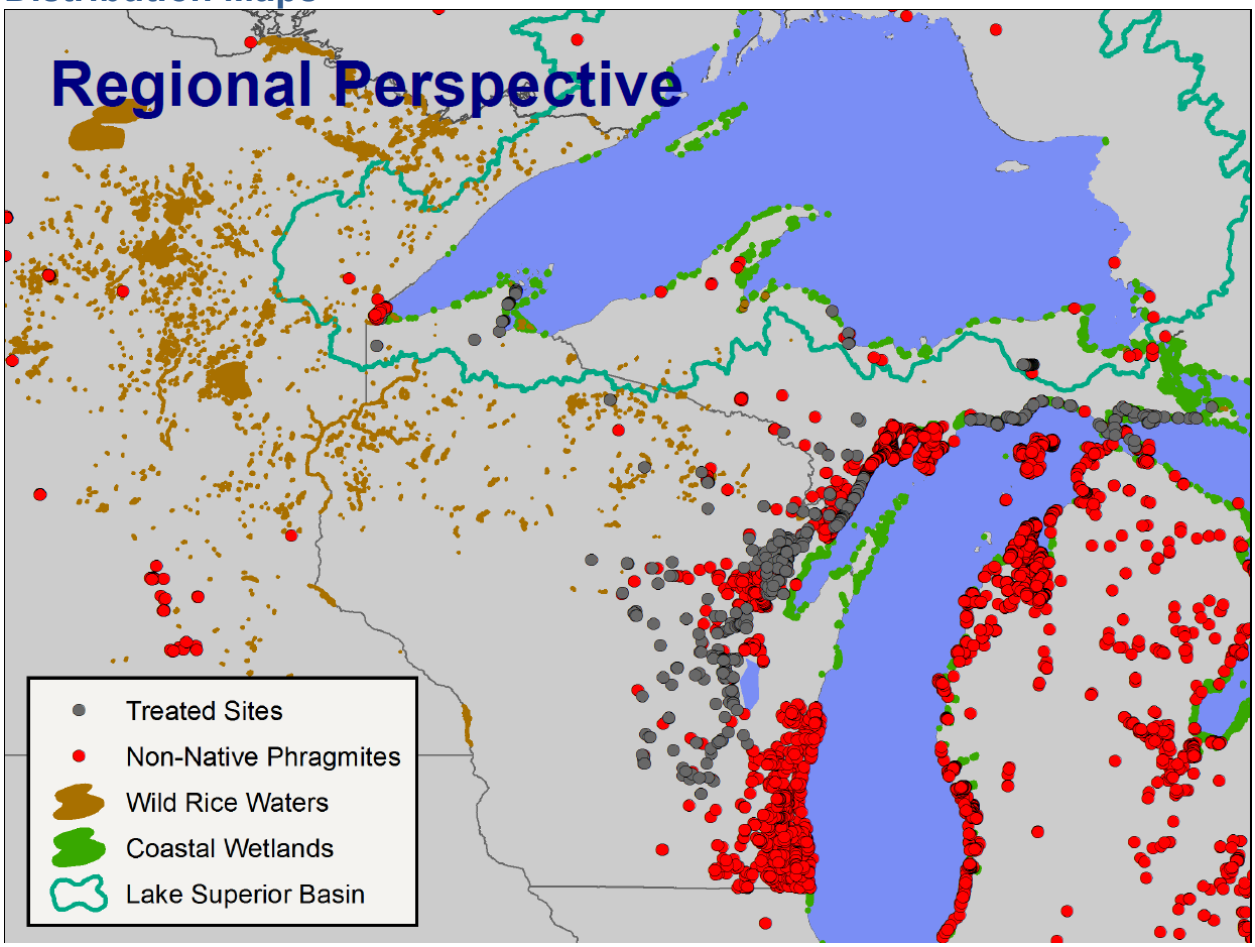


Introduced *Phragmites* seed presence and seed viability (MNPhrag).
Map accessed 8-19-2019. Web site: https://www.maisrc.umn.edu/phragmites-map

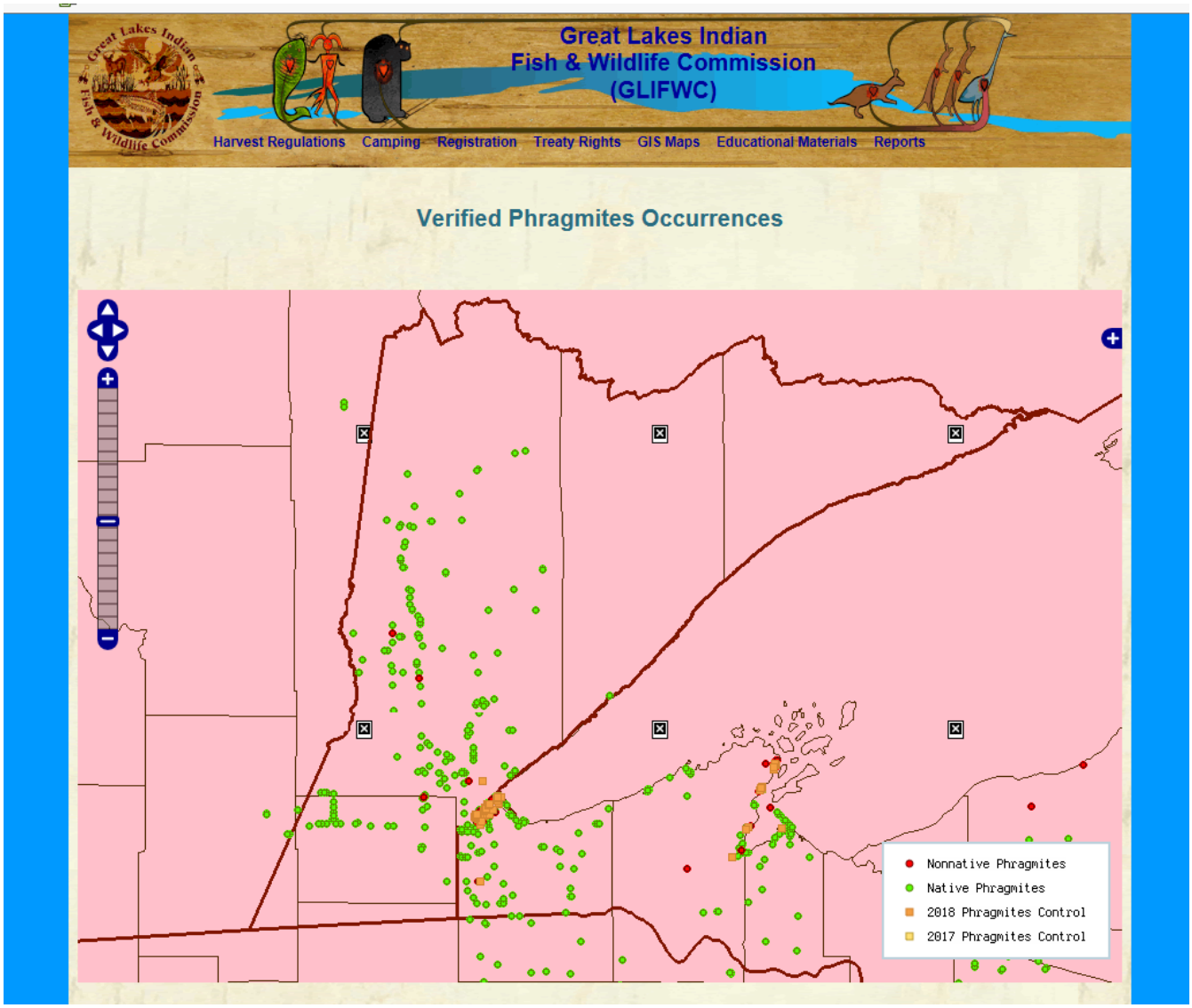


Map indicates 16 waste water treatment plants with introduced *Phragmites* (MNPhrag). Map accessed 8-19-2019. Web site: https://www.maisrc.umn.edu/phragmites-map

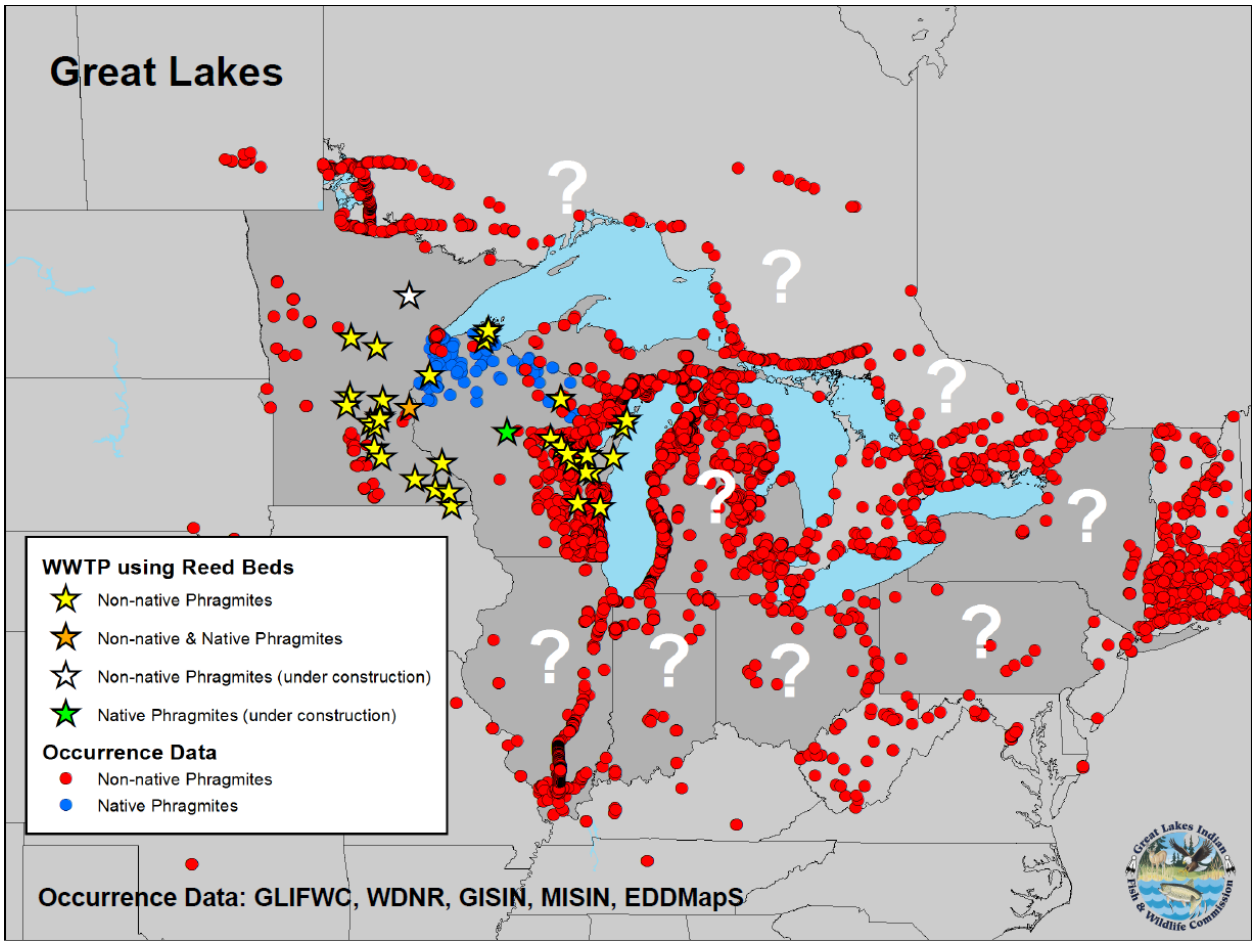
Distribution Maps



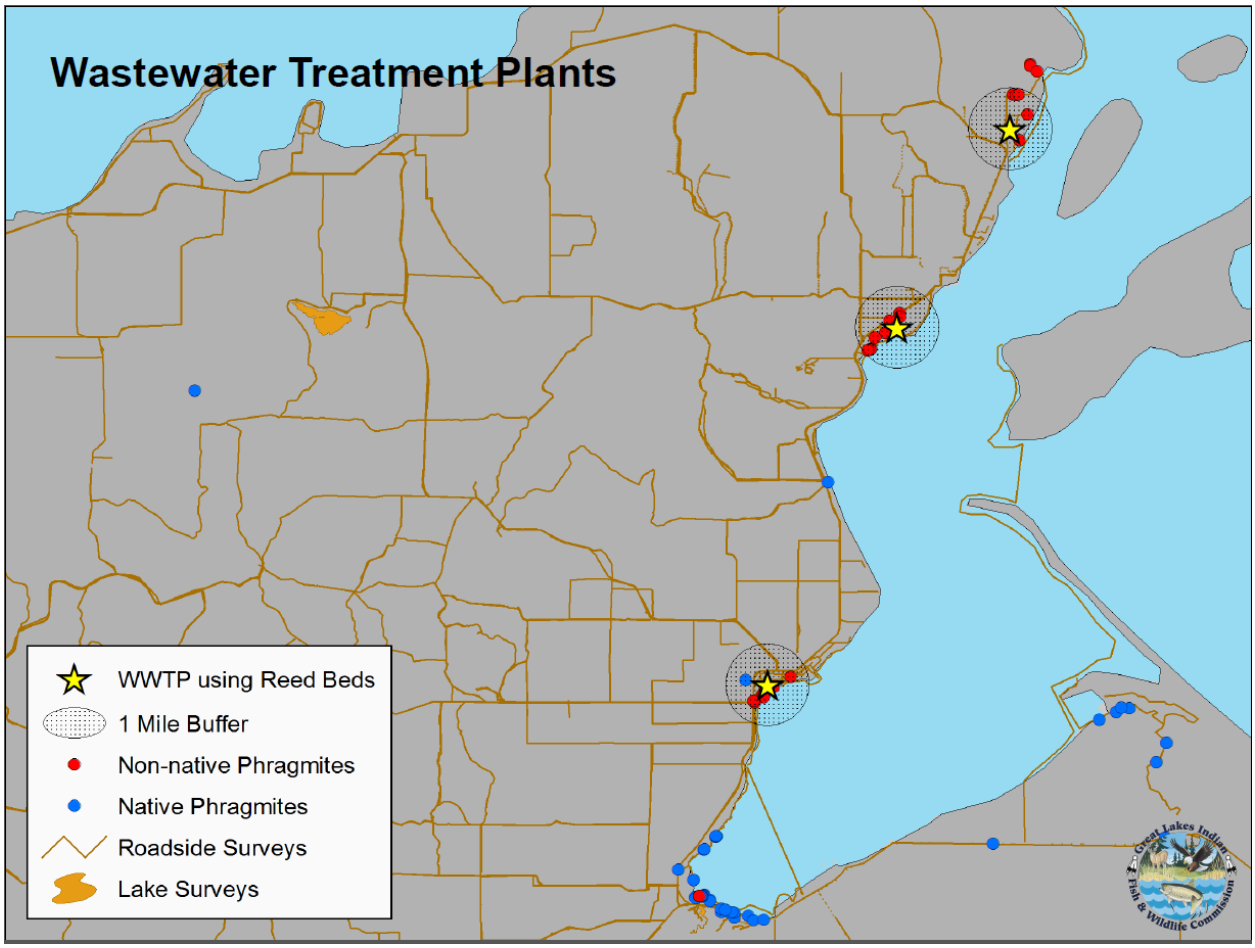
Mapped infestations of *P. australis subsp. australis* in the western great lakes region. This map is included to highlight the difference in invasion intensity between Minnesota and other nearby states. Data points are from EDDMapS and Great Lakes Indian Fish and Wildlife Commission. (Falck and Olson 2015).



Illustrative map from GLIFWC showing Introduced and native *Phragmites* stands including areas of treatment near Lake Superior.
Map accessed 08-19-2019. Web site: http://invasives.glifwc.org/phragmites/



Relative degree of invasion between Minnesota and other Great Lakes States. Also included are locations of wastewater treatment plant reed beds using *P. australis subsp. australis*. (Falck 2015)

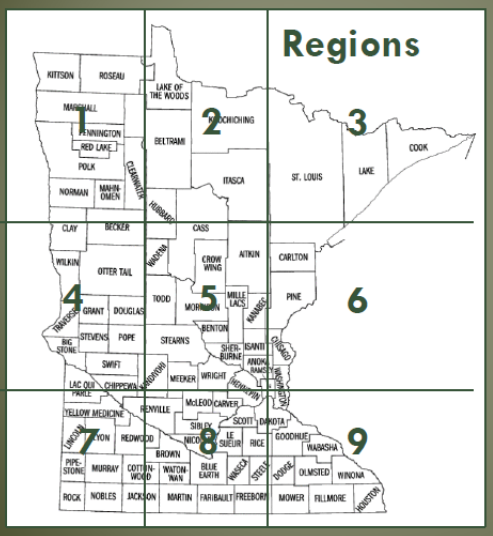


Wastewater treatment plants using *P. australis subsp. Australis* along the Chequamegon Bay of Lake Superior, showing locations of alleged escapes. (Falck 2015).

Appendix C:

Evaluate Reproductive Potential

Viable seed **does** develop in at least the southern 2/3rds of MN



Preliminary Viability Results				
Region	# Populations	Popul w/ No Seeds	Popul w/ No Viable Seed	Popul w/ Viable Seed
1	1	1		
2	0			
3	2	1	1	
4	5	2	2	1
5	8		1	7
6	6	2	1	3
7	1			1
8	5		2	3
9	5			5

MNPhrag project seed viability results.

PowerPoint accessed June 19, 2019 at website:
https://www.maisrc.umn.edu/sites/maisrc.umn.edu/files/invasive_phragmites_pushback.pdf

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